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CRISTIANO R. SANTOS

ENTREPRENEURSHIP AND COMPLEXITY ECONOMICS
TOWARDS A FRAMEWORK FOR PUBLIC POLICY PURPOSES IN BRAZIL

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Tese apresentada ao Corpo Docente do Programa de Pós-Graduação em Políticas Públicas, Estratégia e Desenvolvimento do Instituto de Economia da Universidade Federal do Rio de Janeiro como requisito parcial à obtenção do título de Doutor em Políticas Públicas, Estratégia e Desenvolvimento.

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BANCA EXAMINADORA:

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Orientadora: Profa. Dra. Renata Lèbre La Rovere (IE - UFRJ)

____

Prof. Dr. Fernando Fagundes Ferreira (EACH - USP)

____

Prof. Dr. Marcelo Matos (IE - UFRJ)

____

Prof. Dra. Maria da Graça Derengowski Fonseca (IE - UFRJ)

____

Prof. Dr. Thiago Borges Renault (DCAC - UFF)

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RESUMO

SANTOS, Cristiano Roberto dos Santos. **Entrepreneurship and Complexity Economics, Towards a Framework for Public Policy Purposes in Brazil**. Tese (Doutorado em Políticas Públicas, Estratégia e Desenvolvimento): Instituto de Economia da Universidade Federal do Rio de Janeiro, 2019.

Esta tese propõe analisar, avaliar e sugerir propostas de estudo sobre o sistema de empreendedorismo no Brasil. Essa análise se constitui na combinação de visões dos Sistemas Nacionais de Empreendedorismo (NSE) e dos Sistemas Nacionais de Inovação (NSI), para testar hipóteses sobre o Sistema Brasileiro de Empreendedorismo (BES), que são: o BES, em termos de criação e evolução de novas empresas, é um sistema complexo; este sistema complexo pode ser simulado; o resultado dessa simulação pode servir para fins de políticas públicas. As técnicas que a tese explorou são redes complexas de mobilidade de emprego para verificar quão complexo é o BES e um modelo baseado em agentes para simular o comportamento dos indivíduos ao longo de sua trajetória em firmas ou como empreendedores. Os resultados da simulação são usados para indicar como construir uma estrutura de ações de política no contexto de um cenário de recursos escassos. A tese apresenta alguns achados sobre o cenário de complexidade na BES: o BES pode ser visualizado, modelado e analisado como um sistema complexo; a complexidade dos setores industriais do BES diminuiu o longo da primeira década e da primeira metade da segunda década do século atual; a estrutura institucional do sistema de empreendedorismo é crucial para a formação da dinâmica complexa, como na visão do NSI.

Palavras-chave: Empreendedorismo; Economia da Complexidade; Sistemas Nacionais de Inovação; Sistemas Nacionais de Empreendedorismo; Redes Complexas; Modelos Baseados em Agentes; Políticas Públicas, Sistema Nacional de Empreendedorismo.

ABSTRACT

This thesis proposes to analyze, evaluate and suggest proposals of study on entrepreneurship system in Brazil. This analysis is based on the combination of views of National Systems of Entrepreneurship (NSE) and National Systems of Innovation (NSI), to test hypotheses on Brazilian Entrepreneurship System (BES), which are: the BES, in terms of creation and evolution of new firms, is a complex system; this complex system can be simulated; the output of this simulation can serve for a public policies purposes. The techniques that the thesis explored are complex networks for employment mobility to verify how complex is the BES, and an agent-based model to simulate the behaviour of individuals along their trajectory in firms or as entrepreneurs. The results of the simulation are used to indicate how to build a framework of policy actions in the context of a scarce resources scenario. The thesis presents some findings on the scenario of complexity in BES: the BES can be viewed, modeled and analysed as a complex system; the complexity of industrial sectors in the BES had been reducing along the first decade and the first half of the second decade of the current century; the entrepreneurship institutional structure system is crucial for the formation of the complex dynamics, in accordance with NSI ideas.

Keywords: Entrepreneurship; Economy of Complexity; National Innovation Systems; National Systems of Entrepreneurship; Complex Networks; Agent-Based Models; Public Policies, National System of Entrepreneurship.

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INTRODUCTION

1. Contextualization

Based on the complementary analytical models of National Systems of Entrepreneurship (Acs et al, 2014) and National Systems of Innovation and using complexity economics as the fundamental quantitative approach, this thesis describes the necessary steps in the construction of a Brazilian System of Entrepreneurship Statistics that can serve as support for public policies for entrepreneurship. For Acs et al (2014), the specialized literature corroborates the view that entrepreneurship is an important factor for a country's development. Many authors argue on a whole series of economic benefits generated by entrepreneurs, ranging from innovation (Acs and Audretsch, 1988) to job creation (Blanchflower, 2000; Parker, 2009), as well as in more specific points, such as the facilitation of technology transfer between R & D areas and industry (Acs et al, 2009; Grimaldi et al, 2011; Plummer and Acs, 2012).

The National Systems of Entrepreneurship (NSE) are fundamentally resource allocation systems that are driven by the search for opportunities at the individual level, through the creation of new enterprises, with this activity and its results regulated by specific institutional characteristics of the country. In contrast to the institutional emphasis of the approach of National Systems of Innovation (NSI), where institutions engender and regulate action, the concept of NSE assumes that the functioning of systems depends on individual actions, supported by institutions that regulate actions and their results. The NSE approach, in a certain way, brings a rescue of the balance between individual action and the institutional context. Based on these principles, the authors also introduce a new methodology of indicators to characterize the National Systems of Entrepreneurship. The characteristics of the methodology are: systemic approach, which allows interactions between components of NSE; bottleneck mapping, which identifies flow trapping factors that preclude system performance; contextualization, which recognizes that national entrepreneurship processes are always inserted in the local institutional framework of a given country (Acs et al, 2014).

Establishing a Brazilian system of entrepreneurship statistics is important for public policy purposes. Such a system must enable understanding the local specificities both in terms of the character of entrepreneurship in Brazil and the actions of public policies already produced or to be produced. In this sense, it is also worth studying, analyzing, understanding and adapting other frameworks, such as: Shane & Venkataraman´s proposal (2000), which explores the creation of a conceptual framework in which they define the domain of social research of entrepreneurship; or Ahmad & Hoffman's (2008) proposal, which is nowadays, with slight changes, the OECD's base nomenclature that has been used to evaluate entrepreneurial activity in the various sections of society, as well as to allow comparisons between its member countries (Lunati et al, 2010).

2. The Objectives

The main purpose of the thesis is to pave a way of building up a Brazilian model for the measurement of the entrepreneurship economy with a focus on the use of public policies, which should serve to monitor the dynamics of the Brazilian entrepreneurial scenario under the influence of governmental actions.

Other goals of the thesis are: the analysis of entrepreneurship combining NSI and NSE approaches; a typification of the Brazilian NSE based on complexity economics; the presentation of an exhaustive list of existing sources of information for the generation of indicators, identifying possible gaps in them and propose means of overcoming them; the presentation of a synthesis of indicators on the entrepreneurial activity that could serve for longitudinal monitoring of the entrepreneurship economy in Brazil; and giving examples on how to use the approach proposed in the thesis to make a diagnosis of the Brazilian entrepreneurial scenario in recent years through the calculations proposed by the model.

3. Object and Justification

The object of study of the thesis is entrepreneurship, defined as a set of entrepreneurial activities. An entrepreneurial activity corresponds to "the human action of undertaking in the pursuit of value generation, through the creation or expansion of economic activity, identifying new products, processes and markets" (IBGE, 2017). This action, as the definition itself already describes, can only be carried out by the individual, who is the entrepreneur.

This approach uses the action of the individual as the starting point of the systemic analysis and represents a different view from many authors who see in the production of opportunities the great phenomenon to be studied. The approach taken in this thesis carries the notion that the actions of individuals (in addition to the production of opportunities) is the fundamental point for the entrepreneurial process. The objective existence of independent entrepreneurial opportunities does not seem to make sense, since the individual is the only one to combine an existing opportunity with its viability (McMullen and Shepherd, 2006). Acs et al (2016b) argue that the main research questions in the area of entrepreneurship can be summed up to two: why an individual decides to become an entrepreneur while others do not; and why entrepreneurial activity differs so much from country to country (Acs et al, 2016b).

In order to delimit the object of the thesis, entrepreneurship as an entrepreneurial activity developed by individuals, the starting point is the work on NSE (Acs et al., 2014, 2016b), which, due to the systemic nature of innovation, proposes an approach that, for public policy purposes, focuses efforts on the analysis of resource allocation and performance. The authors build an analytical framework that goes through the identification of the agents of the system and the interaction between them. The more detailed the map of interactions between agents, with description and categorization of institutions and individuals and the specificities of their interactions, the greater the chance of mapping emerging behaviors. This analysis includes the identification of possible bottleneck factors of the interaction flows precluding a functional system.

The relationship between entrepreneurship and public policy has been built in developed countries over the past three decades. The general belief among policy makers that it is necessary to train entrepreneurs as an initial step in stimulating business growth and increasing economic dynamics has its origins in Scandinavian countries (Storey, 2003, p. 478). Over time, this way of thinking gained scope and several countries aimed to create policies to support entrepreneurship. Certainly, there are examples of government programs intended to foster entrepreneurial activity, in almost all developed and developing countries.

As an illustration, in Brazil, the latest governmental action involving the theme was in 2012, with a program called National Policy on Entrepreneurship and Business (PNEN), as part of the Brasil Maior Program (La Rovere et al., 2018; MDIC, 2012). There were also attempts to measure the entrepreneurial phenomenon through the construction of meta-synthesis indicators, such as the recent proposal by the European Union to incorporate into Europe 2020 Headline Indicators an additional index combining elements of innovation and entrepreneurship (European Commission, 2013).

However, at the same time as the theme took place on the agendas of most governments in Western countries, there is no apparent evidence that such governments have clear mechanisms for evaluating their initiatives. Despite the current relevance of the issue, its dissemination in society and support initiatives by the third sector, much still has to be done in the discussion of the phenomena and its ability to modify the economy, so that it can be echoed in public policies. In the vast literature that analyzes the economics of entrepreneurship there is still a place for the production of empirical information systems relating to the factors that affect entrepreneurship to the benefits of it. Even in countries where there is an initiative to follow up indicators used in government policies, as in the case of Denmark, the focus is either on small and medium enterprises or on the individual entrepreneur only (Hoffman, 2007). None of these alternatives captures the whole phenomenon.

In addition, although concrete examples of measurement have emerged recently, even in cases where the phenomenon is allegedly analyzed in its scope, as in the model proposed by Ahmad & Hoffman (2008), there is a need to build bases applicable to the Brazilian economy, once the country has different characteristics from those for which the models were designed.

4. Hypotheses

This thesis deals with three main hypotheses. The first one regards the adequacy of the proposed theoretical background to the Brazilian case. Given that the approach of NSE considers entrepreneurship as a fundamental part of a complex system, one must consider how complex the Brazilian system would be. The first hypothesis, therefore, is that <u>the Brazilian entrepreneurship system is a complex system</u>. To test it, it uses measures of complexity (complex networks) described in detail in Chapter 1.

The second hypothesis of the thesis analyses, in the context of entrepreneurship, one of the most important aspects of a complex system: the emergent behaviour in the aggregate level caused by interactions into the micro level. In the model suggested by Acs et al. (2014), the general notion of complexity is combined with the notion of systems, to define a 'complex system'. As previously stated, a complex system is an institution or organization composed by many parts interacting with each other. In such systems, the individual parts (named "components" or "agents") and the interactions between them generally lead to large-scale behaviors that are not easily predicted from a knowledge of only the behavior of individual agents. Such collective effects are called "emerging" behaviors. Examples of emerging behaviors include short- and long-term climate change and price fluctuations in markets (Mitchell & Newman, 2001). This point will be addressed in Chapter 2, where it is shown how to implement an agent based model (ABM) that includes emergent behaviours properties. It is important to note that agent based models were also explored by orthodox economists. Authors like

The conceptual steps, therefore, to establish the systemic and complex character of entrepreneurship in Brazil and its capacity to generate emerging behaviours are as follows: definition of what will be treated as entrepreneurship; definition of what are the agents of the Brazilian NSE; creation of the basic rules of interaction between agents; examination whether the system interactions generate emergent behaviors.

The third and last hypothesis of the thesis brings the idea that reallocation of resources generates a change in the *performance*[1] of the entrepreneurship system (generation of new

[1] The concept of performance is used here in the sense of the evolution of the dynamics in terms of generation of new firms and/or creation of new jobs. It is not the intention to characterize the dynamics like a “competition” among entrepreneurs or firms. It is just a way to understand how to potentialize the impact of policies whose main purpose is to develop the whole economy.

firms and creation of jobs). Acs et al (2014) draw a systematic and systemic framework of a NSE based on the interactions and changes in different variables, pillars and sub pillars that affect the performance of the country in terms of the entrepreneurial dynamics. The authors argue that entrepreneurship is a rooted action: both the individual and the context are important. Therefore, the third hypothesis is to verify the possibility of an increase in the performance at the level of the system by the best reallocation of resources managed by policy makers.

To test the hypothesis, it will be necessary to verify whether the reallocation of resources generates changes in the overall performance of the system, that is, in the generation of new enterprises and in the generation of jobs in the existing enterprises. Once the rules of interaction between individuals and institutions have been identified, simulations that take into account changes in relations and their consequences in the generation of new firms or creation of employment can be suggested. This specific point is explored in Chapter 3.

5. Contributions of the Thesis

There are at least two major contributions that the thesis aims to achieve: a theoretical one, by shedding light on the problem of complexity in NSEs; and an empirical contribution, which is, through the databases available, to establish the main factors that lead the individual to become an entrepreneur and, with this, to use this knowledge to build the framework derived from the systemic view, with a posterior analysis of the results.

From the theoretical point of view, it is not clear in the literature, either in the NSE or NSI approaches, how complexity works in an entrepreneurship system, a proposed causal[2] test that could explain the relationship between complexity of the system and opening new businesses, especially in the innovative ones. The first and third hypotheses are related to this contribution.

The empirical contribution refers to the proposal of construction, analysis and diagnosis of the possible effects of public policies on entrepreneurial activity. The proposed period is the most recent one, from 2001 to 2015, on which structural data are available. To date, there is no systematic way of understanding the phenomenon of entrepreneurship in all its magnitude in the entrepreneurship statistics in Brazil. There is, however, an effort to set a basket of certain parameters linked to the description of the phenomenon, what is equivalent to say that such parameters can not be considered in sufficient number and depth. Organizing and presenting, in a public policy perspective, the apprehension of knowledge about the data is therefore a novelty. The second hypothesis concerns the empirical contribution presented above.

6. Theoretical Framework

It is a fact that the idea of entrepreneurship has been treated in a very heterogeneous way in the economic literature. Link (2006, pages xii and xiii) recognizes as seminal works of

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[2] The term “causal” is used in this context in regard to the statistical properties of the systems. It is important to take into account what is the probabilistic character of the system.

Cantillon (1892), Schumpeter (1911), von Mises (1969) and Schultz (1975), which present several dimensions involved in the concept of entrepreneurship. Wennekers and Thurik (1999) point out that the entrepreneurship view is dependent on the level of analysis in focus, such as the individual's view of the firm and the aggregate levels of economic activity. For Acs et al. (2014), the key issue is that existing approaches to measure entrepreneurship often lack definition. Instead, an attempt is made to directly achieve entrepreneurship measures for a country without providing adequate theoretical or conceptual rationales for the chosen measurement approaches. The result is a myriad of "entrepreneurship" measures that often do not actually talk to each other.

In the context of theories on entrepreneurship, among the various trends that have emerged over time, the most relevant ones are: the historical view of entrepreneurship; those derived from evolutionary economics; those which take into account historic aspects of economic growth; as well as views derived from business management. Carree and Thurik (2002) discuss the role of entrepreneurship for macroeconomic growth and argue for the existence of several types of entrepreneurship, with greater importance for three of them: innovative entrepreneurship, initially analyzed by Schumpeter; Kirzner's entrepreneurship - in reference to Kirzner (1997) - which focuses on the perception of profit; and Knight's entrepreneurship (Knight, 1921/1964), which assumes the risk associated with business uncertainty. In this way, when creating a new product or opening a new business, the entrepreneur acts simultaneously in relation to the three types defined above. Thus, every entrepreneur is innovative, has perception of the opportunities of profit and assumes the risk that the enterprise intrinsically possesses.

The modern discussion of the topic is embedded in the more general precepts that guide the views of neoclassical economics, focused only on the perspective of individual action on the one hand, and economic heterodoxy, which emphasizes the importance of the institutional context, on the other. In the traditional interpretation of the neoclassical model all individual agents have perfect information. Their economic goals are clearly and rationally stated. In equilibrium, consumers and producers reach a set of prices in which the demand for each good is equal to their supply. All markets that are implicitly assumed and also work perfectly well to converge to this set of equilibrium prices. Given this definition of a firm's task, there is no need for an innovative initiative taken by individuals. The neoclassical model, with its production function, the internal logic of rational choice and perfect information, reserves no place for an active entrepreneur (Wennekers and Thurik, 1999).

In addition, even authors who lie in the frontier between orthodoxy and heterodoxy, such as Casson (2003)[3], argue that the neoclassical school has extreme premises on access to information of individuals, assuming that all entrepreneurs have free access to all information necessary for decision making. This view reduces the individual to the mechanical application of optimization rules, which make the results non-adherent to reality and making it impossible to analyze the entrepreneur's role in decision making. Moreover, the usual neoclassical definitions

[3] In fact, Pierre-André Julien criticizes some arguments of Casson, putting him in the orthodox side, like in this excerption (Julien, 2007, pg 22): "Although Casson criticized Walras, who said, in the theoretical world, as his first assistant points out (Antonelli, 1939) that the equilibrium price should be announced before producers take action, he did exactly the same thing with his discussion of the salaries available on the market, saying that the salary had to be sufficient before a potential entrepreneur would take action. The problem with this is that he was referring as much to Cantillon´s entrepreneur employees (an entrepreneur is not the same as the capitalist) as to entrepreneur owners, and used these terms interchangeably. Casson does not admit that entrepreneurs launch businesses because they *believe* they will make money, even if they end up going bankrupt or abandoning the firm during the start-up process if they are unable to innovate and overcome the obstacles in their way, or if they are unlucky."

of entrepreneurs do not go so far as to consider the role of institutions in individual action, as Casson admits, by emphasizing that one of the most common definitions among neoclassical thinkers for the figure of the entrepreneur is that which relates him/her to an accomplished administrator of scarce resources (Casson, 2003, page 21).

If, on the one hand, the neoclassical approach tends to disregard the role of institutions that create opportunities for individual entrepreneurial action, heterodox economics, on the other hand, usually neglects the individual aspect of the phenomenon, as in the case of literature that builds the concept of NSI. Although the systemic approach to understand innovation is attractive in the social sciences, there have been changes in emphasis over the years. In the beginning, one of the main missions of the NSI literature was to criticize the linear model of innovation emphasizing and illustrating the interactive, iterative and cumulative aspects of innovation processes in national contexts (Freeman, 1987, 1988; Freeman and Lundvall, 1988; Lundvall, 1988; Lundvall et al., 2002). This concept became influential because the focus both on institutions and structural changes gave a basis to policymakers for understanding and facilitating the development of innovation (Nelson, 1993). However, with a focus on structure, the NSI literature tends to ignore individual activity (Hung and Whittington, 2011). This means that the NSI framework appears to be ill-equipped to understand emerging innovation systems (Gustafsson and Autio, 2011). The emphasis on national institutions was attractive in the 1990s and early 2000s, while the past few decades have witnessed a growing interest in the role of entrepreneurship and individual activity in driving innovation (Acs et al, 2009; Audretsch et al., 2006; Mueller, 2006).

The concept of NSI turned popular in the political scene in the early 1990s with the publication of three books: “National Systems of Innovations” (Lundvall, 1992); “National Innovation Systems: A Comparative Analysis” (Nelson, 1993); and “Systems of Innovation — Technologies, Institutions and Organizations” (Edquist, 1997). The main theoretical foundations are that: knowledge is a fundamental resource in the economy; knowledge is developed and accumulated through an interactive and cumulative process of innovation incorporated in a national institutional context; and context is important for returns of innovation (Lundvall, 1999). In the NSI literature, the notions of interaction and accumulation of knowledge shifted the emphasis from the individual R & D processes to the institutional and industrial structure in which these processes were incorporated. An important point is that this structure (rather than individual R & D processes) is ultimately what determines the productivity of innovation of nations. Some of the most influential authors in this area were: Richard Nelson, who carried out an international research project comparing 15 countries (Nelson, 1993); Bengt-Åke Lundvall, who emphasizes interactions between producers in innovation systems (Lundvall, 1992) and Chris Freeman, whose early studies of the Japanese innovation system influenced subsequent research (Freeman, 1988). The systems approach has been widely expanded to consider technologies, institutions, organizations and industries as well as countries (Edquist and Johnson, 1997; Malerba and Breschi, 1997).

However, the notion of entrepreneur remains absent in most of the literature on NSI. Radosevic (2007) attributes this gap to the predominantly institutional emphasis of NSI literature, making it difficult to accommodate the individual perspective on the literature on entrepreneurship (Shane, 2003). In the institutionalist tradition of NSI literature, institutions generate, homogenize and reinforce individual action: they are institutions of the country that create and disseminate new knowledge and channel it to efficient uses. The production of opportunities, therefore, and their roots in institutions, are the main focus of this view. In this perspective, individual action is not considered or should occur automatically, subject to the homogeneous influences of the institutions of the country. This emphasis on the strengthening of NSI has proved difficult to reconcile with the individual-centered emphasis focused on the routines of the literature on entrepreneurship (Radosevic, 2007; Schmid, 2004).

Therefore, the definition of NSE goes through the argument that the concept of entrepreneurship can not be properly understood without considering both the processes (attitudes, capacity and aspirations) of the population and the institutional context within which these processes were incorporated. Furthermore, any systemic approach to measure entrepreneurship has to allow system components to interact to produce system performance. This implies that system performance may be retained by bottlenecks, i.e. weakly performing system components.

Feasibility and desirability considerations can be influenced by contextual factors such as resource availability, gender and social attitudes. However, this action-centered approach and other similar approaches in individual entrepreneurial and business-focused research do not consider the various aspects of entrepreneurial action. It is proposed that an NSE perspective should emphasize the interactions between individuals and their institutional contexts in the production of entrepreneurial actions and in the regulation of the quality and results of this action. Any definition of NSE must recognize that entrepreneurship: is a fundamentally individual behavior; mobilizes resources for the search for opportunities through the creation of new companies; is driven by complex interactions at the population level between attitudes, aspirations and ability; is inserted within a multifaceted economic, social and institutional context; and drives economic productivity through the allocation of resources to efficient uses. An NSE is, therefore, the dynamic, institutionally incorporated interaction between attitudes, skills and entrepreneurial aspirations, by individuals, which lead to the allocation of resources through the creation and operation of new enterprises (Acs et al., 2014).

In this context, the main contribution of Acs et al. (2014) is to provide a methodology for the construction of indicators that: helps to contextualize the processes of entrepreneurship at the national level, making it relevant for the study of specific characteristics of the country; incorporates interactions between the components of the system, thus reflecting the complex characteristics of the NSE; identifies bottlenecks that preclude system performance, thus drawing policy attention to specific system components that require more attention; provides a sensitivity idea of system-level performance for bottleneck factors, thus helping to set tangible policy goals and support initiatives to alleviate identified bottlenecks.

In addition to NSE and NSI views on entrepreneurship, one of the most important theoretical foundations of this thesis is the field of Complexity Economics. The first point to take into account on this is that complexity, even in a quantitative way, is a measure with different meanings. Much of the current discussion about complexity theory in the field of economics stems from the first multi-disciplinary meetings placed in the Santa Fe Institute in 2004 and 2005 (Mitchell, 2009). Such meetings generated works on the fundamentals of the theory of complexity economics as a junction of the fields of economics research and information theory, but also with contributions from biology, and much of computer science. Information theory, in turn, was born as a branch of physics[4], with a specific development in the analysis and definition of entropy, a physical phenomenon which occupies a central role in thermodynamics with further developments in an extensive list of areas.

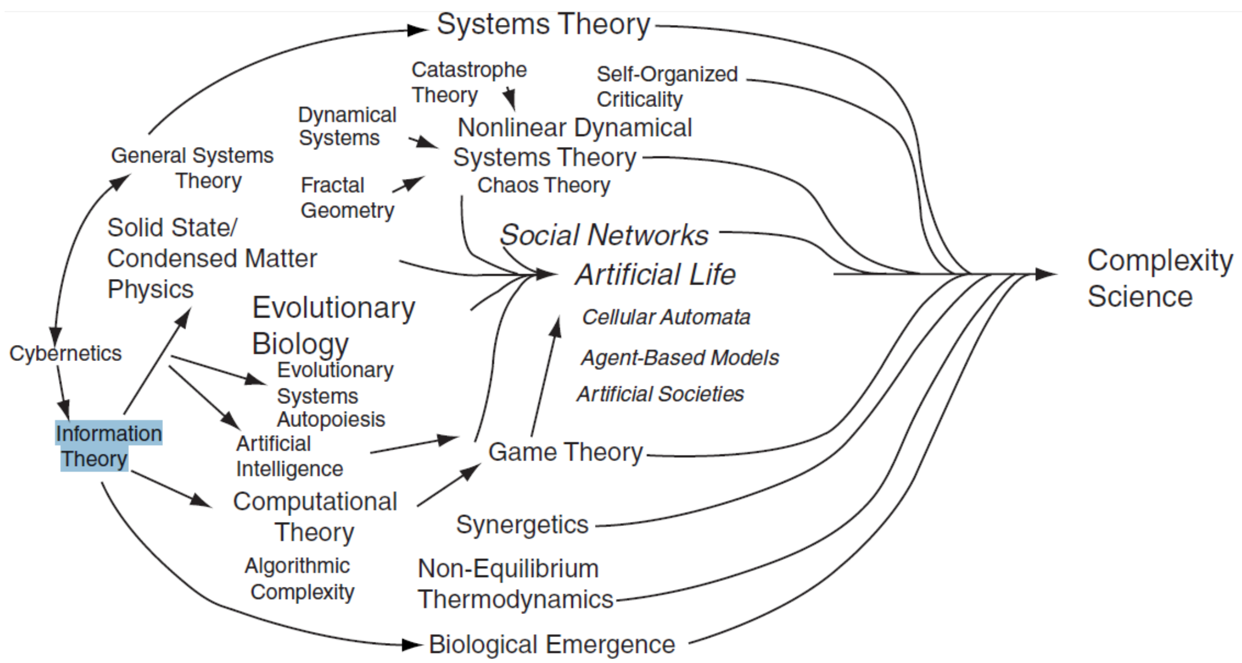
Mitchell (2009, chapter 7), a representative author from Santa Fe Institute's nascent ideias, presents the different notions and measures of complexity most commonly used: complexity as size, complexity as entropy, complexity as content of algorithmic information, complexity as logical depth, complexity as thermodynamic depth, complexity as computational capacity, statistical complexity and complexity as hierarchy degree. Other important authors of this complexity theory school and their most outstanding works are: Doyne Farmer (Farmer and Foley, 2009; Lillo et al, 2003; Farmer and Sidorowich, 1988), Jim Crutchfield (Feldman and Crutchfield, 1998; Crutchfield, 1994; Crutchfield and Young, 1989), Stephanie Forrest (Balthrop et al., 2004; Dasgupta and Forrest, 1996; Forrest and Mitchell, 1993; Forrest, 1990), Eric Smith (Andolfatto and Smith, 2001; Smith, 2007), among others.

Another important line in the study of the relationship between entrepreneurship and complexity are those that come from management schools, such as Hazy et al. (2007), which establish a model to describe innovation and entrepreneurship. To do so, they use the concept of "context" to position entrepreneurship in the nexus of two categories of links: the rate that resources can be appropriated provides the capacity of how to exploit opportunities; the rate

[4] The original works of Shannon, for example, were applied in telecommunications, with special interest in engineering.

that information becomes accessible drives efforts in an evolving, specialized and distributed environment. Summarizing, Figure 1 is a representation of the relations between the various disciplines that, combined, are in the formation of complexity science. It is interesting to note in Figure 1 that information theory occupies a seminal role in the discussion of complexity and entrepreneurship (Hazy et al., 2007).

Figure 1: Complex System Theory - Areas of Research



Source: Hazy et al.(2007).

Because of this foundational character of the information theory in regard to the complexity economics, the following paragraphs are dedicated to interpret some choices made in this thesis by the light of this important area of research. In this way, in information theory, on the one hand, an important author is Kolmogorov, for whom complexity is regarded as the minimum length of the description of an information packet: it is a lower limit in compressibility. On the other hand, another important author is Shannon, whose concept of entropy can be interpreted as the number of pairs of zeros and ones required for optimal encoding of an information packet from a random source (Dehmer and Mowshowitz, 2011).

In order to estimate the Shannon entropy, it is assumed that the data are generated by some probability distribution. This assumption is not taken by the Kolmogorov complexity, which is the minimum length of the description of the chain in question, and not the minimum length of the contingent description in some probability distribution that generates it.[5] Therefore, the entropy of the system is estimated in light of the actual data and Kolmogorov's complexity measures the minimum length of the description of an information packet, so that one computer program can reconstruct it and stop without taking into account any probability distribution. Therefore the complexity of Kolmogorov is not computable. However, its limits can be formally described when describing the program that will decode it and the language used to describe it.

This thesis proposes that the original ideas developed by Shannon and Kolmogorov can be combined with the present approach developed by the field of complexity economics[6]. In this way, frequently used tools like complex networks or ABMs apply similar concepts to those from physics, sometimes in the sense of Shannon entropy, sometimes in the sense of

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[5] In order to calculate the entropy of an information packet in a given language, for example, some notion of how it was generated is needed: in this case, an alphabet with, for example, 26 characters, some of which are more likely than others.

[6] Here there is no relation of opposition between the original ideas of information theory and the research field of complexity economics. In fact, many propositions in the actual approach developed by complexity economics are derived from information theory. The intention here is just to emphasize that the theoretical background behind tools like complex networks or agent based models is more directed linked to the original works than has been written in papers published in journals of social sciences.

Kolmogorov one. In the case of complex networks, for instance, experts usually interpret the concept of complexity of a network as a version of Shannon's conceptualization: they look for properties based on probability distribution of graphs, for example. The development of this approach was possible only after the advent of Erdos-Renýi model, which describes a systematic way to generate random graphs. Later advances in this area of research were in the direction of the presentation of new and more realistics models but always in comparison with the random noise. Chapter 1 uses the approach of complex networks to characterize the complexity of employment mobility in the way discussed above: the features of the contingent description in the probability distribution of employment mobility in a given period.

ABMs are close to Kolmogorov's ideas of complexity. The goal of an ABM is to reproduce the macro behaviour of a system from a minimal set of interaction rules of agents, in an institutional context. This means that, with a minimum volume of information about agents (inputs), the model leads to an interpretation of a maximum of information of the system (outputs)[7]. Chapter 2 treats this case, implementing an ABM where the agents are employees, firms and other institutional constructs while the interaction rules lead the system to generate an amount of firms founded by employees who decided to become entrepreneurs.

Summarizing, the empirical approach was chosen based on economic assumptions on entrepreneurship. These assumptions provided the general notion of development through growth of firms and number of employees. The empirical research behind this idea tests the adequacy of complexity theory to reality, then proposing a simulation to model complex flows

[7] Continuing with the example of a language, 26 letters would represent the inputs of a translator.

of employees quitting jobs and opening new firms, and then, finally, showing how to use the simulation to establish boundaries in the action of a specific policy action.

7. Empirical Approach

The empirical approach of this thesis uses a conceptual model to compare real world information with results derived from simulation (Figure 2). In order to test the hypotheses stated previously, a database is compiled containing information on employees, entrepreneurs, firms and other constructs. Evidence of complexity is found through these data using complex networks techniques. Those evidences serve as a guide in the search of a simulation model (an ABM one) to reproduce the real world behaviour. Once the model is validated by evidence from real data, the simulation can be used for the exploration of new frontiers of reality unreachable only with available information. The new frontiers explored by ABM generates knowledge on how to build a framework for entrepreneurship.

Figure 2: Real World Data x Modeling Data Working Together to Test Hypotheses

Source: Authors' elaboration.

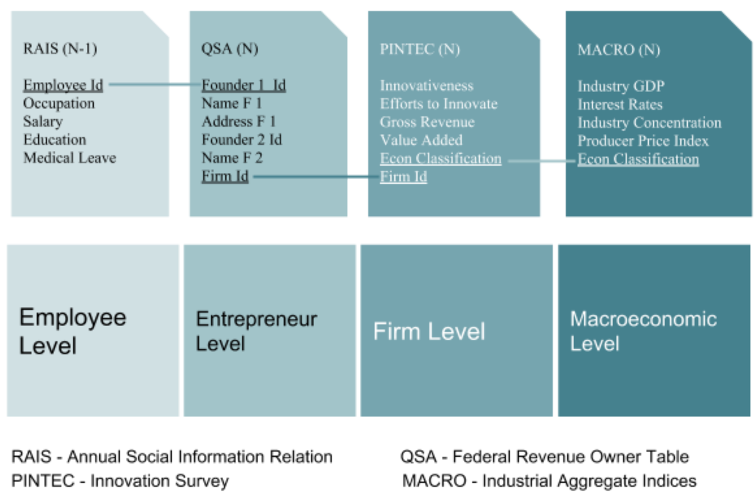
8. Databases

The starting point of our empirical analysis is the mapping of the professional trajectory of individuals through Brazil´s Annual Social Information Database (RAIS[8]), which registers all formal employees in this country yearly, from 2001 to 2015. Towards determining which factors are important to the decision of opening a new business, the second step is to link information from the RAIS with the Federal Table of Revenue Ownership (QSA[9]) in order to identify which individuals who were once formally employed[10] opened new businesses in the following corresponding period. As the focus of the thesis is the discussion regarding economic growth, and especially about the generation of employment, one can derive the subgroup of individuals who opened businesses that experienced a rising in the number of persons employed, which are important factors for the success of the enterprise.

[8] All acronyms regarding to Brazilian databases are in their original language (Portuguese). More information in: http://www.rais.gov.br/sitio/sobre.jsf
[9] http://idg.receita.fazenda.gov.br/interface/lista-de-servicos/cadastros/cnpj/consulta-quadro-de-socios-e-administradores-no-cnpj-acesso-via-portal-e-cac
[10] Other categories:left their jobs; were dismissed; and were no longer formally employed.

The third step of building up the necessary information structure to describe the phenomenon is to link those firms with Brazil´s innovation survey (PINTEC). This step allows to link micro-events performed by individual agents with the macro-level, where innovation can be observed. Finally, information on firms is linked with the environmental level, that includes a cast of macroeconomic indices like GDP and inflation indicators. Figure 3 represents these stages and hierarchical structure.

Figure 3: Databases Relationship



Source: Authors' elaboration from the following databases: Annual Social Information Database (RAIS); Federal Table of Revenue Ownership (QSA) and Innovation Survey (PINTEC).

Figure 4 shows the algorithm to find which individual becomes an entrepreneur over time. The idea is to follow all individuals employed in the firms presented in PINTEC sample in a given wave[11]. If the individual is in RAIS in a given year N then he/she is a formal employee in a

[11] *Wave* in this thesis means a specific edition of a given survey.

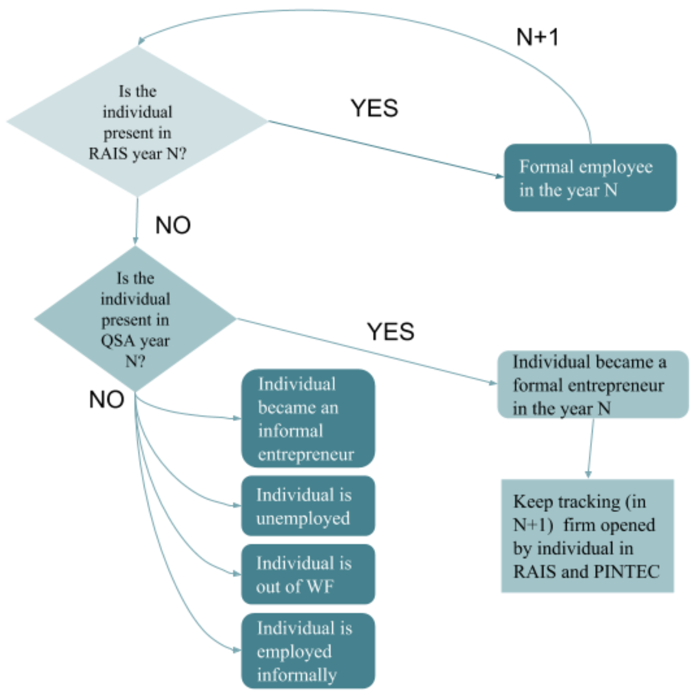
firm. If not, then it is verified the presence of him/her in the QSA in the year N. If the answer is positive, then it is said that the individual *became* an entrepreneur in the year N. Consequently, information on the firm opened is tracked over the next years. If the answer is negative, then four unreachable situations are possible: the individual became an informal entrepreneur; the individual was unemployed; the individual was out of the workforce, that is, he/she was no longer searching for a new job; the individual was employed informally. As mentioned previously, it is not possible to verify the information regarding these four alternatives, once there is no database available for it[12].

The application of this algorithm drives to a set of tables that are the result of a merging of RAIS, QSA and PINTEC. It is interesting to notice that the size of tables varies both by year and by innovation survey wave[13]. The upper two graphs in Chart 1 reveal that, when joined with QSA and RAIS, the PINTEC wave released in 2008 has the highest volume, followed by 2011, 2014, 2005, 2003 and 2000. Actually, there seems to be an inversion of the tendency in increasing the volume of data, registered in the waves 1 (2000) to 4 (2008), with decreasing from wave 4 to wave 6. Part of this is explained by a methodological aspect of the 2008 sample, which was designed to overcome the international economic classification transition from ISIC Rev 3 to ISIC Rev 4 (United Nations, 2002; 2008).

[12] It is not considered the possibility of an individual´s death once there is information on it in RAIS.

[13] PINTEC has had six waves until now: 2000, 2003, 2005, 2008, 2011 and 2014.

Figure 4: Tracking Individuals and Firms



Source: Authors' elaboration from the following databases: Annual Social Information Database (RAIS); Federal Table of Revenue Ownership (QSA) and Innovation Survey (PINTEC).

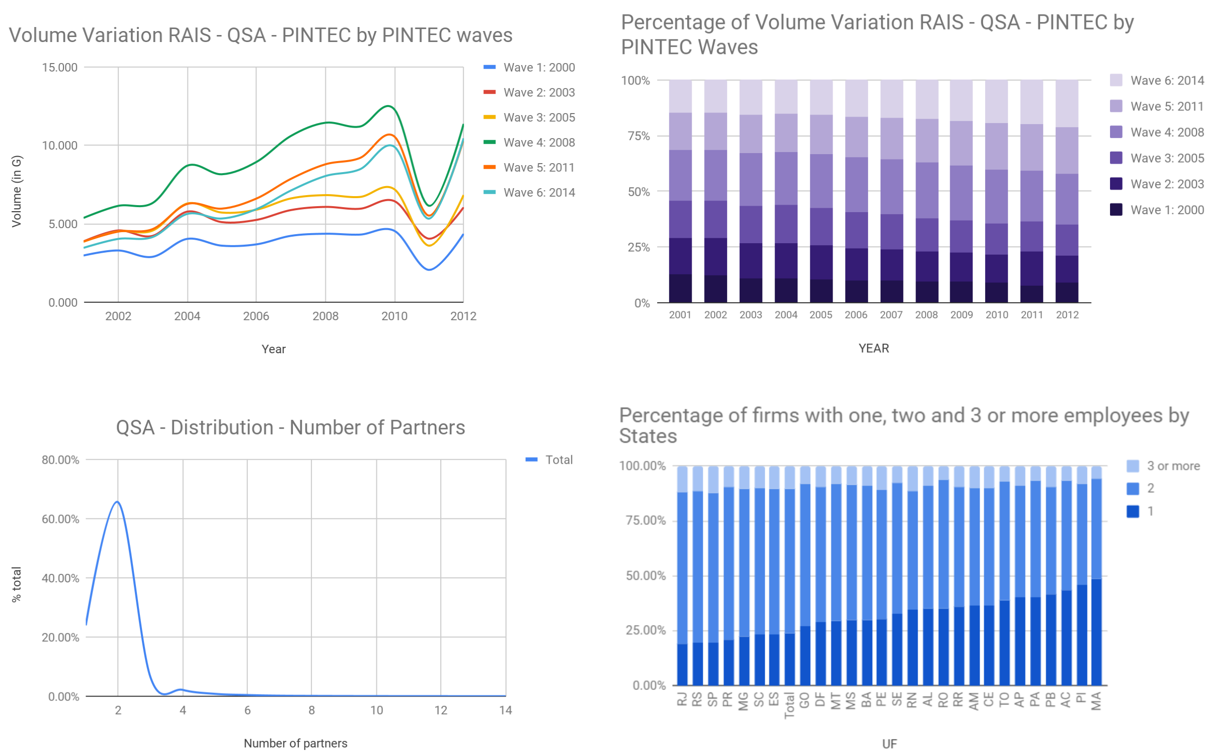
From the modeling results, it is expected to obtain a set of relevant variables for the differentiation between individuals who chose to open businesses and those who did not, that is, two different lists of variables that explain entrepreneurial behavior. Figure 4 illustrates how data is organized and how it is possible to separate information over time. Suppose that an individual in 2011 is employed in the Brazilian formal market. The question is whether the individual made the decision to quit the job in order to open a formal enterprise in Brazil in 2012. If this individual does not appear in the QSA 2012 and does appear in RAIS 2012, then it is counted as having taken the decision to remain in the formal job market as an employee. In

2013 the same individual appeared in QSA 2013 as a member of a new venture. In addition he/she is no longer registered in the RAIS (2013) as an employee in the formal market. From this point, the research focus, the object, becomes the firm that the individual opened in 2013. One can therefore investigate the firm's trajectory in terms of generating new jobs, revenue generation, high growth, innovation, etc. Thus, the dependent variables that are present in IBGE's economic survey are analyzed.

As the focus of the thesis is the entrepreneurial individual and the factors that make him successful in terms of job creation, we aggregated the information from all the bases mentioned above (Chart 1), in order to identify the main factors of influence in the decision to open a business and to become a source of employment.

There are some results derived from this methodology that can be further exploited: for individuals with a long history in the series, from 2002 to 2015, successes and failures can be considered in subsequent ventures as variables of influence for the later success of the enterprise; variables that can be constructed are also those that relate to the "success" of the employee in the firm, through salary increase, for example, as a factor of influence in the decision to open a business.

Chart 1: Evaluation of joined databases RAIS - QSA - PINTEC



Source: Author’s elaboration

Still about Chart 1, the lower two graphs represent the distribution of the number of owners in Brazil in 2015. The left one shows that more than 65% of firms have 2 owners, while about 25% has just one owner. Although the percentage of larger firms is bigger in more economically developed states (such as Rio de Janeiro, Rio Grande do Sul and São Paulo), these numbers mean that 90% of firms in Brazil in 2015 had one or two people engaged in the firm (owners and employees), which reinforces the idea that to treat firms in Brazil is almost equal to treat small and medium enterprises.

9. The Structure of the Thesis

The thesis contains, in addition to this Introduction, three essays accommodated as the following three chapters. The last chapter brings the conclusions. These three essays treat different subjects, as follows:

- Chapter 1: Employment Mobility and Complex Networks
- Chapter 2: Entrepreneurship as an Economic Complex System
- Chapter 3: Public Policies for Entrepreneurship

Chapter 2 focuses on the structure of the complexity in terms of employment mobility, exploring complex networks by economic activities, their time evolution, education level, occupation, hierarchical structure and innovation. Chapter 3 shows the implementation of an ABM having with it the central point the creation of new firms by entrepreneurs (agents). Chapter 4 uses the validated simulation described in Chapter 3 in order to explain how to build a framework of entrepreneurship which could serve for public policy purposes.

CHAPTER 1 - EMPLOYMENT, MOBILITY AND COMPLEX NETWORKS

This chapter explores aspects of complex networks of employment mobility in the formal labor force. The main idea is to consider the knowledge diffusion that employment mobility provokes from the point of view of the economic complex system theory. A database of Brazilian firms and employees, with more than 80 million people along 15 years are analysed taking into account 900 different categories of occupation, education level and 16 economic activities spread out mining and manufacturing industries. The results show that there are at least three different patterns in the complex networks generated by employment mobility, in a range from clusters with a low level of complexity (calculated by a cast of indicators of subgraph, product and entropy measures) up to a very high level of complexity. The results also indicate that employment mobility can be modeled as a non-linear adaptive system.

1. Introduction

Complex networks theory is a broad field of research, with origins in topology and statistics, which has been incorporated as a tool in the scientific area of complexity economics since the first works in the decade of 1960. Many authors find complex networks a useful way to comprehend interesting and fundamental properties of social systems, mostly because heterodox economic thinking can have its principles tested and analysed. The ideas of information asymmetry of individuals or local influence of agents, for instance, can be implemented in a realistic way using available techniques from complex systems approach.

The first work towards a consolidated field of research in the theme of complex networks was made by Erdos and Renýi (1959), who developed the Erdos-Renyi model for random graphs. Later, the Watts-Strogatz model brings light to so-called small-world networks (Watts and Strogatz, 1998). Finally, Barabasi and Albert propose a model to treat scale-free networks, a type of network more realistic once considering a growing number of nodes (Barabasi and Albert, 1999). In the field of employment mobility, there are many works modelling the workforce movement as a problem of optimization. Schneck (2009) develops an optimal employee-to-employer strategy based on a search for higher wages. Gianelle (2014) discovers a regional small world network of labour mobility by using an employer-employee database. Schmutte (2014) applies complex network analysis to describe boundaries to job mobility. Guerrero and Axtell (2013) create an object that they call labor flow network (LFN), representing employment mobility as edges of a network in which the nodes are firms. Derzy (2012), using a social security database, shows that employment mobility exhibits a scale free distribution function, small average path length and high clustering coefficient.

2. Methodology

The complex network analysis is a methodology that studies the existing relationships between the different entities that build up a system. Normally these entities are known as agents or nodes and have associated certain attributes. Their relational connections are called links and these relationships determine patterns that shape what is known as the structure of the network. Based on all this, various indicators are derived that allow characterizing the system and making inferences about it. So the fundamental premise of the social network analysis is to explain social phenomena through the analysis of relationships between actors, developing a study in three ways: the behavior of individuals at the micro level; macro-level patterns or network structure; and the interactions between the two levels.

Three main models of creation and analysis of complex networks have been developed since the first works of Erdos and Renýi. Based on the discussion presented by Albert and Barabási (2002), it is important to keep in mind the main properties of each model:

- The Erdos-Rényi Model (1959): degree distribution is binomial which for a large number of nodes can be represented by Poisson distribution; average path length scales with the number of nodes; clustering coefficients depends only on the coordination number of the lattice; principal eigenvalue can be isolated in the graph spectra.
- The Watts-Strogatz Model (1998): small world networks; some eigenvalues appear at the same level in the graph spectra.
- The Barabási-Albert Model (1999): degree distribution follows a power law with preferential attachment, resulting in scale free networks; average path length scales as the exponential of the degree exponent; no vestige of main eigenvalues in the graph spectra.

Therefore, many of the most interesting aspects of the complex networks analysis, explored by complexity economics literature, can be grasped through a set of indicators created to accommodate the results in the horizon of the characteristics of the three main models described above. Inspired by Gianelle (2014) and Bonchev and Bruck (2007), one feasible cast of indicators is presented in Table 1. However, some reflection on the statistical properties of a complex system represented by a graph is needed before moving forward in this methodological direction.

Kim and Wilhelm (2008), for example, offer an interesting discussion on how complexity, in general terms[14], could be interpreted by the topological features of a graph. They argue that, despite a variety of measures proposed by literature, there is a large class of measures with high correlation with the complete number of edges, like: the number of spanning trees; arithmetic variations of the relation between the adjacency matrix and a given vector; or the conditional complexity (Kim and Wilhelm, 2008). Nonetheless, neither of these measures takes into account how intricate the modularity structures of a graph are, what it would be the most important characteristic of a complex network. In order to remedy this difficulty, the authors propose a series of measures based on three different types of calculation: subgraph measures, product measures and entropy measures. Some authors concentrate efforts in formulating and understanding only one of these groups of measures, like Dehmer and Mowshowitz (2011), who outline a literature review on entropy measures. In this sense, a challenge to be tackled in this area is to choose, from a pleyade of options, the measures that can be considered the best ones to interpret the phenomenon in question.

In addition, although the approach proposed by Kim and Wilhelm (2008) and other authors seems to be promising, one of the barriers to quantify satisfactorily the dimension of a complex network is the computability of the calculations. Some of the options, considered the

[14] "In general terms" means beyond the regular way of interpretation of results used by complexity economics literature. Certainly, it is not the intention in this text to withdraw with previous works on complexity economics. It is an alternative way of analysis the data under the light of physics. This interpretation could be a central point of observation of the phenomenon and, simultaneously, complementary to the Erdos-Renýi / Watts-Strogatz / Basabási-Albert taxonomy.

best ones, have their computational time proportional to the square or cubic number of edges or vertices, which means that, for larger networks, it is not feasible to calculate this type of magnitude in a reasonable time lapse. For the case of this chapter, the content of some graphs reaches more than one thousand vertices or edges. This puts the computational task at an unachievable level. Therefore, the choice taken in this paper is to compile “classical” measures in addition to new computable ones, not with the intention to classify the networks into the “traditional” models presented before, but in an attempt to interpret the results through a clustering method, independently of the taxonomy consolidated by the complexity economics literature.

Table 1: Main Network Statistics

Acronym	Definition
NC	Number of vertices
NL	Number of links
SD	Standard Deviation
DT	Density
WCC1	Size of giant weakly connected component (network coverage)
WCC2	Size of the second largest weakly connected component
SCC1	Size of giant strongly connected component (network coverage)
SCC2	Size of second largest strongly connected component
IN	Size of IN component (network coverage)
OUT	Size of OUT component (network coverage)
APL	Average number of individual jobs jumps
APL - ER	APL of the random network (Erdós-Rény)
APL - IOD	APL of the random network based on the joint in- and out-degree distribution of the actual network
ACC	Average clustering coefficient of the actual
ACC - ER	ACC of the random network (Erdós-Rény)
ACC - IOD	ACC of the random network based on the joint in- and out-degree distribution of the actual network
A/D	The ratio of the total adjacency and the total distance of the graph, or, in other words, the ratio of the average vertex degree and the average distance degree
B	Complexity index corresponding to the sum of all ratios between vertex degree by the distance degree
SC	Generalized Platt Index including the calculation of all cycles in a subgraph count.
OC	Sum over the values overall connectivity
TWC	Total Walk Count

Source: Author’s elaboration based on the works of Gianelle (2014), Bonchev and Bruck (2007), Kim and Wilhelm (2008) and Dehmer and Mowshowitz (2011).

The idea is, through the analysis of the indicators presented in Table 1, to interpret the formation of groups of economic activities with similarities in terms of complexity measures.

The starting point of empirical analysis is the mapping of the professional trajectory of individuals through Brazil´s Annual Social Information Database (RAIS[15]), which registers all formal employees in this country yearly, from 2001 to 2015[16]. To build up the network we define two different types of structures in terms of vertices and connections. The first type considers two kinds of vertices: the firms, represented by the identification firm number in RAIS; and the employees, represented by social security numbers. Each employee has to be linked to a firm. In a given year, when an employee moves from one firm to another, a connection between the two firms is created to represent the movement of the employee in that period. This type of construct is called, in this thesis, Network Type 1 and it is used in subsections 4.1 and 4.2 of the results section.

Another type of construct used in this thesis, that is called Network Type 2, is similar to what Guerrero and Axtell (2013) named labor flow networks (LFN). These authors use a database with information of Finland, using employees who move from one firm to another to establish connections between firms. In the present paper, we use this approach to build the networks presented in subsection 4.3 and 4.4, which contains just firms as nodes and employees moves as connections.

Another interesting point of the complex systems is the possibility of representing emerging behaviour of the group of agents. In this case, the emergent behaviour studied is the innovation performed of an economic activity. In case of Brazil, microdata from Innovation

[15] We opt to use the acronyms in the original language (Portuguese): Relação Anual de Informações Sociais (RAIS). More information in: http://www.rais.gov.br/sitio/sobre.jsf

[16] The main database considered here is RAIS that is available for n - 2 year (n = current year). In this case, as the calculations take computational resources to include each year, it was not possible to add the years of 2016 and 2017 once they were released when the thesis was already in progress

Survey[17] (PINTEC) were used to map the innovators spread out into 16 economic activities. The purpose is to identify the emergence of innovation in firms and activities through the behaviour of employees. Given the fact that this emergence appears from the connections, it is straightforward to say it is a product of agent interactions.

Therefore, the results in section 3 are shown as follows: subsection 3.1 presents an analysis of the evolution of individual firms along 15 years through network visualization; subsection 3.2 shows how to consider information of employees education level with the visualization technique; subsection 3.3 presents the emergent behaviour of systems by the representation of innovation; and subsection 3.4 brings results of indicators presented in Table 1 for each economic activity labor flow network, as well as an analysis of indicators of complexity by a clustering method.

3. Results

3.1. Evolution of the firms and economic activities

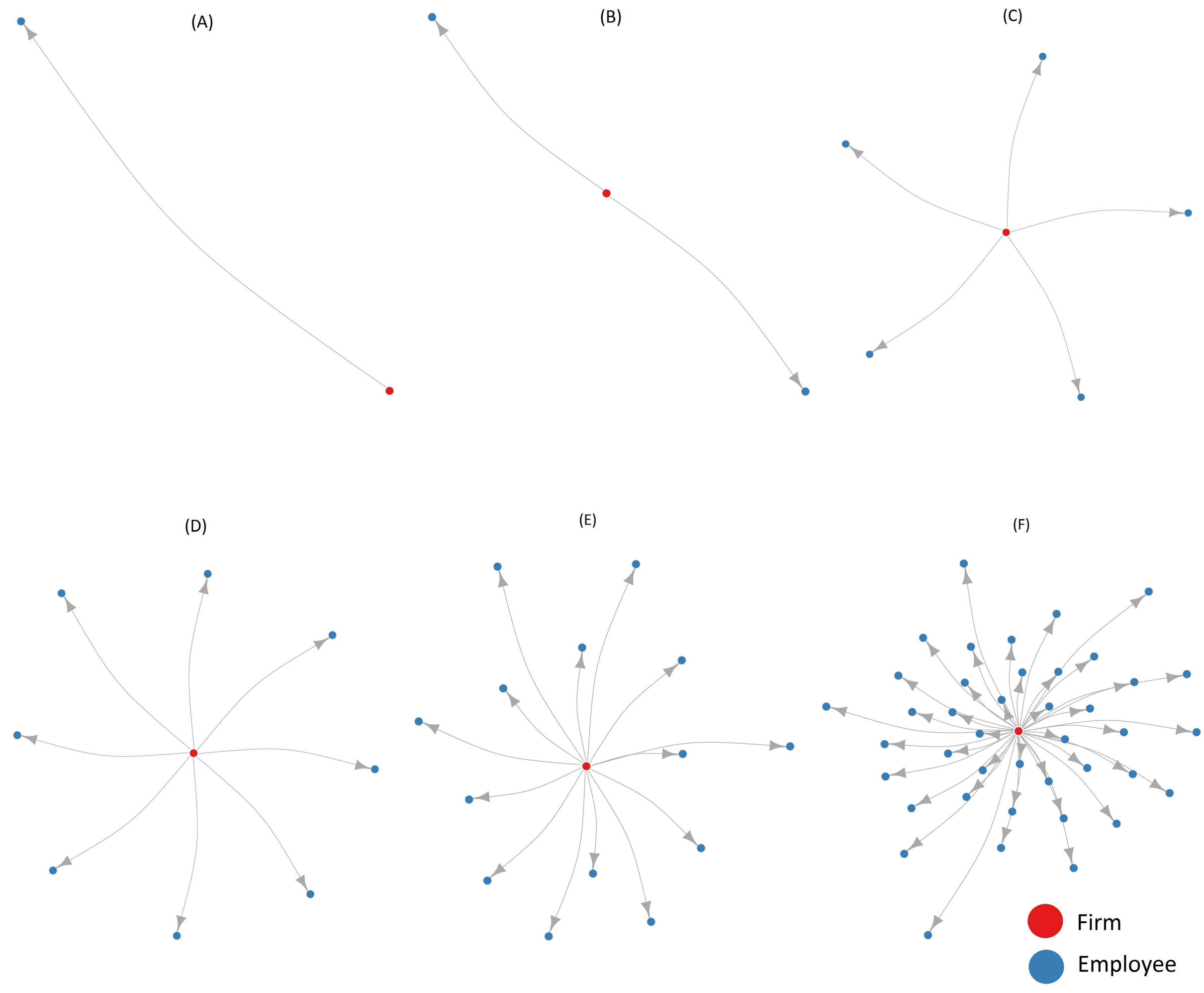
By using information from microdata it is possible to plot the evolution of the firms over time. Figure 5 shows an example of the evolutionary trajectory of only one firm. It represents the visualization history of a given firm along 10 years. Blue dots represent employees and red dots represent firms. The idea is to follow the path of employees from the original firm to others. The firm in question was born in 2001 having only 2 persons engaged: the owner and

[17] Pesquisa de Inovação, PINTEC. More information in: www.ibge.gov.br/pintec.

only one formal employee. In the last trackingpoint, 2010, the same firm reached 44 persons engaged. In this sense, although the subject of evolution of the firm is a good research object per se, the goal of this chapter is to analyse the flow of employees amid firms, that is, it is supposed that the endogenous aspects of the flow (like moves from and to different positions inside the firm or personal leaves) are out of the scope. In this sense, the object of interest of the chapter is closer than the Figure 6 shows.

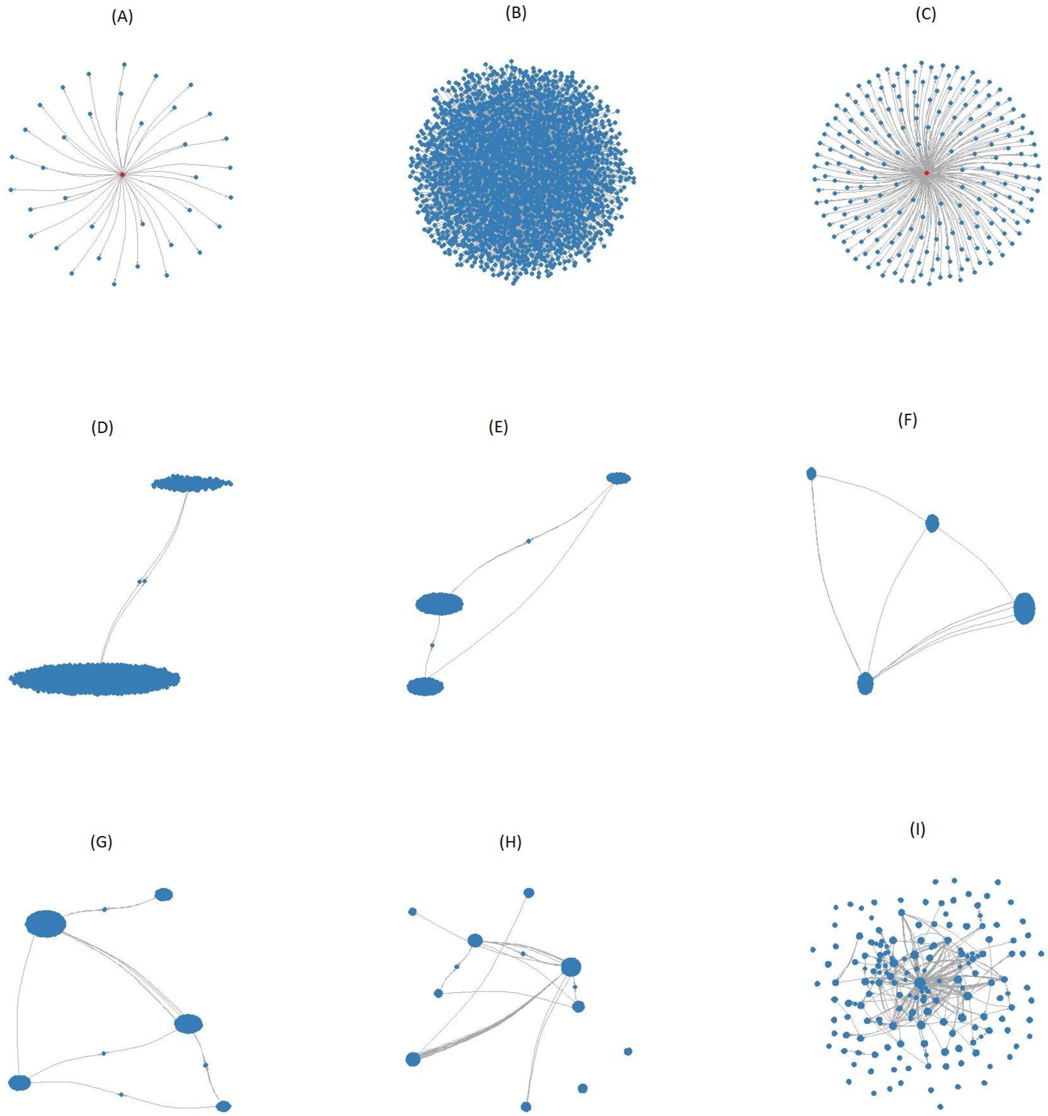
Figure 6 represents the network visualization of a firm´s industrial cluster. Panel A presents the same firm shown in Figure 6. Panels B and C show two other firms of the same economic activity (which can be named by firm B and firm C respectively). It is interesting to note that the density of firm B, in terms of number of employees, is higher than firm C. In Panel D it is possible to see a connection between firm B and firm C. This connection is formed because, in the year of observation, two employees moved from B to C. In this case, there is an inward flow in terms of firm B and an outward flow in terms of firm C, which is equivalent to say that the in-degree of firm B is equal to two and the out-degree to firm C is equal to two as well. The other panels of the Figure 6 simply are “stages” of a zoom out around the first firms in consideration in the Panel D: Panel E shows the interactions of three firms; Panel F has 4 firms; Panel G, 5 firms; Panel H, 10 firms; and, finally, Panel I shows all firms of the economic activity in the year of observation.

Figure 5: Network visualization of a firm's evolution (example).



Source: Authors' elaboration from the following database: Annual Social Information Database (RAIS). Note: Evolution by selected years of one firm in the database: Panel A, year y = 2001, number of employees n = 1; Panel B, y = 2002, n = 2; Panel C, y = 2003, n = 5; Panel D, y = 2004, n = 8; Panel D, y = 2008, n = 14; Panel E, y = 2010, n = 44.

Figure 6: Network visualization of a firm's industrial cluster (example).



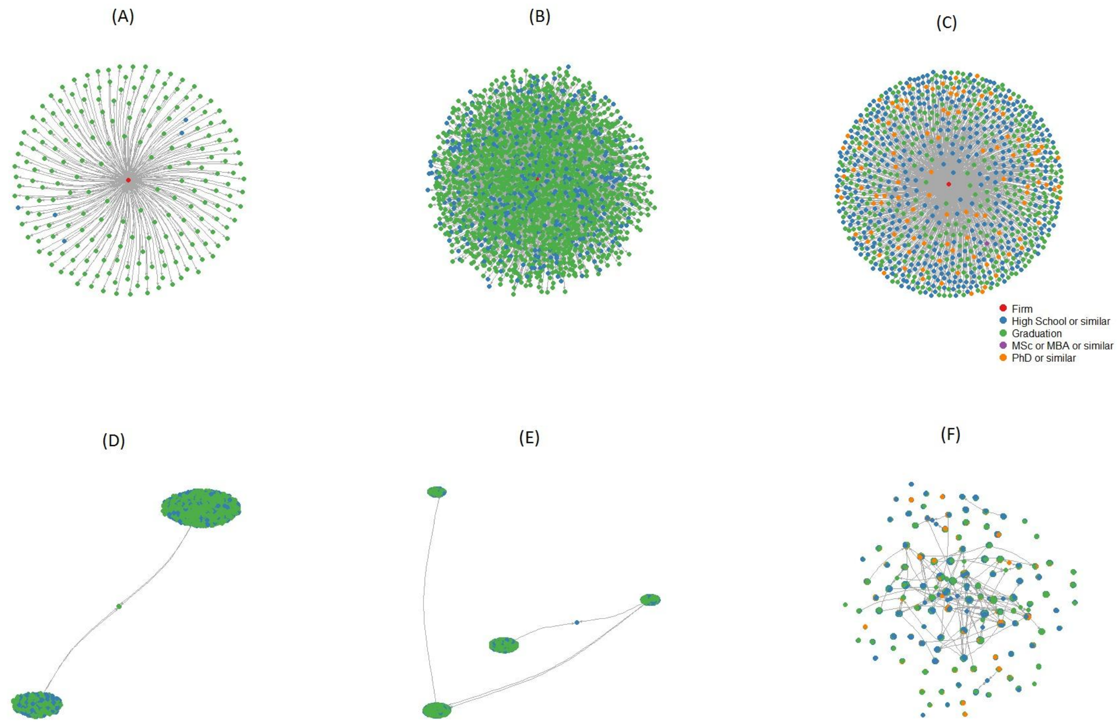
Source: Authors' elaboration from the following databases: Annual Social Information Database (RAIS); Federal Table of Revenue Ownership (QSA) and Innovation Survey (PINTEC). Note: Example of cluster, CNAE 159 (manufacture of beverages), for the RAIS year 2001 and PINTEC year base 2000: Panel A, (fm_1) firm 1, number of employees $n = 15$; Panel B, fm_2, $n = 230$; Panel C, fm_3, $n = 58$; Panel D, interaction $fm_2 - fm_3$, knowledge exchange by employee mobility $ee_{23} = 2$; Panel D, interactions $fm_1 - fm_2$ ($ee_{12} = 1$), $fm_2 - fm_3$($ee_{23} = 2$) and $fm_1 - fm_3$($ee_{13} = 2$); Panel E, interactions $fm_1 - fm_2$($ee_{12} = 1$), $fm_2 - fm_3$ ($ee_{23} = 2$), $fm_1 - fm_3$($ee_{13} = 2$), $fm_1 - fm_4$($ee_{14} = 4$), $fm_2 - fm_4$($ee_{24} = 1$)...; Panel F, 4 firms and their interactions; Panel G, 5 firms and their interactions; Panel H, 11 firms and their interactions; Panel I, all firms and interactions in the CNAE 159.

This type of topology is compatible with what Aldrich and Kim call scaled free networks (Aldrich and Kim, 2007). In fact the network follows a power law in the distribution of their nodes, which means that the average in-degree (2.12 for this case) in combination with a large standard deviation (3.28) results in a solution space dominated by a small number of hubs (firms). This type of characteristic can be found in the majority of economic activities and it serves as an example of the power of visualization in combination with measures: the subsection 3.4 presents details in this regard.

3.2. Representing Employment Mobility and Education Level

This type of visual technique can also be useful to characterize the structure of the firm or cluster in terms of the education level of the people engaged. Figure 7 shows some examples of it. In the upper line we present three different enterprises of the CNAE 341 (manufacture of cars, vans and other vehicles). The enterprise on Panel A had 93 employees in the year 2008, 5 of them with education level equivalent to the secondary level plus 88 graduated people. The same could be described for the firm in Panels B and C. It is worth to note that both B and C are big companies, but with diverse characteristics in terms of qualification of their employees: although fm_3 (Panel C) is smaller than fm_2(Panel B) in terms of number of persons engaged in, fm_3has employees with higher qualification than fm_2which can be observed by the appearance of the orange color (PhD or similar level of education) in fm_3 representation rather than the green one which is predominant in the fm_2.

Figure 7: Characterizing the firms by education level (examples).



Source: Authors' elaboration from the following databases: Annual Social Information Database (RAIS)Note: Example of cluster, CNAE 245 (manufacture of cars, vans and utility vehicles).

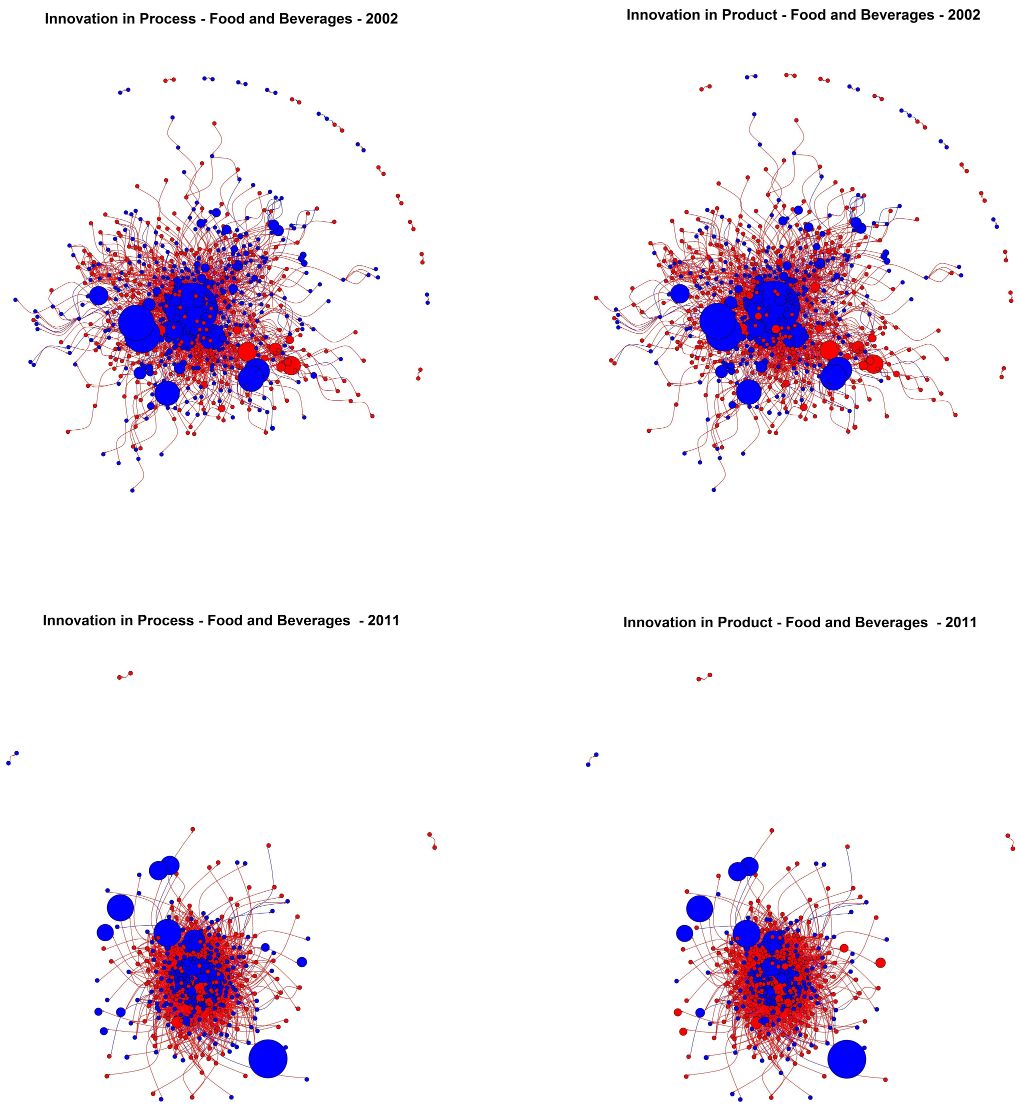
Panels D, E and F follow the same representation of Figure 6, zooming out from the local interaction to all firms in the economic activity (manufacture of cars, vans and utility vehicles). It is interesting to note in Panel F the predominance of colors in each enterprise in terms of centrality. It seems that higher qualification of employees, in this economic activity, is not a factor of great influence to put firms in the center of the employment mobility network. Hence, big companies with a high capacity of absorption of employment did not use this advantage to hire employees with higher education. In addition, some of the companies with the highest percentage of qualified people are not connected with the network, which can be interpreted as a retention.

3.3. Innovation as an Emergent Behaviour

Although the type of visual tool, presented in the previous sections, can help in the analysis of the clusters, the visualization of the whole economy can be a struggle. In order to get this task easier, one simple translation of characteristics can be useful. Another way to represent this type of interaction is placing the firm as the main type of vertex in the network, hiding the employees that do not provoke interactions between firms and considering those employees that provoke interactions as their own connections (Guerrero and Axtel, 2013). Figure 8 presents this type of visualization in terms of innovation in process and innovation in product as well, for the sector of food and beverages, both for the years of 2002 and 2011. The size of each vertex is proportional to the number of employees in the firm. The color blue which some vertices carry is related to the appearance of innovation (in process on the left side and product on the right one).

It is interesting to note the evolution of centrality of big firms in a temporal gap of nine years. Despite the central role of the network being played by the largest firm in both years of analysis, the kind of centrality is different over time. In 2011, part of the biggest firms are closer to one of each other than in 2002, that is, the closeness in 2011 (2.3) is much higher than in 2002 (1.1).

Figure 8. Innovation in Product and Process - Food and Beverages - 2002 and 2011



Source: Authors' elaboration from the following databases: Annual Social Information Database (RAIS) and PINTEC.

Another point to highlight is that the complexity index B, corresponding to the sum of all ratios between vertex degrees by the distance degree, is higher in 2002 than 2011. Other measures could be listed, such as Total Walk Count or Generalized Platt Index, all of them corroborating with the view that the year 2011 is less complex, in terms of labor force mobility, than 2002. Despite clear and profound evidence that innovation profiles of sectors are different between than, the complexity measures present the same behaviour along the time: loss of complexity, reflecting in a scarce distribution of innovative firms.

One of the behaviours that would be interesting to analyse is the emergence of innovation. The phenomenon of emergence, described in the introduction of the thesis, represents the possibility of jumps in the macrobehavior caused by micro elements, agents. In the case of innovation, the emergence could be viewed as a transition in the dynamics of the agents, when a sector turns from the non-innovative sectors cluster to the innovative one[18]. As mentioned in the introduction of the thesis, the main signal of an emergent behaviour can appear, in the context of networks, is when the distribution of connections and nodes follows a power law. Distributions that fit power law distribution presents all elements to perform jumps in the macrobehavior. Following the approach developed by Clauset et al. (2009), Table 2 presents statistical tests for power law (and other) distributions for each industrial sector´ employee mobility networks for 2002 and 2011.

[18] According to the ranking of innovative sector (OECD, 2011), the set of innovator sectors is:

Table 2: Adherence Distribution Test for Sectoral Employment Mobility Network

Industrial Sector	power law *p*		Poisson LR		Poisson *p*		log-normal LR		log-normal *p*		exponential LR		exponential *p*		power law + cut off LR		power law + cut off p		support for power law	
	2002	2011	2002	2011	2002	2011	2002	2011	2002	2011	2002	2011	2002	2011	2002	2011	2002	2011	2002	2011
C15 - Food and Beverages	**0.58**	**0.31**	8.90	7.53	**0.00**	**0.00**	-0.66	-0.90	0.56	0.76	4.56	5.67	**0.00**	**0.00**	-0.74	-0.53	0.12	0.42	**good**	**moderate**
C16 - Tobacco	0.00	0.00	12.89	13.98	**0.00**	**0.03**	0.15	0.77	0.36	0.45	19.76	18.00	**0.00**	**0.00**	0.00	0.00	1.00	1.00	none	none
C17 - Textile	0.05	0.03	4.56	7.98	0.45	0.76	-1.95	-1.75	**0.03**	**0.05**	0.84	0.78	0.23	0.32	0.09	0.12	0.76	0.43	none	none
C18 - Clothing	0.01	0.00	2.56	1.98	**0.02**	**0.04**	-0.34	-0.45	0.32	0.53	2.87	5.98	**0.01**	**0.00**	-0.03	-0.12	0.91	0.95	none	none
C19 - Shoes	0.03	0.02	1.23	4.56	**0.00**	**0.00**	-1.63	-2.89	0.87	0.43	1.43	1.28	**0.00**	**0.00**	0.17	0.21	0.45	0.54	none	none
C20 - Wood Products	0.04	0.00	6.90	3.20	**0.05**	**0.06**	-1.10	-1.05	**0.02**	**0.03**	12.45	10.98	0.32	0.56	-0.14	-0.08	0.65	0.70	none	none
C21 - Celulose	**0.34**	0.01	2.33	4.66	**0.00**	**0.00**	-2.21	-1.11	0.77	0.50	1.33	1.89	0.22	0.34	-1.23	0.09	**0.07**	0.67	**with cut-off**	none
C22 - Printing	0.06	0.01	1.65	1.80	**0.00**	**0.00**	1.09	1.00	0.43	0.28	3.90	4.30	0.43	0.78	-0.84	-0.56	0.48	0.51	none	none
C23 - Fuels	0.00	0.00	14.90	17.80	**0.04**	**0.08**	17.09	24.87	0.78	0.56	21.90	24.67	0.32	0.54	0.00	0.00	1.00	1.00	none	none
C24 - Chemical Products	**0.32**	**0.24**	1.23	1.68	**0.00**	**0.00**	-1.67	-1.98	0.43	0.43	0.27	0.28	0.65	0.72	-0.75	-0.64	**0.02**	**0.05**	**with cut-off**	**with cut-off**
C25 - Plastic Products	**0.73**	0.01	0.99	0.94	0.62	0.55	-1.96	-1.77	**0.07**	**0.08**	0.45	0.43	0.70	0.65	-0.77	0.02	**0.01**	0.62	**with cut-off**	none
C26 - Non-metallic Minerals	0.01	0.00	1.80	1.92	**0.01**	**0.03**	3.98	4.32	0.76	0.56	3.54	5.90	**0.01**	**0.01**	-0.07	0.00	0.78	0.98	none	none
C27 - Basic Metallurgy	0.00	0.00	2.66	6.31	**0.00**	**0.00**	0.12	0.94	0.98	0.54	2.21	2.66	**0.03**	**0.00**	-0.03	0.01	0.55	0.62	none	none
C28 - Metal Products	0.03	0.00	3.98	2.78	**0.04**	**0.01**	-2.34	-2.45	0.45	0.78	9.03	8.54	**0.00**	**0.00**	-0.03	-0.10	0.79	0.67	none	none
C29 - Machinery	0.06	0.00	4.93	1.87	**0.02**	**0.02**	-1.80	-3.90	**0.00**	**0.01**	1.20	3.89	0.45	0.56	-0.01	0.00	0.89	0.90	none	none
C30 - Computers and others	0.00	0.00	8.76	6.23	**0.03**	**0.01**	9.43	7.89	0.45	0.67	12.90	11.00	0.23	0.54	0.00	0.00	1.00	1.00	none	none
C31 - Electrical Equipment	**0.37**	**0.71**	1.33	1.89	**0.01**	**0.05**	-0.87	-0.65	0.77	0.59	1.55	1.82	0.22	0.73	-0.72	-0.55	**0.10**	0.62	**good**	**moderate**
C32 - Telecom Equipment	**0.12**	0.03	1.20	0.56	**0.02**	**0.01**	-1.29	-1.27	0.32	0.56	0.35	0.78	0.34	0.45	-2.45	-3.65	**0.08**	0.51	**with cut-off**	none
C33 - Medical Products	**0.11**	0.00	5.33	3.21	**0.00**	**0.00**	-1.22	-1.88	0.68	0.44	12.56	10.41	**0.00**	**0.01**	-2.44	-0.03	**0.09**	0.91	**with cut-off**	none
C34 - Vehicles	**0.61**	0.12	1.34	3.25	0.43	0.32	1.50	0.32	0.43	0.76	2.56	4.78	**0.00**	**0.01**	-0.83	-0.01	**0.09**	0.90	**good**	none
C35 - Other transports	**0.41**	0.00	2.44	2.87	**0.00**	**0.00**	-0.72	-0.54	0.65	0.54	1.33	3.32	**0.00**	**0.00**	-0.44	0.00	0.45	0.77	**moderate**	none
C36 - Furniture	0.00	0.00	4.78	3.90	**0.00**	**0.01**	0.23	0.45	0.34	0.45	3.80	4.24	**0.00**	**0.01**	-1.23	-1.54	0.87	0.78	none	none

Source: Authors' elaboration, using an approach developed by Clauset et al. (2009), from the following databases: Annual Social Information Database (RAIS) and PINTEC.

The idea is to analyse which sectors could have signals of emergence through the analysis of the fit with a power law distribution. It is important to note there are few sectors indicating good or moderate fit with this type of shape: *food and beverages* (good fit), *electrical equipment* (good), *vehicles* and *other transports* (good), *cellulose* (with cut-off)*, chemical* (with cut-off), *plastic products* (with cut-off), *telecom* (with cut-off) and *medical equipments* (with cut-off)for 2002; and only *food and beverages* (moderate), *electrical equipment* (moderate) and *chemical products* (with cut-off). In addition, not only are there few sectors with good, moderate or cut-off fits with power law distribution, but this small number decreases over time while turns weaker. These features reinforce the idea that Brazilian employment mobility network is losing complexity in the beginning of the twenty-first century. This point is revisited in the next subsection.

3.4. Complexity Measures by Economic Activity

Chart 2 represents the evolution of the number of edges of networks by economic activity (divided by the size of the sector in terms of employees) from 2001 to 2015[19]. This type of analysis is interesting because of the trajectory of the indicator. In fact, it appears that Brazilian economy is "losing" connections since the early decades of 2000, with a consequently decreasing complexity. Other results for Brazil regarding indicators of economic complexity can be found in the literature and present the same characteristics of the results shown in Chart 2. For instance, Alencar et al. (2018), using a database from UN Comtrade[20], calculate an Economic Complexity Indicator for four Latin American countries (Mexico, Argentina, Brazil and Chile), showing a persistent decrease in the level of complexity in Brazil since the mid of 1990´s decade.

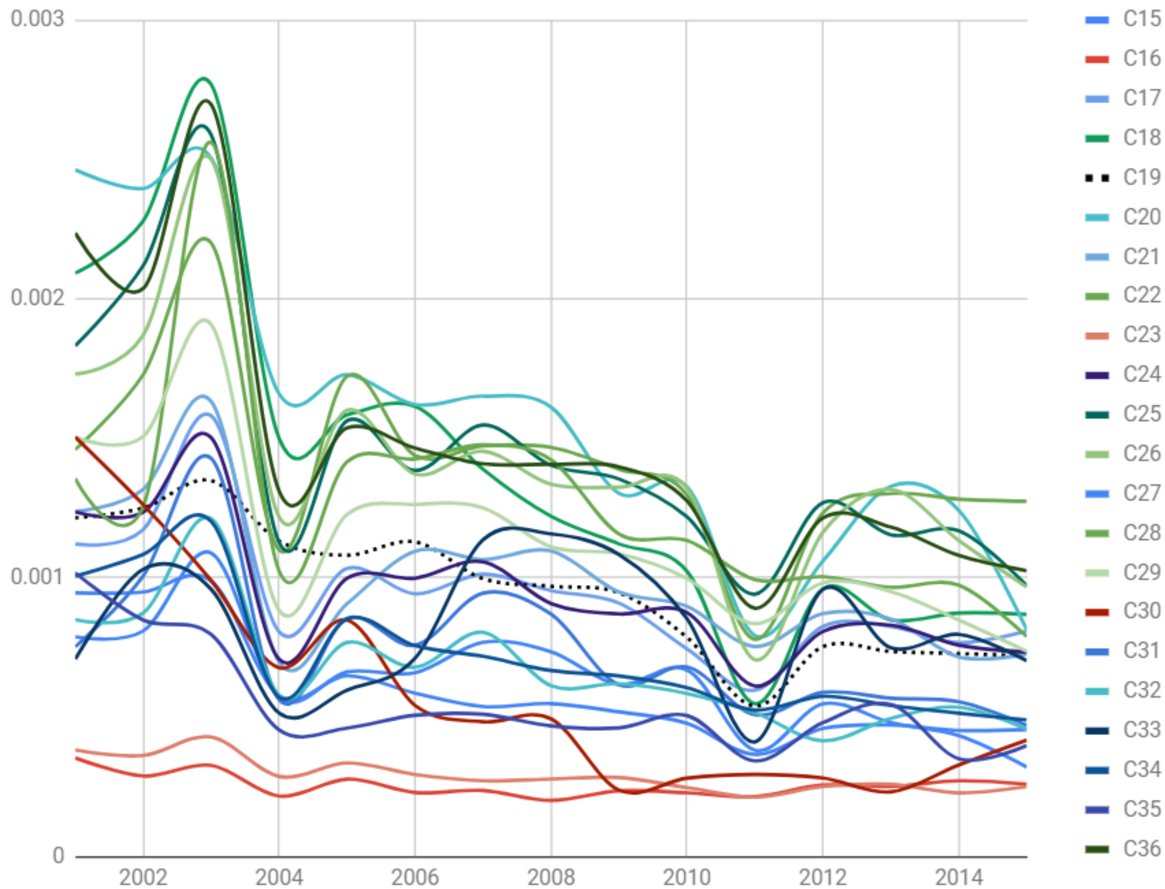
Despite the negative shift in the level of complexity along the time, Chart 2 shows a movement in the curve of employment mobility similar to cycles, especially prominents in the years 2003 to 2004, and 2010 to 2011 as well, although in a smaller variation. The first period (2003-2004) experienced a spark in 2003 followed by a prominent fall in 2004. The economic context of this period in Brazil show a considerable raise in the GDP and gross fixed capital formation in the 2004, indicating that the high dynamism in the employment mobility in 2003 could be considered as a certain anticipation of the entire economy growth in 2004: more people changing their jobs for taking good opportunities opened by firms in preparation for big rounds of investment. The case of 2010 and 2011 could be interpreted in the same way. The

[19] Appendix A brings mathematical formulation of this measure.
[20] https://comtrade.un.org/

differences, for this period, lie in the fact there were no sparks in 2010 but an increase in relation to 2009, followed by a depression in 2011.

Still on Chart 2, in terms of sectoral analysis, all manufacturing industries present the same behaviour, although we can identify at least three different groups of economic activities. The first group, containing the sectors with highest mobility, can be found in the following sectors: *Confectioning of Clothing and Accessories*; *Manufacture of Wood Products*; *Manufacture of Non-Metallic Mineral Products*; *Manufacture of Machines and Equipment*; *Manufacture of Chemical Products*; and *Manufacture of Electrical Machines, Apparatus and Materials*; and *Manufacture of Furniture and Miscellaneous Industries*.

Chart 2: Evolution of Number of Edges by the size of the sector, for 26 economic activities 2001 to 2015



Source: Authors' elaboration from the following databases: Annual Social Information Database (RAIS); Federal Table of Revenue Ownership (QSA) and Innovation Survey (PINTEC). The vertical axis represents the number of vertices in a given industrial sector divided by the number of firms in the sector. The scale of 10^{-3} is considered relevant by the hypothesis test.

The second group consists of the following sectors: *Manufacture of Textile Products*; *Manufacture of Cellulose, Paper and Paper Products*; *Manufacture Of Electronic Equipment And Communications Equipment*; *Manufacture of Medical and Hospital Instrumentation Equipment*;

Precision and Optical Instruments; *Industrial Automation Equipment, Timetables And Watches*; *Manufacture and Assembly of Automotive Vehicles, Trailers and Bodyworks*; and *Manufacture of Other Transportation Equipment*.

The third group, with the lowest rates of edges per employee, is formed by *Manufacture of Tobacco Products*; *Manufacture of Coke, Oil Refining, Elaboration of Nuclear Fuels and Alcohol Production*; and *Manufacture of Desktop Machines and Computer Equipment.*

In fact, the results[21] seem to indicate a clear separation of sectors in three subsets. In terms of clustering, the results are presented in Figure 9. The best results were obtained using a 3-means clustering[22], contemplating a set of 8 indicators suggested by Kim and Wilhelm (2008). The red dots represent the more complex activities. The green ones present a lack of complexity while black dots have indicators compatible with a Erdos-Renyi model, that is, a random network system.

It is interesting to note how different the three economic activities that present random behaviour are: the sector of manufacturing of tobacco products is dominated by a small number of big firms, which have a role of centrality in the networks, delegating the others to a subaltern level.

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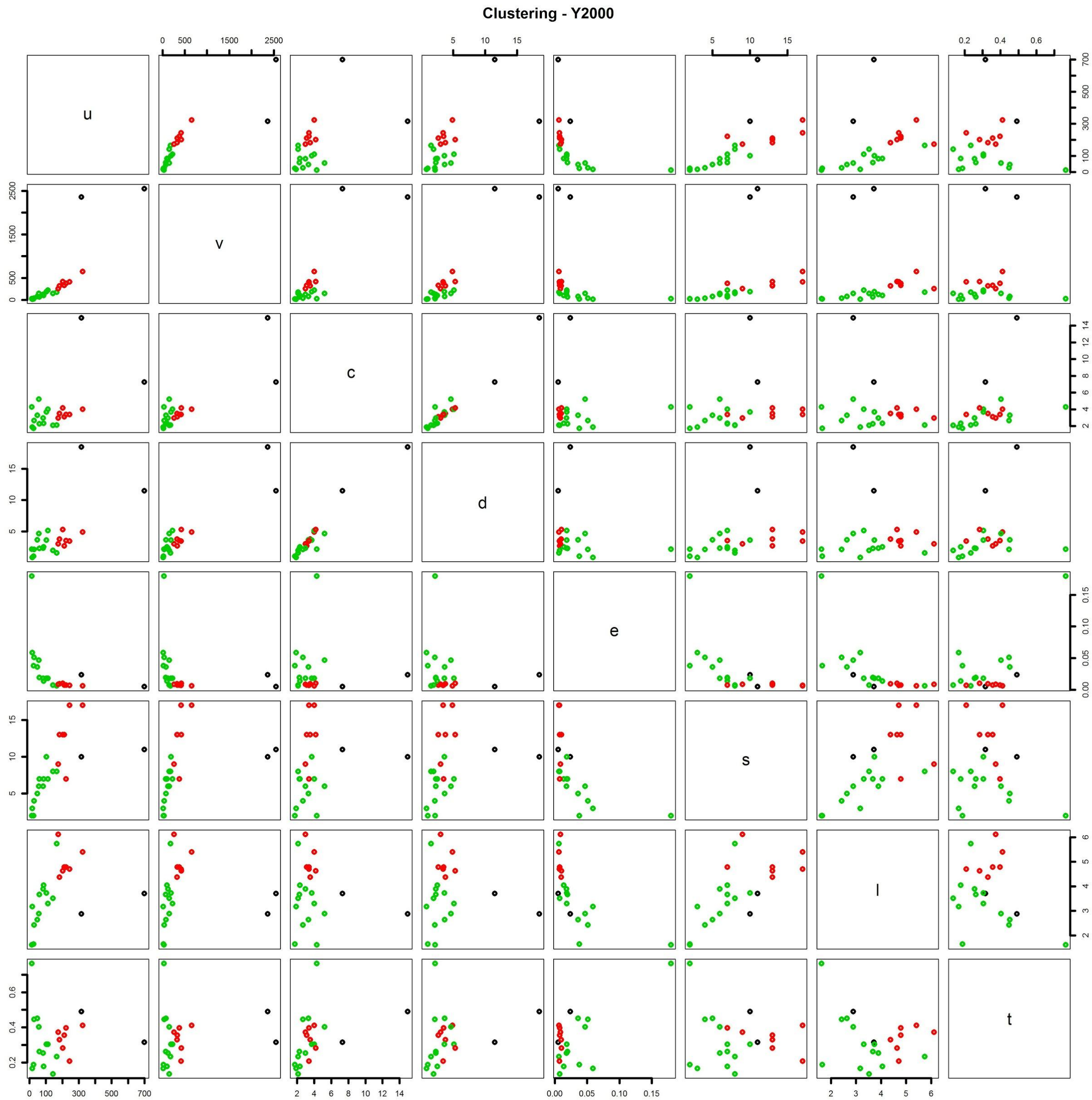
[21] Presented in detail in the tables and graphs in appendix C.

[22] The method used here to infer that 3 clusters are the best option in splitting a set of information is the so-called k-means, that calculates the optimal number of centroids that fits the solution space accurately by a neural network.

Figure 9. Clustering sectors by complexity level



Source: Authors' elaboration from the following databases: Annual Social Information Database (RAIS); Federal Table of Revenue Ownership (QSA) and Innovation Survey (PINTEC).

The case of *chemical products* and *electric machines* is more challenging. Both are populous sectors in terms of firms and employees as well. Both present high node density.

However, the flow of employees through the firms seems to be random, which indicates that the sectors do not take advantage of employees' specialization to growth in terms of knowledge.

The second group is the most numerous in terms of economic activities: there are 9 sectors with complex behaviour in regard to the flow of employees. As Kim and Wilhelm (2008) observe, many of the most interesting social systems that can be described by this type of technique lies in the middle of the spectrum of complexity measures. The extremes are linear systems and chaotic systems at the opposite side.

4. Summary and Conclusions

This chapter presents evidence of the complex character of sectoral employment mobility based on the analysis of a Brazilian database in the period between 2001 and 2015. As mentioned by Kim and Wilhelm (2008), a set of indicators appears to present a scenario of decreasing complexity in Brazil since 2001. More than this, it is possible to cluster information by economic activities, allowing to conclude there are at least three groups of industrial sectors in terms of complexity. The most numerous one is also the most complex one, revealing a structure of complexity in the system behind them.

The sectoral profile of innovation is also an interesting point of discussion presented in the chapter. One of the most important findings is on the interaction of small firms with big innovative firms is, from the perspective of labor force mobility, it seems that possible benefits (for the smaller firms) of this type of interaction is in decreasing over time: the rate of innovative small and medium-sized firms with closeness above 0.5 to central big firms (that is, the most connected ones with those which play a central role in the network) falls dramatically from 2001 to 2015. Moreover, it is important to emphasize that the modelling proposed in the chapter was implemented only for manufacturing sectors. The inclusion of activities like services, retail and wholesale could change dramatically the findings.

Finally, this chapter, in accordance with other works with similar approaches and subject, opens an interesting point of research which refers to the treatment of the theme of employment under the light of complex systems. It is considered desirable to explore more of this new approach, not only because of the novelty of the theme, but also because a better understanding of the behaviour of the system can bring fresh ideas to the field of public policies, taking into account an immanent characteristic of the systems: complexity.

CHAPTER 2 - ENTREPRENEURSHIP AS A DRIVING FORCE OF AN ECONOMIC COMPLEX SYSTEM

This chapter elaborates questions on the role of entrepreneurship as a driving force of an Economic Complex System. The point of departure are the ideas of National Systems of Innovation and National Systems of Entrepreneurship on productivity and enterprise growth. The main purpose is to use these approaches to analyze how micro-events (new or young firms entering the market) can produce dynamics compatible with a complex system. Through an agent-based model, from a small set of agent behaviours (interactions of a pair of agents like firms, entrepreneurs, employees and other institutional constructs) and the kind of connections between them, it is possible to analyze the emergence of effects like innovations. Some evidence is presented analysing employment mobility in Brazil along 16 years using a database with more than 6 millions firms and 80 million people.

1. Introduction

In economics, since the first works in the Santa Fe Institute in the decade of 1980, it is widely believed that heterodox thought can consider evolutionary economics from a complex system perspective (Foster, 2004). Holt et al. (2010) presents three different visions on complexity in regards to economics: a general view, a dynamic view, and a computational one.

In the first one, it is emphasized that the hierarchical structure of systems follows precepts of information theory owing to the idea of building up macro-patterns from micro-interactions of the parts[23]. The dynamic view stresses the point that a complex system has a condition of opposition to a kind of 'steady behaviour', in relation to the passage of time. The third view is connected to that influence of computation has had in this theme especially regarding simulation (Holt et al, 2010).

In general terms, some immanent properties of an economic complex system are:

> It is a dissipative structure that transforms energy into work and converts information into knowledge for the purpose of creating, maintaining and expanding the organised complexity of the system. Such a system is a whole in itself, as well as being a component part of some systems and oppositional to others—it is the connections that are forged between systems that permit the emergence of organised complexity at higher levels of aggregation. Such a system must exhibit some degree of structural irreversibility owing to the inherent hierarchical and 'bonding' nature of the connections between components that are formed as structural development proceeds. It is this that results in the inflexibility and maladaptiveness that precipitates a structural discontinuity of some kind. The evolutionary process that such a system experiences can only be understood in an explicit historical time dimension—phases of emergence, growth, stationarity and structural transition can be identified in the historical time domain, leading to theoretical questions concerning the factors that result in the generation of variety, innovation diffusion, selection and system maintenance (Foster, 2004).

Such an approach not only reinforces the field of information theory, from which the discussion of information complexity and systems entropy comes from, but also projects its results (Shannon, 1998; Kolmogorov, 1968). For Kolmogorov, for example, complexity is

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[23] In information theory, the notion of complexity is linked to how much a given finite sequence of fully specified information packets resembles a random sequence (Lempel and Ziv, 1976). This idea can also be translated as the length of the smallest binary program that generates a given finite sequence (Kolmogorov, 1968). In addition, the idea of Kolmogorov is to create an opposition between "less" complex sequences, that is, generated by smaller and lighter algorithms, and those more complex, generated by larger algorithms and more difficult to implement. Measures of complexity, therefore, can be applied to the information of the databases related to the economic systems, which can generate a powerful analysis tool that takes into account the complexity of the information present in a database as a proxy of the complexity of the system that it was generated from.

regarded as the minimum length of the description of an information packet: it is a lower limit in compressibility. On the other hand, Shannon's entropy can be interpreted as the number of pairs of zeros and ones required for optimal encoding of an information packet from a random source. To estimate the Shannon entropy, it is assumed that the data are generated by some probability distribution. This assumption is not made for the Kolmogorov complexity, which is the minimum length of the description of the chain in question, and not the minimum length of the contingent description in some probability distribution that generates it. In order to calculate the entropy of an information packet in a given language, for example, some notion of how it was generated: in this case, an alphabet with, for example, 26 characters, some of which are more likely than others. Therefore, the entropy of the system is estimated in light of the actual data. In contrast, Kolmogorov's complexity measures the minimum length of the description of an information packet, so that some computer programs can reconstruct it and stop without taking into account any probability distribution. The complexity of Kolmogorov is not computable. However, its limits can be formally described by describing the program that would decode it and the language used to describe it. Therefore, in the case of the information contained in the databases to be explored in this paper, one must consider all the available variables to describe the behavior of the individual over time in their pre and post trajectory to become entrepreneur as a set of information which calculates the upper limit of the complexity that a system that had produced such information could have.

Another important theory of complexity was presented in the 1980s by Wolfram (1985) and developed by numerous authors ever since (Lansing, 2002). The author's initial approach takes into account the strategy of focusing his study on capturing the fundamental characteristics of the generation of complexity. The central idea is that simple rules of interaction between individuals can generate complex behavior. In the case of entrepreneurs, one must seek to map, besides individuals, the institutions important to the system and their interactions with each other. Once the interactions can be mapped, one can verify the appearance of emergent behaviors given a configuration of rules of interaction between individuals and institutions.

In authors such as Mitchell (2009) and Goldstein et al. (2010a, 2010b), there are compilations of definitions of complexity most used by disciplines such as physics, biology, computer science and economics. Simon (1996) remarks that in the XX century there were three bursts of interest in complexity: the first after World War I, when issues of holism and gestalt made their way in several sciences; the second after World War II, when interest in information, cybernetics, and general systems increased; and the third during the 1990´s, with the growth of studies on chaos, adaptive systems, genetic algorithms and cellular automata. As observed by this author:

> Complexity is more and more acknowledged to be a key characteristic of the world we live in and of the systems that cohabit our world. It is not new for science to attempt to understand complex systems: astronomers have been at it for millennia, and biologists, economists, psychologists, and others joined them some generations ago. What is new about the present activity is not the study of particular complex systems but the study of the phenomenon of complexity in its own right (Simon, 1996, pp.181).

Treating of economics specifically, Arthur et al (1997), for instance, attributed part of the success of the introduction of complex theory in the field of evolutionary economics to the change of focus proposed by this field from rational agents to adaptive ones, which makes the resulting dynamics to be treated as complex (Arthur et al., 1997)[24]. Co-evolution and adaptive

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[24] The key element here is the discovery of a way to include bounded rationality mathematically into the models: “Bounded rationality is another piece of the puzzle to which more than lip service is being rendered, receiving considerable modeling attention and gradually finding its place in

systems are indeed considered to be a core issue of evolutionary economics (Foster and Pyka, 2014)[25] .

A needed next step, therefore, would be to consider the path of complexity theory in the field of economics of entrepreneurship. Some efforts have been made in this way: in the discussion of complexity and entrepreneurship, some works conclude that the complex systems modelling provides the best approach to represent entrepreneurship (McKelvey and Andriani, 2005; Crawford et al., 2015); Plowman et al. (2007) recognize that the entrepreneurial system can be seen as a complex adaptive system; Lichtenstein and Plowman (2009) find four sequential phases in the entrepreneurial emergence process: disequilibrium state, amplifying actions, recombination self-organization and stabilizing feedback; McKelvey (2010) establishes as an important issue on entrepreneurship regarding the model that defines the point at which the system moves from requisite variety to complexity and complexity to chaos; Dooley (1997) finds as crucial to survival and success of firms the fit between the organizational form and organizational context. In addition to these previous works, this chapter intends to focus efforts that comprehend the overall discussion in the systemic view of Acs et al. (2014).

As mentioned in the introduction of this thesis, it is important to differentiate NSE from NSI (Acs et al, 2016b). NSI is an approach created in the decade of 1980´s with focus on the innovation as a main driving force of the economy (Lundvall, 1999; 2007). NSE, for its turn, is a recent approach which combines certain concepts explored by NSI, like national institutional

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the methodological puzzle. This is mostly due to a loose consensus about the applicability of certain computational methods, particularly genetic algorithms and classifier systems, to the problem of choice, behavior, and (social) learning." (Arthur et al. 1997)

[25] See, for instance, the book by Koen Frenken called Innovation, Evolution and Complexity Theory (Frenken, 2006) and the Journal of Evolutionary Economics 2014 special issue on complex adaptive systems (Foster and Pyka, 2014).

structure and capabilities, but also attempting to reassign the role of individuals as agents of change, repositioning the entrepreneur in the center of the economic system.

The concept of National Systems of Innovation derives from the vision of F. List, who first introduces the term ‘National Systems of Political Economy’ as a framework linking policies to development (Freeman, 1995). As Lundvall (1992) argues, the definition of National Systems of Innovation shall be considered in a narrow and a broad perspective as well. A narrow definition, which was the first approach designed, includes crucial elements as organizations and institutions in searching and exploring in order to organize production and technology towards development. A broad definition incorporates other elements of economic structures, like finance and marketing systems, including individual capabilities as agents of change. Advances in the theory have been made continuously since the first criticisms on linear relationship between R&D and economic growth, the main field of study of the early times of NSI approach. From the crucial aspects of institutional change, technological innovation and development, researchers have explored subjects related to the financialization of the economy, human agencies, socio-economic development, different perspectives from the Global South and so on.

National Systems of Entrepreneurship, hence, proposes a new equilibrium between the individual behaviour and the institutional structure that compound the system. Because of this new emphasis on the entrepreneur, NSE seems to be a reliable approach under which it is possible to combine micro-elements of the dynamics with the emergency behaviour in the macro structure.

This chapter is organized as follows: section two describes methodological issues, especially related to agent-based models; section three presents the results of the simulation in comparison with real data; and section four brings a discussion on the results and some reflections on the applicability of this kind of modelling approach to shed light on the complex properties of entrepreneurship systems.

2. Methodology

The choice of using an agent-based model to describe the dynamics of new firms seems evident. An agent-based model consists of three different elements: (1) macroscopic events (patterns) emerge from (2) local interactions of (3) autonomous agents (De Langhe, 2018; Bonabeau, 2002; Heath et al, 2009). In the case of this chapter the elements are: (1) the rate of innovativeness of a given industrial sector as the macroscopic event; (2) Stigmergic interactions occur between (3) autonomous individuals (employees, entrepreneurs, investors, etc) and institutions (firms, governmental agencies etc).

Since the first efforts in this area that were made by Axtell (2005), who has developed a model that simulates the behaviour of firms and employees among them, an increasing set of papers have been published taking into account elements of entrepreneurship in economic systems. Innovation systems can be considered as complex systems, as they fulfill their main properties: they are formed by a large number of heterogeneous elements; these elements interact with each other; the interactions produce emergent behaviors that are different from the effects of the individual elements, and these behaviors persist over time and adapt to changing circumstances.

To study this type of systems, different methodological approaches have been proposed, such as Social Network Analysis and Agent-Based Simulation or Modeling. Each one focuses on addressing different aspects of the complex system under study; on the one hand, the agent based models techniques have strengths in representing the feedback loops, simulating the dynamics of the system in real time, plotting the interaction between individual agents, showing the interaction between multiple levels and incorporating the heterogeneity of the elements of the system; while the social network analysis, on the other, in addition to personifying the interaction between heterogeneous agents, this approach allows to investigate the complex relational structures of the system.

The importance of the connections established by agents, so that they can contribute with their capacities to innovation, leads to complement the agent based models with the use of social network analysis, that is to say, to study a system based on the existing relations between the actors that compose it. This allows to understand the functioning of the network, to visualize the position of the actors within it, to know which actors are related to each other, and, from that, to understand what opportunities and limitations both these actors and the network itself, to subsequently design growth strategies and development.

Now, the intention to use the social network analysis for results obtained previously in an agent based simulation is to provide a deeper analysis in a search for new findings. It is taken into account that both methods are recognized for their ability to represent, analyse and project complex social phenomena, allowing deciphering non-linear and unpredictable behaviors[26].

[26] A good example of how this type of modeling can act is the works of Fagiolo, Dosi, Roventini and others who implemented the so called "Schumpeter meets Keynes" models (Dosi, Fagiolo and Roventini, 2010). This is an important contribution in this area, despite the fact this model doesn't fit with the general assumptions of a complex phenomenon.

The empirical contribution of this chapter, therefore, refers to the proposal of describing the dynamics of new and young firms in Brazil through an agent-based model and then to compare the results using social networks analysis. The proposed period is the most recent one, from 2002 to 2015, on which structural data are available. The following subsections describe the agents, interactions, databases and the rules that generate the dynamics regarding the model.

2.1. Entrepreneurs and Firms as Autonomous Agents

According to Wooldridge and Jennings (1995), the key element of the dynamics is the proposition that intelligent individuals interact both with each other and with the environment reacting to the change in the neighbourhood and the behaviour of neighbours. Indeed, intelligent agents are autonomous, social, situated and proactive (De Langhe, 2018).

This model implemented here considers the following agents: the **firm**, a unit formally constituted with the proposition to act in an economic activity; the **founder**, that is the individual who opens and/or possess the firm, with or without partners[27]; the **investor**, the individual or firm who invests in the firm[28]; the **employee**, an individual hired by firm receiving paid salary[29]; **BNDES**, the Brazilian development bank[30]; **Sebrae**, the agency that helps new

[27] In terms of database, is the CPF (civil register identity) associated with the firm as a partner in the date of firm registration.
[28] CNPJ (firm) or CPF (individual) who appear in the societal partnership accompanied by a change in VAL (valuation). Pragmatically, this information can be gathered when the firm changes the societal structure, including new partners followed by a considerable increasing of firm patrimony.
[29] CPF (individual) registered as an employee in RAIS in a given year.
[30] Specific CNPJ that appears as a partner of a firm in a given year.

entrepreneurs with training and capacitation[31]; **governmental agencies**, other agencies like municipalities services, and so on; and **Banco Central**, the Brazilian central bank.

2.2. Agent Interactions

Grasse (1959) and Sumpter (2003) provide a theoretical explanation on how the mechanism of agent interactions is built. Here, the concept of stigmergy is raised, that is, how global coordinated tasks can emerge from a system without central supervision or direct communication by leaving traces that other agents respond to (Heylighen, 2007). The dynamics depends on feedback loops by which autonomous agents influence each other's behaviour indirectly, through traces in the environment.

Table 1 represents the set of possible agent interactions applied in the model. We specify the interactions as follows: the **firm-founder**, that is the fundamental connection, representing the firm´s birth and the change in the role of the individual from an employee to the founder. This connection´s weight is the maximum (one) in early stages of firm, changing (decreasing) along time by the number of employees; the **founder-founder**, with connections´ weights given by the inverse of number of employees; the **founder-partner**, with connections´ weights given by the proportion of firm age and the moment that individual becomes partner; the **founder-employee**, with connections´s weights determined by how long the employee is working in the firm. The same for partner-employee connection; the **partner-employee**: with connections´ weights given by the proportion of firm age and the moment that individual becomes partner; the **firm-partner**: connections´s weights given by the proportion of firm age

[31] There is a database relating this specific CNPJ to others, that is, new firms that received training from Sebrae.

and the moment that individual becomes partner; the **firm-employee**, that is the most common interaction, whose weights depend on salary, occupation and time of relationship with employee has with the firm.

Table 3. Agents and Connections

Interaction Number	Agent 1	Agent 2	Total Weight Interaction
1	firm	founder	1
2	founder	founder	1
3	founder	partner	0.9
4	partner	partner	0.8
5	partner	employee	0.8
6	employee	employee	0.6
7	firm	investor	0.9
8	firm	government	0.8
9	firm	BNDES	0.8
10	firm	SEBRAE	0.7
11	firm	partner	0.9
13	firm	employee	0.6

Source: Author´s elaboration.

Table 2 represents the list of two-by-two interactions and their respective weights. The weights, in a first attempt, are fixed overtime. A new set of dynamic weights, that is, weighs change over time, are discussed later in the subsection that describes the dynamics.

2.3. How the system evolves

In order to generate the dynamics through simulation, the idea is to treat entrepreneurship as concerning new firms. In this specific case, entrepreneurship is the phenomenon related to opening a new business. The birth of a firm is the focus of the dynamics. A process of mapping agents and links, as described previously, is started and the efforts are to find clusters of people that were responsible, in some way, for innovation in process, product, organization or marketing[32].

In the case of Brazil, microdata from PINTEC were used to map the innovators spread out into 16 economic activities. The purpose is to identify the emergence of innovation in firms and activities in using an agent based model. Given the fact that this emergence appears from the connections, it is straightforward to say it is a product of agent interactions.

The way agents make decisions in the economic environment takes into account some clauses as described below. In terms of employee behavior, there are five clauses involved:

Clause 1: Perception that own salary is below the firm's average.

$$sal\left(ee_{k,p}^{CBO_k}(t)\right) \ll \frac{1}{N}\sum_{i=1}^{N} sal\left(ee_{i,p}^{CBO_k}(t)\right)$$

[32] Another approach that could be useful here would be those techniques involving simulated agents, that is, to consider endogenous variables without connections with real data. This alternative shows to be unnecessary once the model, just using exogenous variables, produces reliable results.

where $ee_{k,p}^{CBO_k}$ refers to employee k engaged in the firm $p$with an occupation CBO in a time t, $sal \equiv sal(.)$is a function of the salary of a given employee ee and N is the total number of employees in the firm p with the same occupation.

Clause 2: Perception that firm's revenue is above competitor's revenue average.

$$rev\left(fm_{k}^{CNAE_k}(t)\right) \gg \frac{1}{M}\sum_{j=1}^{M} rev\left(fm_{j}^{CNAE_k}(t)\right)$$

where $fm_{k}^{CNAE_k}(t)$refers to a firm $k$engaged in an economic activity $CNAE$ in a time t, $rev \equiv rev(.)$ is a function of the revenue of a given firm $fm$and $M$is the total number of firms in the economic activity $CNAE$.

Clause 3: Perception that firm is not growing in terms of employees.

$$n_{ee}\left(fm_{k}^{CNAE_k}(t)\right) \leq n_{ee}\left(fm_{k}^{CNAE_k}(t - 1)\right)$$

where $n_{ee} \equiv n_{ee}(.)$is a function of the number of employees engaged in the firm fm.

Clauses 4: Perception of firm's innovativeness.

$$innov_{l}^{t}\left(fm_{k}^{CNAE_k}(t)\right) = 1$$

where $innov \equiv innov(x)$ is a function of innovativeness depending on type t: $\{product,\ process,\ organizational,\ marketing\}$ and locality $l = \{internal,\ local,\ global\}$of innovation (0 when there is no occurrence of innovation, 1 when there is occurrence of innovation).

Clause 5: Perception of economic activity enhancement

$$\frac{\sum_{j-1}^{M} rev\left(fm_j^{CNAE_k}(t)\right)}{\sum_{i=1}^{N}\sum_{j-1}^{M} rev\left(fm_j^{CNAE_i}(t)\right)} > \frac{\sum_{j-1}^{M} rev\left(fm_j^{CNAE_k}(t-1)\right)}{\sum_{i=1}^{N}\sum_{j-1}^{M} rev\left(fm_j^{CNAE_i}(t-1)\right)}$$

Each agent perceives reality and makes decisions independently. In addition, each type of agent has different uses of perception clauses, that is, the set of rules that each type of agent is exposed differs.

Table 4. Relationship Clauses - Employee (ee) Behaviour

Agent	CLAUSES					BEHAVIOUR				
	Clause 1	Clause 2	Clause 3	Clause 4	Clause 5	Quit Job	Look for another employment with the same occupation	Look for employment in the same economic activity	Open a New Firm in the same economic activity of previous employment	Open a New Firm in another economic activity of previous employment
ee	FALSE	TRUE	FALSE	TRUE	TRUE	No	No	No	No	No
ee	TRUE	FALSE	TRUE	TRUE	TRUE	Yes	No	No	No	No
ee	TRUE	TRUE	TRUE	FALSE	FALSE	Yes	Yes	No	No	No
ee	TRUE	FALSE	TRUE	TRUE	FALSE	Yes	No	Yes	No	No
ee	FALSE	FALSE	TRUE	FALSE	FALSE	Yes	Yes	Yes	No	No
ee	TRUE	TRUE	FALSE	TRUE	TRUE	Yes	No	No	No	Yes
ee	FALSE	TRUE	FALSE	TRUE	TRUE	Yes	No	No	Yes	No

Source: Author's elaboration.

Tables 3 and 4 present the set of rules concerning the main type of agents in the economic environment: the employee and the firm[33]. It is possible to check the expected behaviour of each agent under certain conditions. Table 3 lists the behaviour of each employee depending on the economic context. Each categorical variable, represented by clause formulation showed previously, is initialized following the real distribution of a given year, in terms of the variable of interest[34] in a certain industrial sector and the distribution of occupation in the same year and industrial sector as well. Table 4 shows the behaviour of firms, in the context of the clauses that affect their decision the process is the same of employees and the clauses are presented in the Appendix A.

This means that, for the first interaction, the probability $p_{t_0}^{CNAE}(.)$ of having FALSE or TRUE in each clause depends on the industrial sector and the year of initialization[35]. After the first interaction, the new probability of having a FALSE or TRUE for a given variable depends on the history of the trajectory and the new distribution of industrial sector plus a stochastic component, that is:

$$p_{t_n}^{CNAE}(x) = p_{t_{n-1}}^{CNAE}(x) + \frac{\varepsilon}{w}$$

[33] The other agent behaviours are presented in the Appendix B, deserved to details of ABM implemented in this simulation.
[34] Employee salary in clause 1, Firm revenue in clause 2 and 5, Number of employees in clause 3, Innovativeness rate in clause 4.
[35] A first approach was tried with homogeneous distribution of initialization, generating no dynamics.

Table 5. Relationship Clauses - Firm (fm) Behaviour

Agent	CLAUSES					BEHAVIOUR				
	Clause 5	Clause 6	Clause 7	Clause 8	Clause 9	Hire ee	Fire ee	Look for another employee with the same occupation of majority firms labor force.	Look for another employee in the same economic activity	Look for another employee anywhere
fm	FALSE	TRUE	FALSE	TRUE	TRUE	Yes	No	No	No	No
fm	TRUE	FALSE	TRUE	TRUE	TRUE	Yes	No	No	No	No
fm	TRUE	TRUE	TRUE	FALSE	FALSE	No	Yes	No	No	No
fm	TRUE	FALSE	TRUE	TRUE	FALSE	No	No	Yes	No	No
fm	FALSE	FALSE	TRUE	FALSE	FALSE	No	No	No	Yes	No
fm	TRUE	TRUE	FALSE	TRUE	TRUE	Yes	No	No	No	No
fm	FALSE	TRUE	FALSE	TRUE	TRUE	Yes	No	No	No	No

Source: Author’s elaboration.

The sequence of initialization for each cycle is as follows:

1. Run clauses for all employees. Unemployed people decide in which sector to seek jobs. Employed people choose to keep the job, to leave to seek another job or to open a business. All employment leaves are registered in order to wait for the vacancies from

firms. All employees who decided to open a firm create a one-person-firm for the first round. In the further rounds the entrepreneur behaviour is represented by the behaviour of the firm in the step n. 5. Demand for education is registered for all employees who decide to take more training.

2. Run clauses for Central Bank: central bank interest rate is given by the history of three latest changes plus a stochastic component;
3. Run clauses for BNDES: development bank updates its long term interest rate and decides how much to spend to concede loans for each industrial sector. The amount per sector is registered in order to wait for the demand for loans from firms.
4. Run clauses for Sebrae: training education offering is updated for each industrial sector. The number of units offered for each industrial sector is registered for further check for individual demands.
5. Run clauses for firms: number of firms is updated; number of vacancies are compared to complete vacancies with people looking for vacancies in each industrial sector. If the number of vacancies are higher than the number of people looking for a job in this sector, then the remaining number of vacancies is registered for further comparison with the people who were fired. If the number of people looking for a job in the sector is higher than the number of vacancies, then people who did not find a job remain employed in the previous firm that the individual was linked to.
6. Run clauses for employees again for people who were fired in the step n.5. New firms are registered and new search for jobs is compared to remaining vacancies by sectors, if

there exist. If an individual becomes unemployed, he/she enters in the first round of next steps, deciding in which industrial sector he/she will seek jobs.

3. Results

The six steps presented in the previous section are run for each cycle and the results are examined after 12 cycles (12 months). For the initial condition, it was created a population of 8 million agents in similar situations in terms of options in the variables (for example, if the employee (ee) is employed ($ee = 1$) or not ($ee = 0$), if $ee = 1$which economic activity the employer (firm fm) is involved ($fm = 100, 110, 111,..., 358, 359$)), following the same distribution shape considering three variables: economic activity, employee occupation and unemployment rate. Then, the probability of an agent ee-type to be in the state 1 ($ee = 1$) in an economic activity $j(fm = j)$ with an occupation $k$is:

$$p(1, j, k) = \sum_{j=1}^{16} ee(j, k)$$

This distribution is calculated based on data of the year 2000, the first year with real data, for a grid of 475 occupations by 100 industrial sectors.

Some control measures are calculated in order to compare with macro-economic indexes collected from real world, per year and sector:

fct_y^{CNAE}: percentage of firms created in the total number of firms.

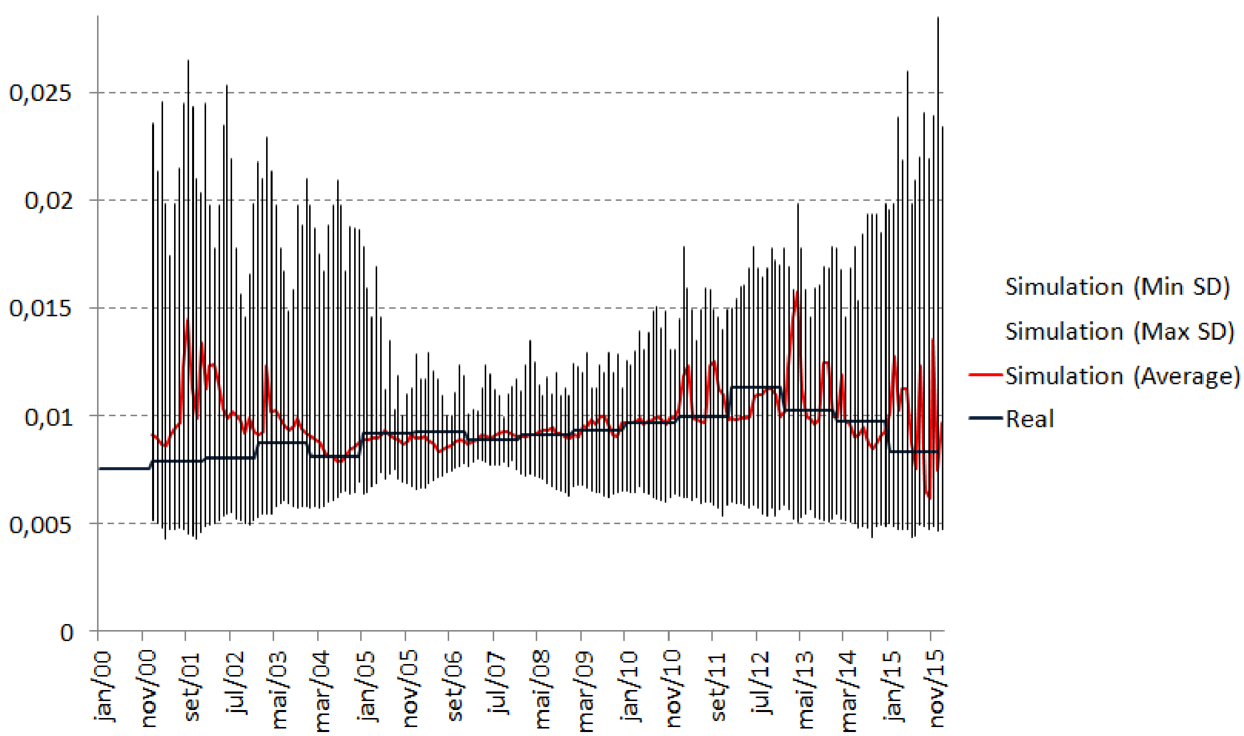
fcl_y^{CNAE}: percentage of firms closed in the total number of firms.

eyf_y^{CNAE}: percentage of employees working in young firms in the total of employees.

ur_y^{CNAE}: unemployment rate.

Chart 3 shows the comparison between the real world and simulation for the control measures presented before, with needed additional information like the number of times the algorithm is running with the same initial conditions (with slight variations of distribution parameters). It is worth to note that the simulation performed better if the interactions occur on a monthly basis. That is, despite the comparisons with the real world made yearly, the transient appears to be overcome when the interactions are more frequent, on a monthly basis.

Chart 3: Simulation x Real Data of the Percentage of Firms created in the Total Number of Firms



Source: Author´s elaboration

From the results of Table 6, it is possible to believe the model performs well after a transient of five years, when the standard deviations fall abruptly, remaining relatively low for more than 4 years, rising again after that. Hence, it is important to stress that the model, in terms of accuracy, works only in an interval of 4 years, after a transient of 5 years.

Table 6. Model´s Accuracy - Observational Metrics

Metrics	Accuracy			
	After 1 year	After 4 years	After 10 years	After 15 years
fct_y	45.45%	63.04%	82.67%	45.00%
fcl_y	42.93%	59.43%	79.54%	49.83%
eyf_y	38.00%	61.97%	80.87%	43.76%
ur_y	52.42%	59.45%	63.56%	48.95%

Source: Author´s elaboration. Metrics: fct_y: percentage of firms created in the total number of firms; fcl_y: percentage of firms closed in the total number of firms; $feyf_y$: percentage of employees working in young firms in the total of employees; fur_y: unemployment rate.

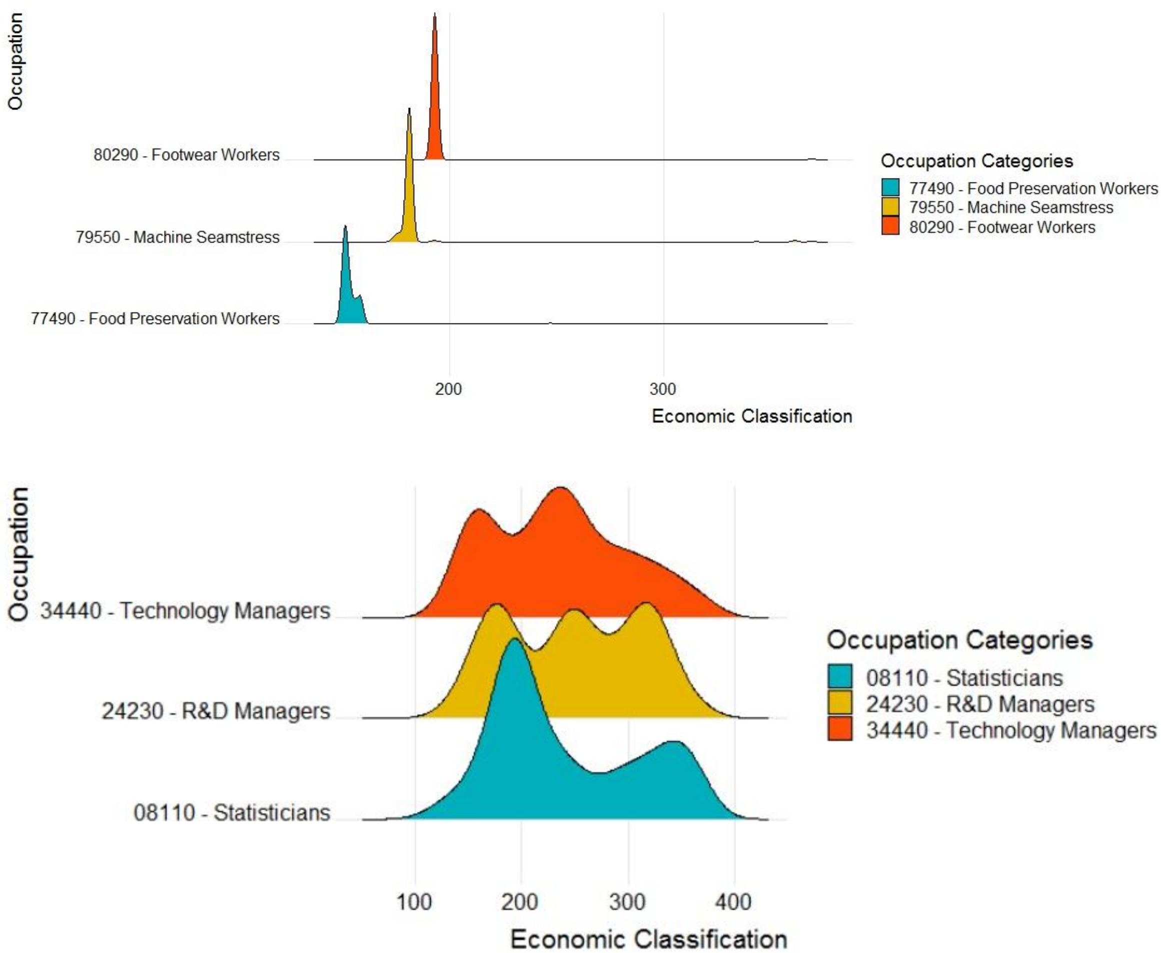
Chart 4 shows the distribution of economic activities for some occupations. In fact, the pattern of distribution shapes drives to three general types of distributions[36]: (a) normal distributions with or without pseudo kurtosis[37], in occupations with specific purposes in terms of industries, like CBOs 80290, 79550, among others; (b) log normal distributions, more frequent in the cases of liberal professions like doctors and lawyers but present in some low qualification professions like CBO 77490; (c) n-modal distributions, in the case of occupations

[36] Tests of adherence were performed to classify the distributions: chi-squared to normal and log-normal distributions and kolmogorov-smirnov test to normal, log-normal and binormal distributions.

[37] "Normality of variables is assessed by either statistical or graphical methods. Two components of normality are skewness and kurtosis. Skewness has to do with the symmetry of the distribution; a skewed variable is a variable whose mean is not in the center of the distribution. Kurtosis has to do with the peakedness of a distribution; a distribution is either too peaked (with short, thick tails) or too flat (with long, thin tails)" (Tabachnick and Fidel, 2013, page 79)

with general purposes, especially high education professionals like CBOs 24230, 34440, 08110 and others. These results mean that those network density distribution power laws[38] are sensitive to the initial conditions: the simulations revealed that small variations in the initial conditions drive to very different trajectories, a phenomenon that many authors would call path-dependency.

Chart 4: Distributions of occupation by economic activities (examples)



Source: Author´s elaboration. In the x is represented the economic classification in the scope of this work. For example, for the occupational category called "food preservation workers" there is a peak of frequency around the classification 15 - manufacture of foods and beverages products[39].

[38] See appendix A for a methodology to analyse the power law distributions and main results.
[39] For a complete list of activities, consult the link https://cnae.ibge.gov.br/?view=secao&tipo=cnae&versao=3&secao=D

The objective to use this type of technique is to analyse if innovation could be considered as a self-organized criticality state, that is whether innovation in firms is the result of social action. One of the evidences of criticality in the system occurred when it is observed high correlations between distant points in the space of phases. This type of correlation results sometimes in avalanches: when many firms (and employees, owners etc) in the clusters innovate at the same time.

4. Conclusions

This chapter proposes a model to address the following questions: whether it is possible to “predict“ emerging behavior in a complex system of entrepreneurship by the analyses of human resources dynamics and whether it is possible to acquire some knowledge on the emergent behavior of a complex system of entrepreneurship. The results show that it is possible to identify, by analysing data on employment mobility, how growth, in terms of creation and destruction of firms and employment, is linked to entrepreneurial activity and how these newly created firms can experience growth in their knowledge basis (measured by the number of years of education).

The agent based model implemented to simulate the dynamics performs well in an interval of 4 years after the initial transient period. However, the search of the best clauses could bring better results. This indicates that it is possible to use this type of approach to model a complex system of entrepreneurship, even though more research must be made in order to identify the optimal set of clauses that leads to the best results. In summary, this chapter contributes to the debate of how complexity has to be treated when the focus is on entrepreneurship.

CHAPTER 3 - PUBLIC POLICIES AND ENTREPRENEURSHIP - THE RELATION BETWEEN THE ENTREPRENEUR AND THE CONTEXT

What is the real purpose of policies to support entrepreneurship? In the context of evolutionary economics, what type of action could be suggested to support new entrepreneurs in order to push them out of the “dying gap” of the first three years of existence? Based on theories of complex systems, this chapter proposes a process of building up a framework to help address the action of state towards a better management of public scarce resources, taking into account the relation between the entrepreneur and the context in a complex environment.

1. Introduction

The questions raised above serve as a guide of what is the objective of this chapter: “what is the real purpose of policies in entrepreneurship?” and “in the context of evolutionary economics, what type of action could be suggested to support new entrepreneurs in order to push them out of the ‘dying gap’ of the first three years of the firm?”. The first question is the fundamental one of this chapter. Behind it, it is possible to find some concerns on the role of entrepreneurs as a prime engine of the economy. Wennekers and Thurik (2009) and Langlois (1997) argue that new young firms become important over time because of the exponential trajectory of the technology that allows big companies to raise productivity reducing dramatically the number of employees. More recently, authors like Brynjolfsson and Mcafee (2016) remind these arguments when they discuss the role of intelligent machines in the new techno economic paradigm. Having in mind this perspective, the new young firm could be considered one of the best options to alleviate the effects of economic concentration in firms with stratospheric revenues but few employees.

Another good argument in favour of new young firms is the effects in the innovation that new innovative small firms can provoke in the medium and long term. Some authors describe these effects as the real motor of change in the economy. The bet is on the young and small firm, because, even in current high tech firms, once the firm becomes big, the need for change is replaced, in most cases, by the application of barrier or monopoly strategies, acquiring newcomers or offering services for free, for example. These strategies annihilate the possibility of revenue in new markets and diminish, somehow, the appetite for disruptive innovations in the entire economy (Chandler, 1999; Das, 2018). For this, it is good for the whole economy that new firms could be successful in passing by the tree first years after the birth of which one, interval where almost 70% of firms closes.

The second question is how to present a comprehensive way to build up a framework of measurement of the economy of entrepreneurship. The context of a dynamical environment, where agents interact, facing continuous changes not only in the type of interaction, but also in the rules of this interaction, proposes that the ideal approach to describe this dynamics and, consequently, ‘discover’ the actions that could leverage the development of entire system, is via complexity economics.

This proposal, for its turn, brings, in its scientific body, the belief that is impossible to know clearly what happens when a specific policy is implemented. What is known, in fact, at best, is a confidence interval where the effects of the policy could lie, posing the models in an uncomfortable situation of low capacity of predictability. By the way, with the advances of techniques like agent based models or complex networks, a light is shed on how to preserve the main characteristics of evolutionary system keeping accuracy under reasonable boundaries, that is, in plausible limits in terms of consequences of policy making[40].

Acs et al (2016b) present an interesting discussion on what is a policy focused on (or, at least, perceived by) entrepreneurs. For them, “entrepreneurship-friendly policies are those which in some way it easier or cheaper for a person to start a new business, maybe or maybe not conditional on that they have developed a new business idea or invented something.” In this way, the cause-effects studied by the models implemented here have the underlying idea that it is possible to get easier or cheaper to open a new firm. Innovation, in this approach, is a point of arriving for some entrepreneurs (firms) and not a focus of the process, as some authors consider.

[40] In other words, the choice made here was to manage the linkages between “policy maker desires of predictability and confidence on future” and the realization that the system is complex by establishing upper and lower effects of an action in the creation of new firms and employment using an evolutionary model. In this context, the belief on linear models to “solve” the problem of the future in entrepreneurship could be considered a trap.

Additionally, some words have to be said on the nature of opening a new firm. Acs et al (2016b) separate entrepreneurs into two categories: routine and novel ones. If, on the one hand, the first type of entrepreneur needs to acquire capabilities to achieve success, the second one, on the other hand, as Schumpeter exhaustively discussed, needs other tools to build up the new market. Certainly policies that enable the first group to achieve success may not be the same as policies for the second group[41]. The models implemented here have no intention of differentiate the policies for these two groups.

This chapter proposes that the causal relationship between the theoretical point of view and the empirical approach adopted leads to treat entrepreneurship as a complex system, and to apply bottom up techniques subject to institutional structures. Then, in terms of public policies evaluation, we need to find a way to construct measures that reflect the complex character of the phenomenon. In this point, the theoretical field of the evaluation of public policies is still very incipient: few schools focus on this subject and literature is still under construction. Authors such as Costa (2015), Rodrigues (2011) and Faria (2005) have focused on discussing the public policy agenda, its importance and how it is constructed. Gussi (2008) presents the evaluation as a field of analysis based on the institutional trajectories of each policy action studied / experienced, which has an impact on the people. Lejano (2012) presents elements of comparison of different approaches to the analysis, its epistemological trajectory, that starts from a vision quite influenced by the positivist schools, opening space later to a constructivist approach, that evolves, like school and practice, for an experiential character view.

[41] In the words of Acs et al (2016b): "Public policies to promote novel entrepreneurship as opposed to routine entrepreneurship are different and cannot be assumed to happen without policy intervention (Baumol et al., 2007). But this intervention is not about market failure because the markets do not yet exist".

It is possible that the positivist approach to evaluation generally makes use of previous hypotheses. The methodologies are appraised in a technical-formal paradigm through scientificity, objectivity and neutrality. The positivist evaluation has a restricted use and is not concerned with evaluation as a category of analysis. The central concern of the positivist methodology, after all, is to weave hypotheses and test them, without contact, beyond observation, with the observed object. In the view of the scientific positivist observer, the observer and the objective of observation do not interact, do not participate in the same realm of existence. The ethics that serve as discourse extols scientific reason as a principle of neutrality: the observer / observed duality has an insurmountable barrier, designed to be so.

Guba and Lincoln (1994) propose a taxonomy for the purpose of the evaluation that takes into account the separation of this category into two distinct paradigms: positivist and post-positivist. For both paradigms, the objective of research is the explanation, ultimately allowing the prediction and control of phenomena, whether physical or human. The ultimate criterion for progress in these paradigms is that the ability of "scientists" to predict and control must improve over time, which is the opposite view of complexity economics since the theme of predictability appears only as a subliminal tool in the whole system.

The constructivist view recognizes the importance of particularity. Each evaluation is unique and there is no way of not taking into account the particular context of each one of them. Thus, this is a vision for the context and the particular, as opposed to the standard and general, of positivist orthodoxy. The purpose of the research is to understand and rebuild the constructions that people (including the researcher) initially take for themselves, aiming for consensus, but still open to new interpretations. The criterion for progress is that, over time, everyone formulates more sophisticated constructions and becomes more aware of the content and meaning of competing constructs. Advocacy and activism are also key concepts in this vision (Guba and Lincoln, 1994). The researcher is placed in the role of participant and facilitator in this process, a position that some authors criticize because of the aforementioned expansion of the researcher's role beyond the reasonable expectations of specialization and competence (Carr and Kemmis, 1986).

Finally, an experiential approach takes into account not only text and context. The counterpoint of this hermeneutic view has an inductive character, based on assumptions instead of hypotheses. Since public policy is immersed in a complex environment, the comprehensive view can implode the positivist methodology. In this view it becomes necessary to construct a rigorous conception of the facts, describing the institutional place of the evaluator, through the institutional cultures, taking the focus of the culture as something instrumental to methodology. Culture is seen as something other than instrumental only. Culture, in this approach, is part of the amalgam of society and, by itself, must be considered as mutant and complex, having to be experienced by the researcher, since the researcher needs to understand the experience and transmit it at the moment of the evaluation of the impacts of political action. Gussi and Oliveira (2016) believe that "the evaluator must approach and be interested in the field, the subjects and their subjectivities, recognizing that these elements are not residual in the evaluative work".

In summary, the purpose of this chapter is to recognize, in the trajectory of building up a framework of entrepreneurship statistics with the objective to contribute to public policies, that an approach based on complex systems theory can be considered not only a comprehensive framework but also plausible to be evaluated.

2. Methodology

The methodology proposed in this chapter has as point of departure the model implemented in Chapter 2 which was designed to simulate the macro behaviour of employment mobility in economic activities. This model has a substantial number of different types of agents, including institutional ones like a development bank or a governmental agency of training. The model also explores the creation of new firms, by tracking the trajectory of the entrepreneurs as employees before the firm´s born. The results of the simulation, in comparison with real data, reveal a practical tool to explore the boundaries of some actions that could serve as public policies in entrepreneurship.

One discussion that takes place in the implementation of an entrepreneurship policy action plan is how to access all possible levels or categories presented in the literature of evaluation models. Ludström and Stevenson (2005) are frequently cited as an interesting compilation of categories of goals: promotion of entrepreneurship; entrepreneurship education; reduction of entry/exit barriers; start-up financing; start-up support; and target group measures. Borges et al (2018), analysing the Brazilian environment, include two more categories: infrastructure; and technology and innovation. In practice, all countries manage with these dimensions to implement their entrepreneurship policy. A good example of this general guidance is the experience of Europe, portrayed in the European Commission Entrepreneurship

2020 Action Plan and summarized in Table 6 (European Commission, 2015). In this table is shown 34 possible actions that could be implemented in Europe by 2020. It is important to note that the main themes are in line with Ludström and Stevenson (2005) and Borges et al (2018), with special emphasis in women and senior entrepreneurship.

Table 7. European Entrepreneurship 2020 Action Plan

N	Main Theme	Policy Action
1	Framework Conditions	Cutting red tape - reducing the number of administrative procedures, simplifying them and avoiding duplication of tasks
2	Framework Conditions	Speed up and simplification of licensing and other permit procedures
3	Framework Conditions	Reduction of tax and social contributions related to effective cash flow of business
4	Framework Conditions	Implementation of the same social security protections available to entrepreneurs as to employees
5	Framework Conditions	Raising awareness of government administrations and their staff about entrepreneurial and SME challenges
6	Framework Conditions	Improve the quality and variety of business support advice for start-ups
7	Facilitating Transfers of Business	Improve legal, administrative and tax provisions for business transfers
8	Facilitating Transfers of Business	Improve information and advice provision for business transfers
9	Facilitating Transfers of Business	Develop, publicise and improve platforms and marketplaces for successful business transfers
10	Efficient bankruptcy procedures/second chances for honest bankruptcies	Develop and expand programmes to mentor, train, advise and support second starters
11	Efficient bankruptcy procedures/second chances for honest bankruptcies	Awareness raising in business and finance community to remove stigma of failure
12	Supporting new entrepreneurs	Increase and improve targeted business support services
13	Supporting new entrepreneurs	Offer dedicated support for SMEs to "go green"
14	Supporting new entrepreneurs	Targeted training, finance, internationalisation support programmes for high growth potential SMEs
15	Supporting new entrepreneurs	Offer support for new businesses to innovate
16	Improving access to finance	Reinforce loan guarantee and venture capital facilities
17	Improving access to finance	Improve financial advisory capacity
18	Improving access to finance	Make tax environment more favourable to early stage financing
19	Entrepreneurial education and training for youth	Create a platform or hub for entrepreneurial learning to share best practice and develop common models for policy, implementation and measurement

20	Entrepreneurial education and training for youth	Entrepreneurial behaviour, skills and mindsets to be embedded in national/regional curricula at all levels – primary, secondary, vocational, higher education and non-formal education and training, alongside integration of work-based teaching and learning in all disciplines and curricula
21	Entrepreneurial education and training for youth	All young people to have one entrepreneurial experience before leaving secondary school (either as a formal part of the curricula or as an extracurricular activity that is overseen by the school or a non-formal education body)
22	Entrepreneurial education and training for youth	Develop a guiding framework to encourage and support the development of entrepreneurial education institutions (vocational and higher education)
23	Entrepreneurial education and training for youth	Increase entrepreneurship education supported via education funding programmes
24	Entrepreneurial education and training for youth	Increase entrepreneurial training in line with national job plans
25	Untapped entrepreneurial potential of women	Continue/expand networks of women entrepreneurship ambassadors and mentors networks
26	Untapped entrepreneurial potential of women	Tailored entrepreneurial training for women
27	Untapped entrepreneurial potential of women	Create/foster female investors and networking among women entrepreneurs
28	Untapped entrepreneurial potential of women	Investment readiness training for women entrepreneurs
29	Untapped entrepreneurial potential of women	Same maternity rights for women entrepreneurs as for employees
30	Untapped entrepreneurial potential of women	Adequate child/dependent care facilities available
31	Seniors – second careers and business experience	Establish networks of volunteer seniors to counsel young inexperienced entrepreneurs
32	Seniors – second careers and business experience	Tailored entrepreneurial training for seniors without previous business experience
33	Seniors – second careers and business experience	Offer grants for unemployed seniors to become entrepreneurs
34	Specific support for migrant, minority or other specific groups of potential entrepreneurs	Tailored support for other specific groups of potential entrepreneurs

Source: European Commission, Report on the Results of Public Consultation on The Entrepreneurship 2020 Action Plan, 2015.

Taking all these elements / dimensions into account, a simulation model that would consider a complete system of entrepreneurship has to include the seven dimensions discussed above. It is clear, by the content of previous chapters, that this is not the intention of this thesis to complete this task. On the contrary, the idea of this chapter is to explore the possibilities that the model implemented and presented in Chapter 2 provides. In this way, it is proposed one approach which combines elements of the dimensions discussed by Ludström and Stevenson (2005) and Borges et al (2018), having in mind the intrinsic boundaries of ABM. Thus, based on the list of agents and relations between them, it is possible to create a set of characteristics that involves actions in public policies and test their limits using the techniques explored in the previous chapter. The characteristics that the model can explore are:

- Education and Training: the model has an agent responsible for the offering of training, giving employees the possibility to raise the number of years of study and, consequently, to get the most desired jobs.
- Monetary Policy: the arbitrary change in the interest rate can be interpreted as change in monetary politics and how this macro parameter can affect individual behaviour. Direct actions linked to this type of politicy can be seen as implicit, once they affect the whole of the economy and not only the entrepreneurs or new firms. However, as the ABM model implemented and explored in previous chapter assumes the changes in the level of economic liquidity as important for the performance of new firms, this kind of policy can be seen as monetary incentives for individuals to become entrepreneurs, as many others discussed in the literature (Parker, 2007; Lerner, 2009)
- Development Policy: the agent that interprets the role of a development bank has, in the simulation, to establish the long term rate to offer credit, generating more vacancies in the industry in the short and mid-terms.

The idea is to vary one of the three variables described above keeping fixed the other parameters. This methodology can reveal the boundaries of an *isolated* action in a set of a specific politics. The impact of the isolated action can be interpreted by the policy makers perspective. This chapter treats of the three examples cited previously, tracing a trajectory on how to use this type of approach to find structures of actions and policies. Certainly, the list of possible actions that could be tested in this type of modeling is far from to be exhaustive, even in the case of this specific application.

3. Results

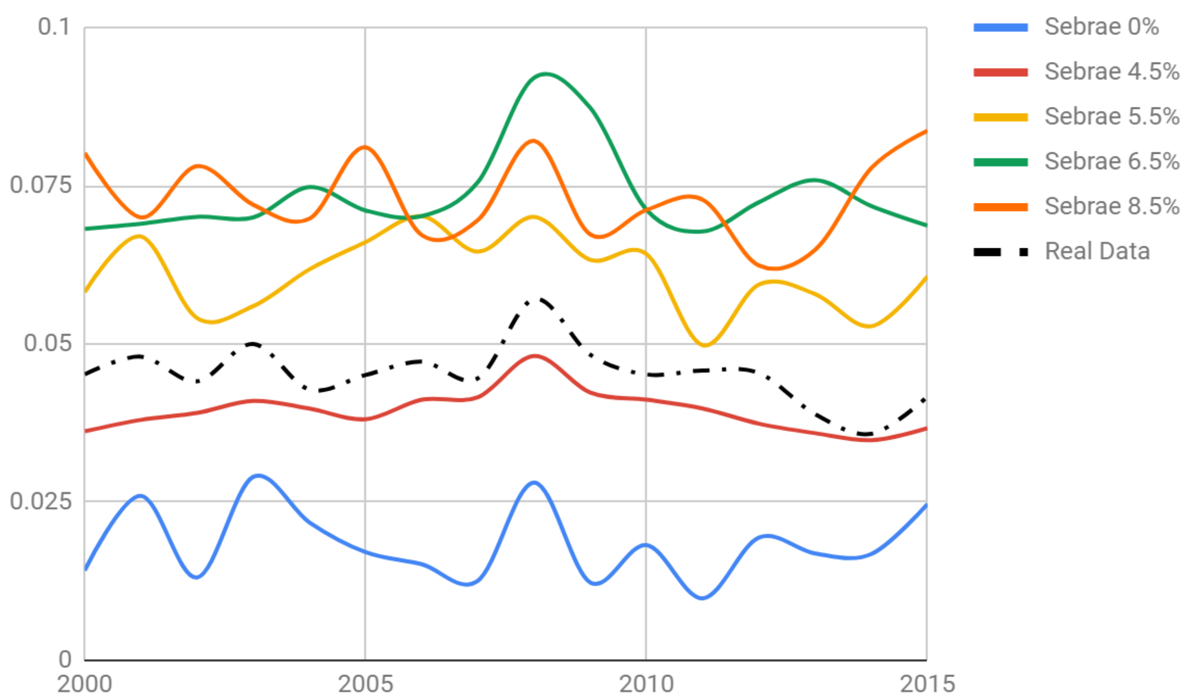
The first characteristic to be analysed is the training and education of agents. In the model proposed in Chapter 2, there is an agent responsible for the offering of external training. The dynamics involving this agent appears in three different steps of all cycles. Firstly, the national offering of courses is given by a percentage of the labor force. This level of offering is arbitrary which means that it could be considered as a policy initiative. In this way, the strategy is to imagine that there is a conscious reason in establishing a giving level of external training year by year. In practical terms, this is a fixed parameter in the model learning stage, but can be varied adhocly when the best fit model is found.

The second step that appears as a training parameter in the simulation is the formation of the demand. Two clauses are taken into account in the individual decision of getting more years of education: one, the perception that the gap between a n-years-educated employee and a m-years-educated employee salaries ($m - n > 0$) in a certain occupation is higher in the occupational neighbourhood (local maximum in the occupation classification with the same upper level digits[42]) than in the current employment; two, the perception that the gap between

[42] For example, an individual with the occupation 08110 (Statistician) working in the economic classification 273 (Steel Industry) has a neighbourhood compounded by the occupational category 08 (Statisticians, Mathematicians, Systems Analysts and Similar Workers) in the economic classification 27 (Basic Metallurgy).

a n-years-educated employee and a m-years-educated employee salaries $(m - n > 0)$ in a certain economic sector is higher in the neighbourhood (local maximum in the economic classification of the firm with the same upper level digits) than in the current employment[43].

Chart 5: Level of Opened Firms in the Economy (fct_y^{CNAE})



Source: Author´s elaboration. The smooth dashed line represents the real data, that is, the percentage of employees becoming entrepreneurs year by year. The red line presents the results of running the simulation previously to obtain the highest accuracy, which means that the goal of the training agency for a given year is about 4.5% of the entire population of employees. Then, the red line represents the level of the parameter that emerges of simulations in the phase of adjusting of all parameters. Once these parameters were fixed, the exercise consists of changing the only training and education variables in order to understand the effect of a change in the politics.

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[43] In this sense, the strategy, discussed in the introduction of the thesis, of tracking traces of knowledge along the trajectory is equivalent here to "feel the smell" of success in some economic variables spread out in the neighbourhood.

Therefore, the other lines (Sebrae 2,5%, Sebrae 5,5%, Sebrae 6,5%, Sebrae 8,5%) are changes in the politics of offering external training education, by changing the percentage of the worker population covered by the program.

The same approach can be used in the case of the other two component tools of policy axes: the central bank interest rate and the development bank long term interest rate as well. Concerning the central bank interest rate, its change, in the model, affects individuals directly and firms indirectly. As explained in Chapter 2[44], in the initial point in time of the simulation the Central Bank has an amount of resources equivalent to 10^8 units of resources[45] that the institution offers to individuals, to the development bank and to investors (firms investing in firms). Then, the individuals can decide if they want to take loans to invest in a new firm, growing faster by hiring workers more rapidly. In practice, if the interest rate rises in 1%, for example, the amount offered in the economy as an incentive to entrepreneurs, to development banks and investors, falls by 1% (the inverse of the rise of the interest rate). In the phase of model training, the trajectory of interest rate follows the historical series[46]. In the case of firms, as the development bank long term rate is affected by central bank interest rate, the firms are affected by the same mechanism. Similar approach is adopted for development bank interest rates.

In this sense, Tables 7 and 8 bring a summary of the boundaries of the model for different strategies for each policy action: monetary policy (Table 7) and development policy (Table 8). In the case of Table 7, it is shown that the increase in the central bank interest rate level can affect more strongly the level of firms creation than the opposite movement. This

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[44] Appendix B gives details on this mechanism.

[45] The Brazilian Central Bank has more than 1 trillion reais of compromised operations in the base that form the interest rate.

[46] The historical series are available in: https://www.bcb.gov.br/controleinflacao/historicotaxasjuros

means that a monetary policy of credit contraction leads to a decrease in the intention of employees to leave their jobs to open new businesses that is sharper than the increase in the creation of firms, in the case that monetary policy tends to expand the credit. In other words, it seems easier to slow down firms creation by a shrinkage monetary policy than to accelerate new firms opening by an expansionary monetary policy.

Table 8. Level of Change in the Creation of New Firms by Monetary Policy Variation

Central Bank Interest Rate Variation	Δfct_y					
	After 5 years	After 6 years	After 7 years	After 8 years	After 9 years	After 10 years
Δi= 5%	-7.5 p.p.	-8.3 p.p.	-8.5 p.p.	-8.9 p.p.	-9.5 p.p.	-11.1 p.p.
Δi= 4%	-7.4 p.p.	-7.7 p.p.	-7.8 p.p.	-8.1 p.p.	-8.3 p.p.	-8.9 p.p.
Δi= 3%	-7.1 p.p.	-7.3 p.p.	-7.7 p.p.	-8.0 p.p.	-8.1 p.p.	-8.7 p.p.
Δi= 2%	-6.8 p.p.	-7.1 p.p.	-7.5 p.p.	-7.6 p.p.	-7.8 p.p.	-8.1 p.p.
Δi= 1%	-3.5 p.p.	-4.2 p.p.	-4.3 p.p.	-4.7 p.p.	-5.3 p.p.	-5.9 p.p.
Δi = 0%	-0.5 p.p.	-0.3 p.p.	0.4 p.p.	-0.3 p.p.	0.1 p.p.	0.5 p.p.
Δi= -1%	1.5 p.p.	2.3 p.p.	2.8 p.p.	3.7 p.p.	4.5 p.p.	4.8 p.p.
Δi= -2%	2.9 p.p.	3.2 p.p.	3.4 p.p.	3.8 p.p.	4.9 p.p.	5.3 p.p.
Δi= -3%	5.1 p.p.	5.3 p.p.	6.2 p.p.	6.8 p.p.	7.1 p.p.	7.2 p.p.
Δi= -4%	5.4 p.p.	5.8 p.p.	6.9 p.p.	7.5 p.p.	7.7 p.p.	8.0 p.p.
Δi= -5%	5.8 p.p.	6.1 p.p.	7.3 p.p.	7.9 p.p.	8.3 p.p.	8.9 p.p.

Source: Author´s elaboration. Metrics: Δfct_y^{CNAE}: variation in percentage points of firms created in the total number of firms in a given year

The case presented in Table 8 is not exactly similar to considered in Table 7. The effects of development policy through the variation of long term interest rates are almost equal in opposite directions: the increase in the firms creation when long term interest variation is negative, is proportional to the decrease in the firms creation when long term interest variation is positive.

Table 9. Level of Change in the Creation of New Firms by Development Policy Variation

Development Bank Interest Rate Variation	Δfct					
	After 5 years	After 6 years	After 7 years	After 8 years	After 9 years	After 10 years
Δi_{lt}= 5%	-6.3 p.p.	-7.1 p.p.	-7.7 p.p.	-7.9 p.p.	-8.1 p.p.	-9.1 p.p.
Δi_{lt}= 4%	-6.1 p.p.	-6.8 p.p.	-6.9 p.p.	-7.3 p.p.	-7.5 p.p.	-7.7 p.p.
Δi_{lt}= 3%	-6.0 p.p.	-6.5 p.p.	-6.7 p.p.	-7.0 p.p.	-7.3 p.p.	-7.5 p.p.
Δi_{lt}= 2%	-5.7 p.p.	-6.0 p.p.	-6.3 p.p.	-6.0 p.p.	-6.6 p.p.	-7.0 p.p.
Δi_{lt}= 1%	-3.4 p.p.	-3.5 p.p.	-3.2 p.p.	-3.5 p.p.	-4.2 p.p.	-4.7 p.p.
Δi_{lt} = 0%	-0.1 p.p.	-0.5 p.p.	0.4 p.p.	-0.8 p.p.	0.1 p.p.	0.1 p.p.
Δi_{lt}= -1%	2.7 p.p.	3.1 p.p.	3.3 p.p.	4.6 p.p.	5.5 p.p.	5.9 p.p.
Δi_{lt}= -2%	3.8 p.p.	4.0 p.p.	4.8 p.p.	4.9 p.p.	5.8 p.p.	6.2 p.p.
Δi_{lt}= -3%	5.0 p.p.	5.2 p.p.	6.1 p.p.	7.4 p.p.	8.0 p.p.	8.3 p.p.
Δi_{lt}= -4%	5.2 p.p.	6.6 p.p.	7.5 p.p.	8.2 p.p.	8.4 p.p.	9.0 p.p.
Δi_{lt}= -5%	6.1 p.p.	7.0 p.p.	8.0 p.p.	8.4 p.p.	9.1 p.p.	9.6 p.p.

Source: Author´s elaboration. Metrics: Δfct: variation in percentage points of firms created in the total number of firms in a given year

Nevertheless this type of approach, that isolates each variable to discover its effect in the future, still seems somewhat innocuous in interpreting policy outcomes for entrepreneurship as a whole. In a real project of action on entrepreneurship, the policy makers are willing to understand the effects of a combination of actions taken together in order to create results in a comprehensive way. For instance, in a scenario of an upward inflation trajectory, it would be interesting to increase both the central bank interest rate and the long term interest rate in the simulation in order to know how the combination of these elements could impact the creation of new jobs. Table 9 represents some of these scenarios considering the three elements which the model is prepared to simulate with.

Table 9. Combination of Policy Actions and the Effects After 5 Years

Scenario	Policy Actions	Parameters	Δct After 5 years
Strong resources scarcity + high inflation	- Extreme restriction on credit - Extreme restriction on investment - Cuts in budgets for education and training	Δt = - 5% Δi = + 5% Δi_{lt} = + 5%	- 13.7 p.p.
Moderate resource scarcity + high inflation	- Restriction on credit - Restriction on investment - Moderate cuts in budgets for education and training	Δt = - 2% Δi = + 2% Δi_{lt} = + 2%	- 10.8 p.p.
No resource scarcity + high inflation	- Restriction on credit - Restriction on investment - No cuts in budgets for education and training	Δt = 0 % Δi =+ 2% Δi_{lt} = + 2%	- 8.5 p.p.
No resource scarcity + stable inflation	- No restriction on credit - No restriction on investment - No cuts in budgets for education and training	Δt = 0% Δi = = 0 % Δi_{lt} = = 0%	0.9 p.p.
Resources in expansion + stable inflation	- Expansion on credit - Expansion on investment - Rise in budgets for education and training	Δt = + 2% Δi = - 2% Δi_{lt} = = - 2%	5.9 p.p.

Resources in strong expansion + stable inflation	- Strong expansion on credit - Strong expansion on investment - Rise in budgets for education and training	$\Delta t = + 5\%$ $\Delta i = - 5\%$ $\Delta i_{lt} = - 5\%$	11.7 p.p.

Source: Author´s elaboration. Metrics: Δfct: variation in percentage points of firms created in the total number of firms in a given year

4. Conclusions

This chapter presented how an analysis based on a complex system model can be useful in building a framework of entrepreneurship with focus on public policies. It was described how to implement a variation in the goal variable in order to simulate the boundaries of a specific and possible action done by policy making.

In this exercise, three types of actions were analysed: training and education by a governmental agency, monetary politics and development politics. The results show that it is possible to use this type of technique in a broader perspective, giving in hand the necessary data to understand and touch the complex characteristics of the entrepreneurship system. In the case of training and education, it is shown there is an upper limit of effectiveness, that is, apparently a crescent offering of education reaches a top in the increase of the number of new firms and the employment in the economy. For the case of monetary policy, a constant increase in the central bank interest rate diminishes the entrance in the market of newcomers and augments the unemployment. In development policies, the offering of credit for firms, by changing the long term interest rate, causes an almost proportional change in the level of hiring or demissions.

In this sense, the chapter launches a new way to interpret and analyse the results of policy making. Research in this field can be fruitful once the response of the model seems to improve as more variables are added in the model.

CONCLUSIONS

This chapter concludes the thesis[47]. As a set of conclusions on the theme and results, this chapter completes the task of reuniting the findings of the three chapters presented previously in a comprehensive way. In addition to this, and in fact before this, it is considered that it is an outstanding opportunity to include some epistemological reflections applied to the interdisciplinar character of the thesis. These reflections serve as a guide in the analysis of the findings, strengths and weaknesses of the chosen approach. Comments on further developments are included as the final topics.

The chapter content is as follows: Section 1 presents some concerns on the nature of interdisciplinarity and how it can be embraced by public policies; Section 2 brings the main findings of each chapter and a discussion on how to interpret them vis a vis the hypotheses of the thesis; and Section 3 presents the final remarks, which include issues on the exploration of results for new contexts.

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[47] There are 4 more technical chapters in the form of appendices. These chapters: present all outputs generated by the models; go in deep in some questions, like the mathematical formalism behind the choices made in the Chapter 2 or 3; and bring classification of economic activities and occupation as well.

1. Reflections on the Interdisciplinarity of the Thesis

The point of the departure of this section is a subtle perception that essential issues were not discussed in any part of the thesis. To solve this lack in the central conjectures concerning the interpretation of results, we propose two issues: the idea of a complex system as an intermediate situation between order and chaos and how this way of thinking modifies the logic of public policies; and the challenge of incommensurability once the concept of 'complexity' is intensively spread out in scientific knowledge. The next two subsections treat these two themes separately.

1.1. Complexity, order, chaos … and public policies

The idea of a complex system as an intermediate situation between order and chaos is well established in physics. However, an analytical treatment of complex systems within the general theory of dynamic systems still poses a challenge to mathematicians.

In this sense, the perception that there is chaos in order and there is order in chaos represents important progress in understanding non-linear systems. In one way, usual ordered and regular phenomena generated by deterministic laws, such as the laws of motion of classical mechanics, can also lead to long-term unpredictability associated with chaos. In the opposite way, within a chaotic structure, traces of order survive in many cases, related to regular but unstable developments. It is possible to use these remnants of order to control chaos, employing them to produce a rapid passage from one situation to another far from the original one.

A complex adaptive system seems to exist in the middle of the spectrum which order and chaos are the opposite limit points. Instead of the observation that deviations from the initial conditions produce an uncertainty in the predictions that grows according to an exponential law, in the case of a complex system, the growth occurs according to a power law, making the system much less predictable. The spontaneous evolution of the system would tend to lead it to a self-organized critical state in an order / chaos frontier.

In adaptive complex systems the behavior in space-time contains strong correlations between distant points and between the present and past history. Thus, unlike Markovian systems, they have memory. In this view, what is called 'order' is represented by evolution that is entirely predictable and regular. 'Order' is a kind of steady behaviour: a predictable system in which the future are analytical, numerical or semantic asymptotes. 'Chaos' refers to a system that changes all the time with complete irregularity. 'Chaos' is a type of system with a very special condition: it is possible to understand the macro behaviour of it, but it is impossible to know all individual behaviours compounding the trajectory. The 'complex adaptive system' has a self-organized criticality, in constant evolution *and* becoming different as it changes.

For the reasons presented in the previous paragraph, it is important to emphasize that to affirm that an 'entrepreneurship system' is a 'complex system', is to say that those elements described above are presented in this system, the Brazilian System. In this point, this thesis completes the task of presenting some of these elements but, certainly, is far away from the task to discriminate the vast forest of elements that this system is supposed to have. In some cases the phenomenon can be more tangible, like in the vision of the order into chaos, that was revealed in Chapter 2, when it is discussed the negative shift in the overall complexity of the industrial sectors. The analysis of the innovation in terms of emergent behaviour, posed in Chapters 2 and 3, is another example of it, on how correlation between distant points can occur in specific clusters depending on the criticality of the system, causing the passage from a scenario with a low rate of innovativeness to one with a high rate. Three or more elements could be described from the thesis, but even a dozen of these elements could be insufficient to describe the whole tenor of complexity in a type of system like the Brazilian entrepreneurship system. Therefore, caution is advised when using this type of stylized facts to build up a broad framework. The application to public policy is not straightforward: complex systems are not easy to describe, but are worse to interpret.

Finally, the ultimate element to add in this framework is public policies. A big challenge is to think the field of public policies for an adaptive complex system, how to implement a strategy that takes into account the phenomena associated with the complexity, observed in the thesis: self-criticality of innovation, represented by the jumps of innovation rate in some economic activities; macro indicators that can be bounded from micro behaviour, as in the evidence of a limit of influence of training capacity in the creation of firms, discussed in Chapter 2; heterogeneity to the probability of distribution law, showed in both Chapters 2 and 3, presenting at least three different types of complex networks. For this, the task of building a framework of entrepreneurship that takes into account elements observed in a complex system can be though.

1.2. Incommensurability

The challenge of writing a thesis in an interdisciplinary area has to be considered here. Firstly, the field of public policies is supposed to include four pillars: social sciences, economics, statistics and law. This means that any interpretation of complexity has to consider these four disciplines, in addition to physics and mathematics, the original ones.

Especially in the shadow areas, the incommensurability *a la* Kuhn can appear, giving the researcher an impossible task of mixing concepts, or adopting only part of definitions. In this way, the risk of reductionism is real, once one can opt to accommodate his/her set of scholar beliefs in boxes of a given theoretical body that it was not designed for.

According to Kuhn (1962, 1977), immeasurable ways of seeing the nature of phenomena produce differences between schools of thought and their choices, although competing models may be called simultaneously scientific. In general, the use of the concept relates to the lack of a common standard for deciding which characterization (from a basket of distinct theories) is correct (Sankey and Hoyningen-Huene, 2001). This could indicate that the incommensurability between theories can be obtained per se, which means that the lack of common patterns of evaluation or variations of meaning among theories are only aspects or constituent parts.

The impact of incommensurability on the rationality of scientists' choices has certainly been the subject of scrutiny by many authors since the seminal work of Kuhn in the 1960s. One of the fundamental points, widely discussed, is the cumulative view of science history. The Popperian view, for example, implies that the possibility of refutation of theories drives scientific progress, since more comprehensive theories must be constructed under the rubble of those who have been falsified. The question of incommensurability raises doubts about the structuring thought of science derived from Popper. As proponents of new theories may employ distinct vocabularies, or in addition, the same vocabulary with different meanings, or record empirical evidence differently, or even describe nature with other visions, the task of refutation becomes impossible. Consequently, without common standards or procedures, the reasons offered for each choice may be at best persuasive, not rationally conclusive. The solution to this apparent paradox is, in Kuhn, related to the fact that there are cycles of normality in science, in which dominant theories are evolved under a given paradigm, generating the impression of progress. Such cycles inevitably result in crises, during which different scientific communities struggle until a new paradigm is established by the larger or more influential group (Rouse, 2003).

Understanding interdisciplinarity as a phenomenon of integration and interaction of disciplines, both methodologically and theoretically, the incommensurability effect imposes certain difficulties in the convergence trajectory of the different areas of scientific knowledge. By admitting the existence of semantic deviations, such as the untranslatability pointed out by Carrier (2001) or the perverse meanings explored by Boyd (2001), it is necessary to promote a rebalancing of forces between the disciplines in an active way, as pointed out by Chang (2012) . In addition, some authors stress the point that the causal relationship - incommensurability - interdisciplinarity must be reversed. Bhambra & Holmowood (2001), for example, explore incommensurability not as a problem for interdisciplinarity but as a condition: there would be no room for integrating disciplines if they did not have incommensurable elements between them. One must then find ways of dealing with the immeasurable when it comes to undertaking an interdisciplinary scientific journey (Bhambra, G. and Holmowood, 2001).

In this sense, the pluralistic view embraces the cause of convergence, indispensable to interdisciplinarity, including tolerance and interaction with researchers' agendas (Chang, 2012). Although the epistemic challenges of interdisciplinarity are constantly present, efforts must be focused on communication between disciplines (using distinct concepts to describe clusters of overlapping phenomena, generating language simplification) and on the integration of meta-cognitive resources conciliation.

With this context in mind, it is a relief to know that the research field of complexity economics has been evolving when it comes to organize the ontology of the area, especially in regards to the relationship of neo-Schumpeterian evolutionary theory of economic change. Robert et al. (2017) establish a vast landscape of how complexity has been treated by economics. They find it is possible to separate all literature produced in this theme in five major groups: habits and routines, self-organization, cumulative causation, innovation systems and increasing returns. This methodology deals with, in a certain way, the task of reducing edges between the various disciplines that compound this field of research. However, the task of including the main goal of public policies is still a challenge.

2. Summarizing the Findings of the Thesis

The thesis followed the ‘traditional’ trajectory of gathering the theoretical and empirical structures to put to the test its hypotheses. In this way, the complementarity of the chapters deals with the most important aspects of the amalgama of the main objective of the thesis, which can be summarized in some findings:

1. The Brazilian Entrepreneurship System can be viewed, modeled and analysed as a complex system: by applying models of complex networks of the employment mobility and using measures of complexity (subgraph, product and entropy measures), Chapter 1 brings some evidence that the behavior of the set of employees in a given industrial sector has characteristics of a complex system; in Chapter 2 there are evidences that the individual moves from a firm to another, or the actions to become an entrepreneur, are non-linear, and the individuals take her/his decisions based on the context, that is, based on the conditions of the neighbourhood (economic activity and occupation neighbourhoods were explored in that chapter); and Chapter 3 presents a way to analyse the data to produce a framework of entrepreneurship in a perspective of complexity, indicating how to test policy actions and how to confront the boundaries of their effects in a scenario of scarce resources.
2. The complexity of industrial sectors in the Brazilian entrepreneurship system has been reducing along the first decade and the first half of the second decade of the current century: measures presented in Chapter 1 reveals a diminishing of complexity levels of all industrial sectors for labor force network between 2000 and 2015; in the ABM showed in Chapter 2, the set of agent interaction clauses with best fit of real world contains decision rules which seem to influence on the loss of the system complexity, especially in the case of the reduction of offering

of credit to firms by developing bank. Other compilations of economic complexity across countries show the same trajectory, as in the case of The Atlas of Economic Complexity (Hidalgo, 2018). These compilations also show that this reduction of complexity is not the same for other countries: while some countries have been facing increasing in the complexity, like South Korea, others have stable trajectories along the time.

3. <u>The complexity in Brazil varies from one to another industrial sector and, more than this, demands different approaches to different contexts:</u> Chapter 1 reveals differences in the density of complexity along industrial sectors, allowing to cluster manufacturing activities, at least, into three sets. This means that one type of policy action that could be successful in a specific area can be unsuccessful in another, leading to the conclusion that it must be necessary to design policies differently depending on economic activity is in question.
4. <u>The entrepreneurship institutional structure system is crucial for the formation of the complex dynamics</u>: in Chapter 2, in the search of the minimal set of ABM interaction rules, one finding was that the simulation does not generate complex behaviour without some institutional agents like governmental financial agencies that impose the interest rates of the system (central and development banks). Therefore, a mere individual-firm interaction type is not sufficient to lead the system to emergent behaviours. This finding corroborates the general idea propagated by the National Systems of Innovation literature that institutional

constraints have to be considered, even in an individual-oriented model like what is implemented in this thesis.

5. The impact analysis of policy actions tends to underestimate their effects when each action is considered in an isolated way: Chapter 3 shows that the combination of various policy actions, which seems to be a natural way of doing policy making, intensifies the results of the system, provoking better (or worse) results in the indicators. This means that, when a macro context is considered, a system of actions should be simulated together, avoiding the trap of representing the final results as linear combinations of simpler parts.

Finally, it is important to revisit the hypotheses of the thesis vis-a-vis the main findings presented above. The first hypothesis that questions the adequacy of the complex approach in the case of the Brazilian entrepreneurship system is quite fully answered along the discussion of Chapter 2 and 3. It is clear that the Finding 1 is connected with this hypothesis, opening to the possibility of developing the models following the main principles of complexity economics. The second hypothesis deals with the emergent behaviour generated by interactions into the micro level. In this case, it can be said that the industrial sectoral complexity in Brazil has traces of crucial elements that could lead to an emergent behaviour in the macro level, as shown in Chapter 2 in the case of power law distribution of nodes and connections. However, as Finding 2 shows, these traces have become less evident over time, in the wake of a phenomenon that seems to be more comprehensive: the loss of complexity of the Brazilian industry in terms of generation of labor and job mobility. In terms of the third hypothesis, which deals with the idea of reallocation of resources generating a change in the performance of the system, Finding 5 demonstrates that it is possible to combine policy actions in a way to potentialize the desired policy makers effects.

3. Final Remarks

It is time to say something about weaknesses! However, it seems quite important to try to see these weaknesses as challenges for future research. One of the most obvious challenges when dealing with this type of approach is performing the calculations. A model with the intention to describe all the economy of a huge country like Brazil tends to be heavy in terms of time of processing. The validation of the models are also difficult because of the same issue, once the majority of the “best” indicators commonly used for validation have quadratic or cubic order in the time variable, exploding the time of calculation when the model tries to be “real” in terms of volume of nodes, connections and interactions.

Another big challenge for this type of approach is to consider a crucial element analysed for many authors: the location. As Acs et al (2016a) discuss, entrepreneurs´ ideas and actions seem to be place dependent, that is, in the special case of knowledge spillovers, new firms tend to be in the proximity of knowledge sources. Two “virtual” neighbourhoods are considered in the model implemented in the thesis: economic classification and occupation. However, the understanding of how the model behaves taking into account the way employees, employers and entrepreneurs react to each other in the same geographic locus would be a big step for a real application of this approach. Then, the combination of geographical, economic and occupational neighbourhoods seems to be the most interesting trajectory this research could take in the future.

One point that deserves some attention in future works is the effects of innovation policies in the trajectory of main variables studied in the thesis as well as structural changes caused by the adoption of new legislation. For this, it would be necessary to collect information on funds implemented in the last two decades, like non-refundable grants for research and development, infrastructure investment, subsidies and others. This kind of information should be confronted with changes in patent law, high growth rates etc. In the same way, an interesting use of the ideas carved in the thesis would be to use occupancy taxonomy to determine movement of outsourcing, franchises etc.

Regarding Chapter 1, one interesting element of research is the possibility of labor force networks seizing some memory over the years. It would be fruitful to study employment mobility by cumulative networks, paying attention on how their properties can vary considering employment displacement in a gap of two or three years. The argument in favor of this type of approach is that the worker perceives the labor market not as dynamic as it may seem, that is, once the worker moves in a given year, he/she turns his/her eyes towards the company that hired him, "forgetting" for a while the job market and its possibilities of new change. It would therefore be necessary to know what the time window is for the employee to look again at the market in the expectation of taking advantage of opportunities that could arise.

Still on Chapter 1, a decision was made to neglect employee mobility across industrial sectors, that is, all modelling was designed to understand the behavior of individuals who seek new job opportunities or new business opportunities within the same activity. This option was taken mainly because of computational reasons: efforts to consider cross-sectoral mobility turned algorithms intensively low. For the same reason, interactions between competitors and suppliers have not been implemented. Anyway, with new techniques and the evolution of softwares and hardwares, it could be feasible to consider this part of the phenomenon into the approach, by including new clauses and dynamics in the model of Chapter 2.

Another question that arises in this turn and could be a motive to further analysis is the qualification of opening a new business. The thesis treats this subject in a homogeneous way: to open a firm is equal across both industrial sectors and time. Moreover, different entrepreneurs may have different reasons for opening new businesses. In this point, a deep analysis of the literature on the differentiation of entrepreneurship by necessity and entrepreneurship by opportunity becomes important. Other aspects in this subject can be explored, as the case of the trend of big companies, in a seek of cost reduction, to change the legal relationship with their employers, forcing the dismissal of part of its employees to rehire them as outsourced. This phenomenon occurred intensively in Brazil before the labor reform implemented by the national congress in 2018.

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APPENDIX A - MATHEMATICAL FORMULATIONS

This appendix shows in detail the formulation of weights and measures of complexity cited in the section 2.1.

Let w_{ij} the weight of connection between agent i and j

$$w_{ij} = \alpha_{ij} o_I\left(sal_j\right) + \beta_{ij} o_X\left(sal_j\right) + \gamma_{ij} o_I\left(age_j\right) + \delta_{ij} o_X\left(age_j\right)$$

where $o_I(x)$ is the internal order[48] (in reference to the agent) of the employee j in relation to x, sal_j is the salary of the employee j, age_j is the age of employee j and α_{ij}, β_{ij}, γ_{ij} and δ_{ij} are adjustment parameters with $\sum_{i=1}^{N} \alpha_{ij} = \sum_{i=1}^{N} \beta_{ij} = \sum_{i=1}^{N} \gamma_{ij} = \sum_{i=1}^{N} \delta_{ij} = 1$. For the beginning of the dynamics, the weights are given by an *ad hoc* approach, based on the proximity of different types of agents. When the simulation starts, the formula above is used to adjust the values overtime, preserving the normalization required for constraint parameters.

For the complexity measures it is used the same nomenclature of original work by Kim and Wilhelm (2008). First three represent subgraph measures:

1. One-edge-deleted subgraph complexity with respect to the different number of spanning trees:

$$C_{1e,ST} = \frac{N_{1e,ST} - 1}{m_{cu} - 1}$$

where $N_{1e,ST} \sim O\left(n^{2.376}\right)$ and $m_{cu} \sim n^{1.68} - 10$.

2. One-edge-deleted subgraph complexity with respect to the different spectra of the Laplacian and the signless Laplacian matrix:

$$C_{1e,spec} = \frac{N_{1e,spec} - 1}{m_{cu} - 1}$$

where $N_{1e,spec} \sim O\left(mn^3\right)$ and $m_{cu} \sim n^{1.68} - 10$.

3. Two-edges-deleted subgraph complexity with respect to the different spectra of the Laplacian and the signless Laplacian matrix:

[48] See the appendix B to a detailed description of mathematical formulation of the networks.

$$C_{2e,spec} = \frac{N_{2e,spec}-1}{\binom{m_{cu}}{2}-1}$$

where $N_{2e,spec} \sim O(m^2 n^3)$and $m_{cu} \sim n^{1.68} - 10$.

Itens 4 to 6 represents product measures:

4. Medium Articulation for graphs MAg:

$$MA = R \cdot I$$

where $R = \sum_{i,j} T_{ij} log\left(\frac{T_{ij}^2}{\sum_k T_{kj} \sum_l T_{il}}\right)$, is the information redundancy over T_{ij}, while $I = \sum_{i,j} T_{ij} log\left(\frac{T_{ij}}{\sum_k T_{kj} \sum_l T_{il}}\right)$is the mutual information.

5. Efficiency complexity Ce:

$$C_e = 4\left(\frac{E-E_{path}}{1-E_{path}}\right)\left(1 - \frac{E-E_{path}}{1-E_{path}}\right)$$

where $E = \frac{1}{n(n-1)/2}\sum_i \sum_{j>i} \frac{1}{d_{ij}}$, $n$is the number of nodes and $d_{ij}$the shortest path length from i to j, while $E_{path} = \frac{2}{n(n-1)} \sum_{i=1}^{n-1} \left(\frac{n-i}{i}\right)$.

6. Graph index complexity Cr:

$$C_r = 4c_r\left(1 - c_r\right)$$

with $c_r = \frac{r-2cos\frac{\pi}{n+1}}{n-1-2cos\frac{\pi}{n+1}}$.

The last two indices are in the category of entropy measures:

7. Off Diagonal complexityOdC:

$$OdC = \frac{\sum_{n=o}^{k_{max-1}} ã \, log \, ã_n}{log(n-1)}$$

with $ã = \frac{a_n}{\sum_{n=o}^{k_{max-1}} a_n}$.

8. Spanning tree sensitivity STS:

$$STS = \frac{1}{log(m_{cu})} H\left(\left\{S_{ij}\right\}\right)$$

with $ã = \frac{a_n}{\sum_{n=o}^{k_{max-1}} a_n}$.

In terms of analysis of distributions of nodes and connections in Chapters 1 and 2, the method to analyze the power law distributions are derived from Clauset et al. (2009). The authors combine maximum-likelihood fitting methods with goodness-of-fit tests based on the Kolmogorov-Smirnov statistic and likelihood ratios. In this sense, being k the number of links associated with a node,αan exponential constant parameter, the probability distribution follows the equation:

$$p(k) \sim \frac{\alpha-1}{k_{min}} \left(\frac{k^{-\alpha}}{k_{min}} \right)$$

In this way, the method proposed by Clauset et al. (2009) considers to estimate the parameters $k_{min}$and α calculate the goodness-of-fit between the data and the power law by performing hypothesis tests on the shape of distribution, and, ultimately, compare the power law with alternative hypotheses via likelihood ratio test. For the discrete case, it is considered integer values with a probability distribution like above:

$$p(k) = Pr(K = k) = Ck^{-\alpha}$$

In order to avoid the divergence at zero, it is assumed there is a lower bound on the power-law behavior that can be calculated:

$$p(k) = \frac{k^{-\alpha}}{\zeta\left(\alpha, k_{min}\right)}$$

For this case, it is used the Hurwitz zeta function to normalize $p(k)$, that is:

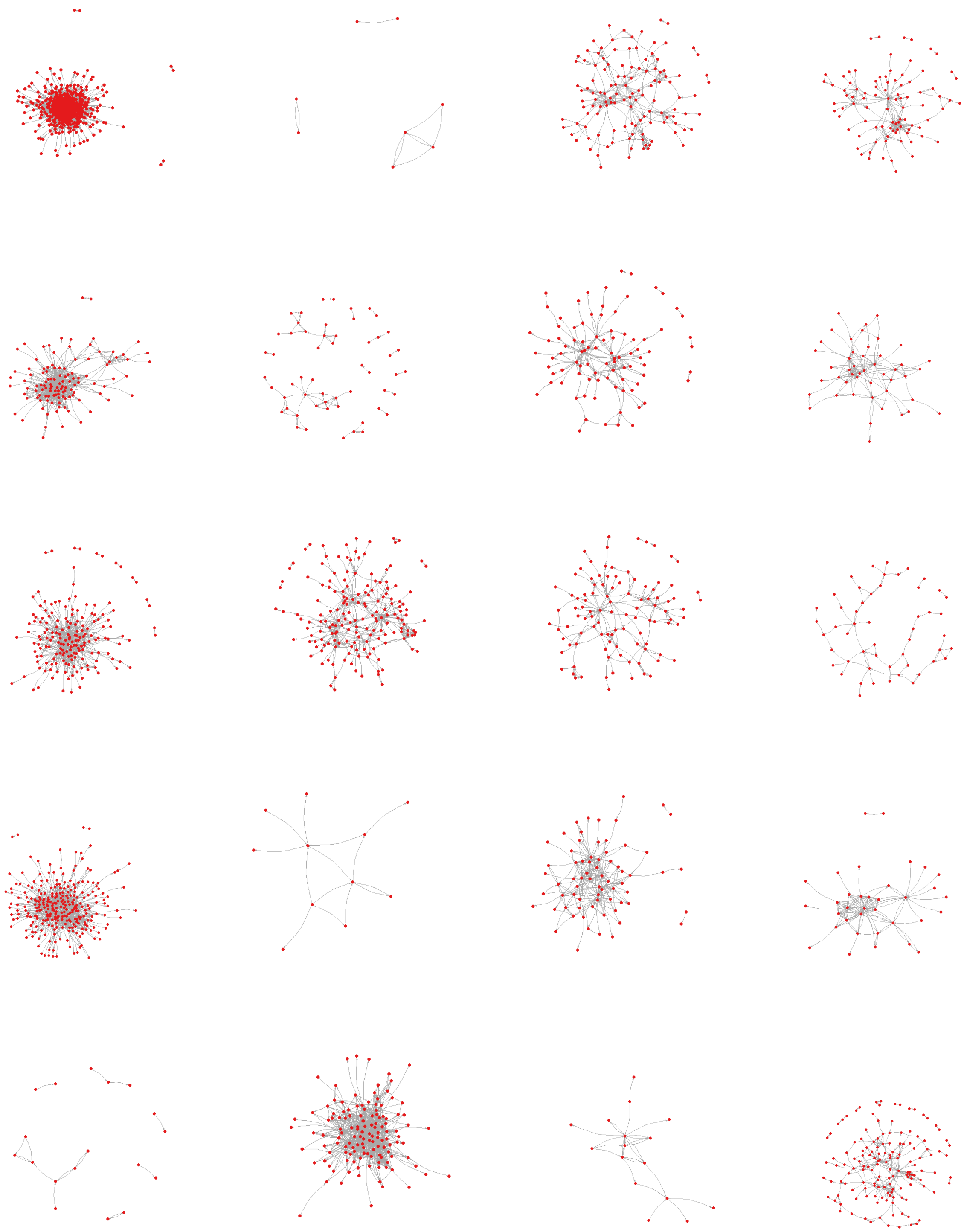
$$\zeta\left(\alpha, k_{min}\right) = \sum_{n=0}^{\infty} \left(n + k_{min}\right)^{-\alpha}$$

APPENDIX B - COMPLEX NETWORKS STRUCTURES BY ECONOMIC ACTIVITIES

This appendix presents the Labor Flow Network by each Economic Activity (20 industrial sectors of ISIC rev 4) by year. Figures B1 to B16 follow the same structure:

- Panel A: Manufacture of Food and Beverages
- Panel B: Manufacture of Tobacco Products
- Panel C: Manufacture of Textile Products
- Panel D: Confectioning of Clothing and Accessories
- Panel E: Manufacture of Wood Products
- Panel F: Manufacture of Cellulose, Paper and Paper Products
- Panel G: Manufacture of Coke, Oil Refining, Elaboration of Nuclear Fuels and Alcohol Production
- Panel H: Manufacture of Chemical Products
- Panel I: Manufacture of Articles of Rubber and Plastic Material
- Panel J: Manufacture of Non-Metallic Mineral Products
- Panel K: Metallurgy
- Panel L: Manufacture of Metal Products - Exclusive Machinery
- Panel M: Manufacture of Machines and Equipment
- Panel N: Manufacture of Desktop Machines and Computer Equipment
- Panel O: Manufacture of Electrical Machines, Apparatus and Materials

Figure 10: Labor Flow Network by Economic Activities, 2000



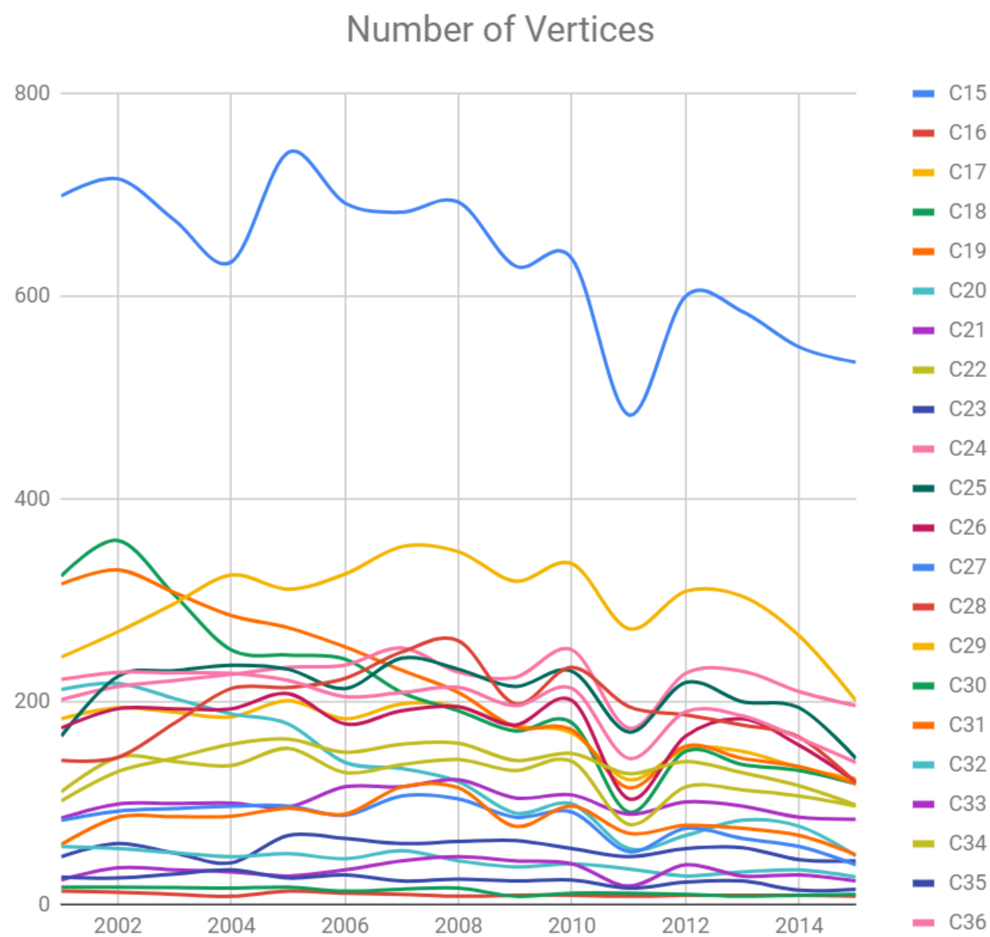
Source: Authors' elaboration from the following databases: Annual Social Information Database (RAIS); Federal Table of Revenue Ownership (QSA) and Innovation Survey (PINTEC).

APPENDIX C - COMPLEX MEASURES BY ECONOMIC ACTIVITY

This appendix shows the metrics calculated for each economic activity social network by year. The nomenclature used for the economics activities are as follows:

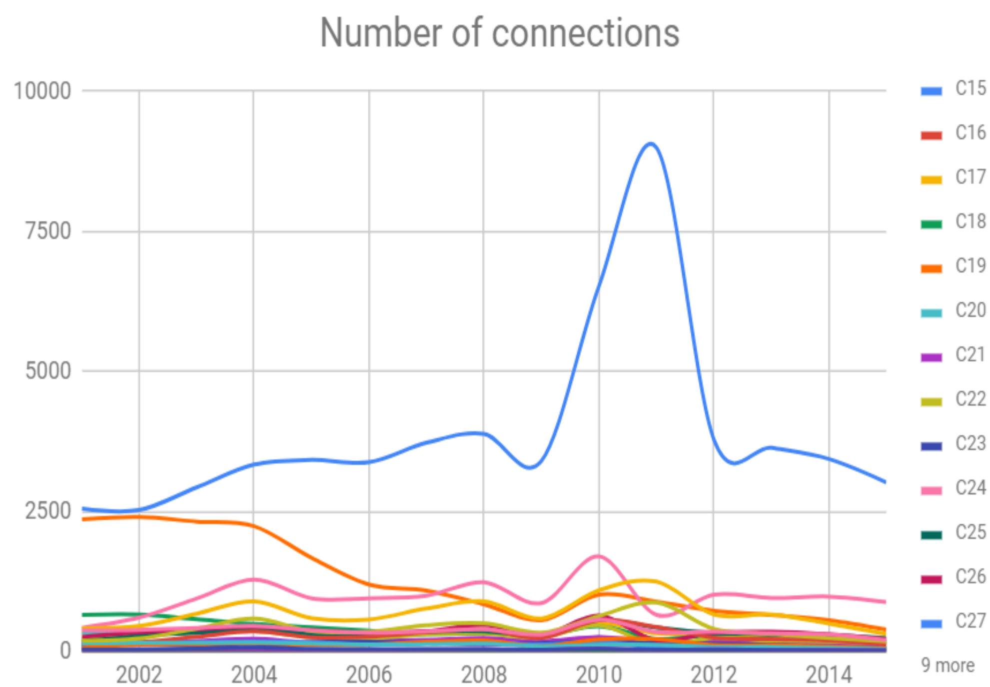
- 15: Manufacture of Food and Beverages
- 16: Manufacture of Tobacco Products
- 17: Manufacture of Textile Products
- 18: Confectioning of Clothing and Accessories
- 19: Leather Preparation and Manufacture of Leather Arts, Travel Articles and Footwear
- 20: Manufacture of Wood Products
- 21: Manufacture of Cellulose, Paper and Paper Products
- 22: Manufacture of Coke, Oil Refining, Elaboration of Nuclear Fuels and Alcohol Production
- 23: Manufacture of Chemical Products
- 24: Manufacture of Articles of Rubber and Plastic Material
- 25: Manufacture of Non-Metallic Mineral Products
- 26: Metallurgy
- 27: Manufacture of Metal Products - Exclusive Machinery
- 28: Manufacture of Machines and Equipment
- 29: Manufacture of Desktop Machines and Computer Equipment
- 30: Manufacture of Electrical Machines, Apparatus and Materials

Chart 6: Number of Vertices, 2000 - 2015



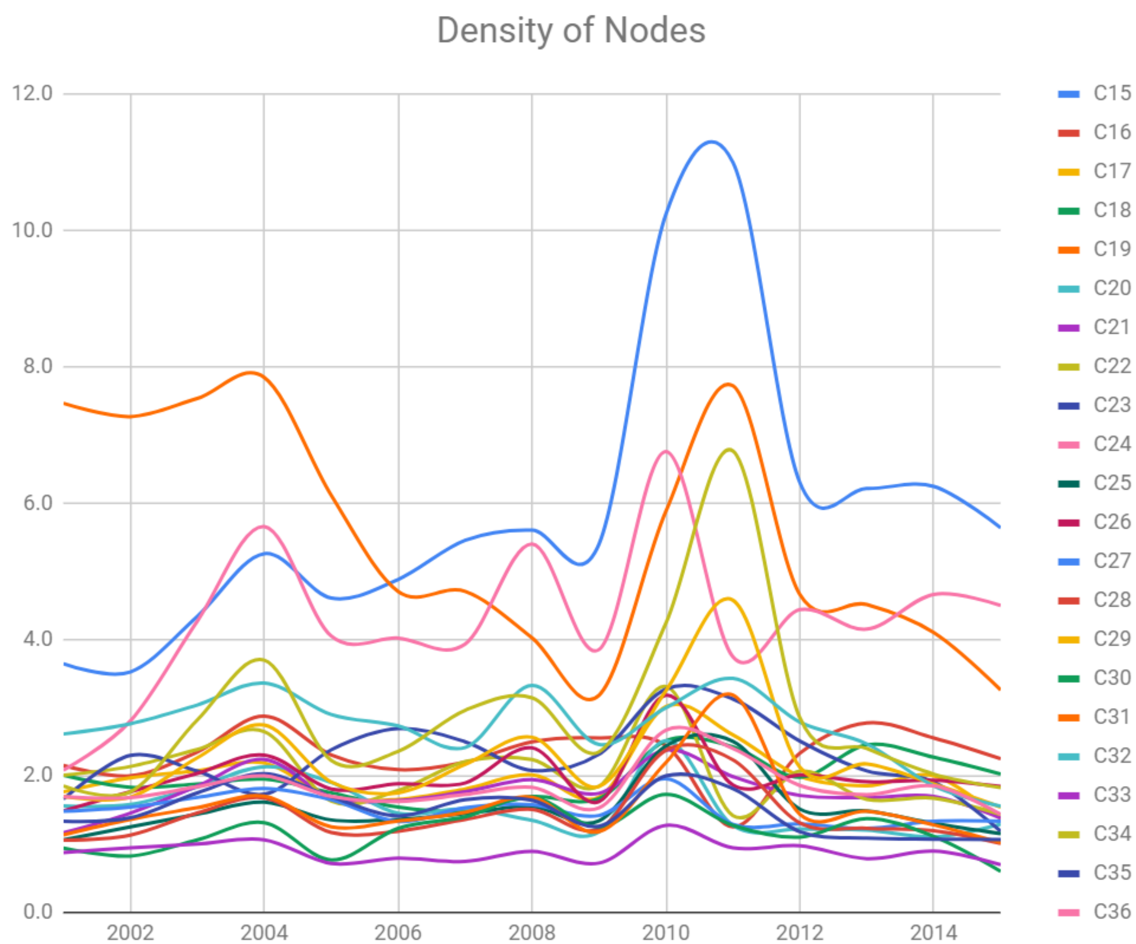
Source: Author's elaboration.

Chart 7: Number of Connections, 2000 - 2015



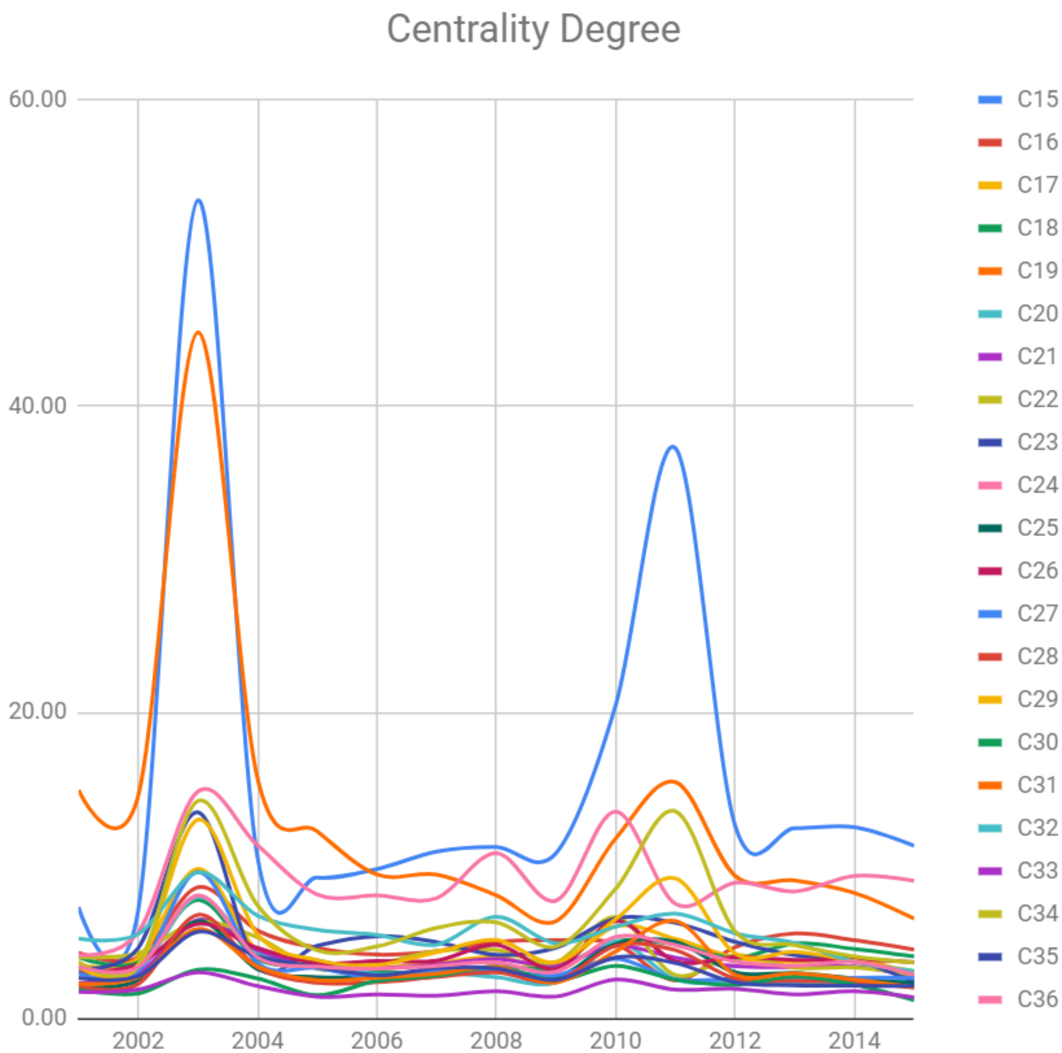
Source: Author's elaboration.

Chart 8: Density of Nodes, 2000 - 2015



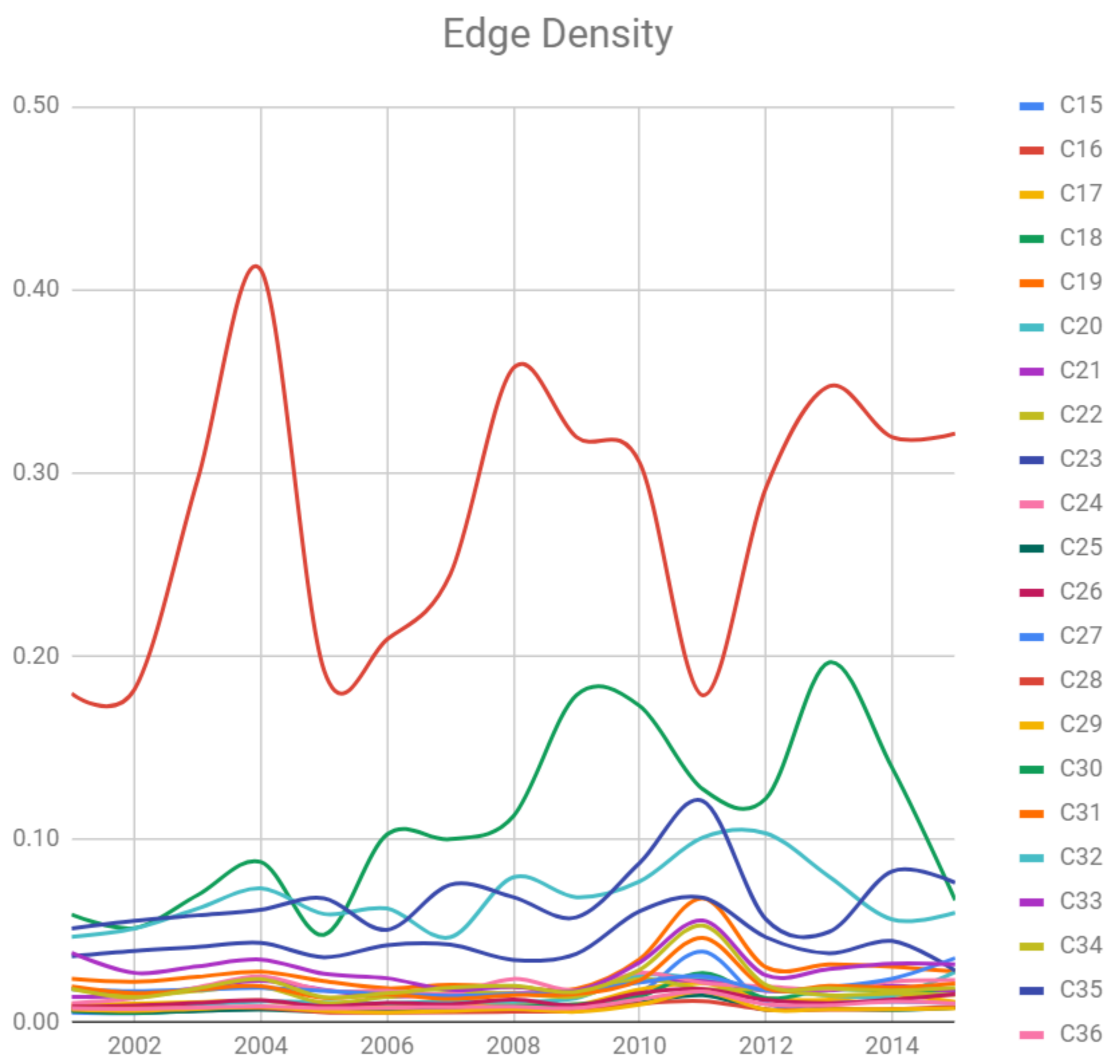
Source: Author’s elaboration.

Chart 9: Centrality Degree, 2000 - 2015



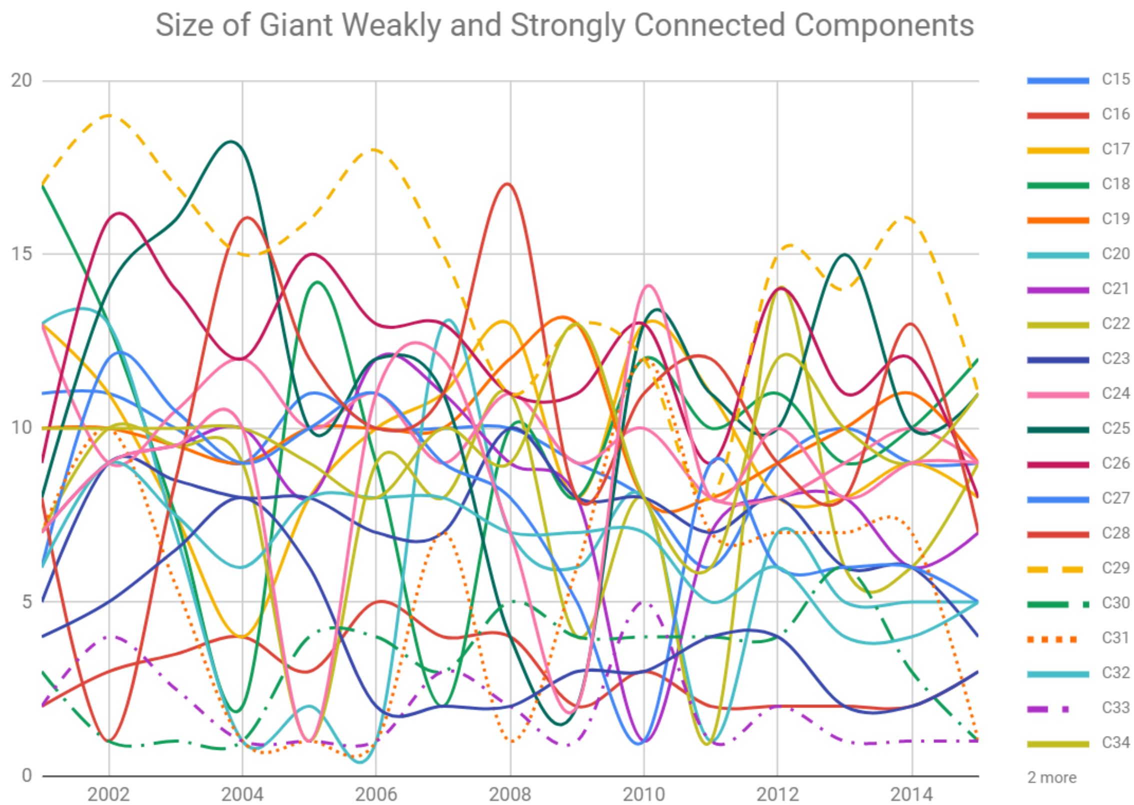
Source: Author’s elaboration.

Chart 10: Edge Density, 2000 - 2015



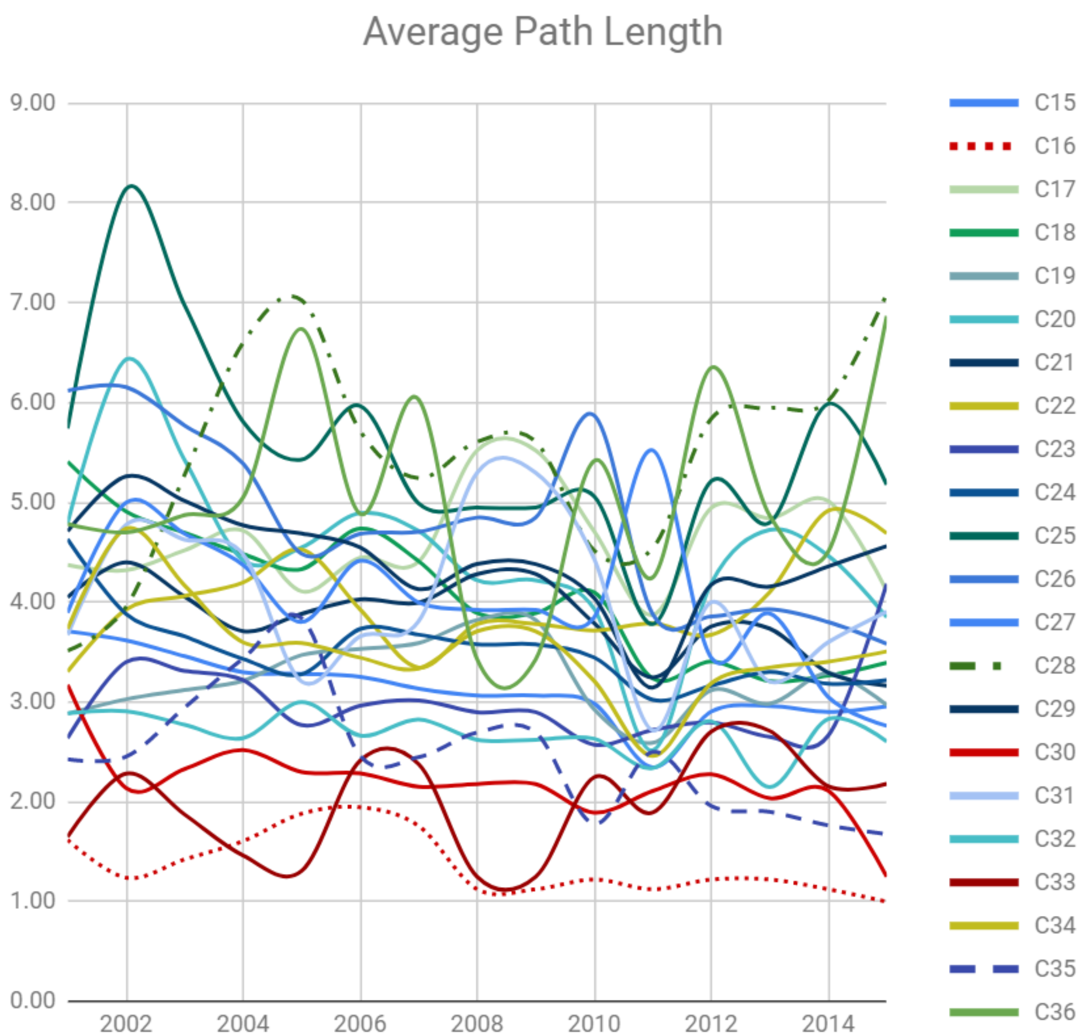
Source: Author’s elaboration.

Chart 11: Size of Giant Weakly and Strongly Connected Components



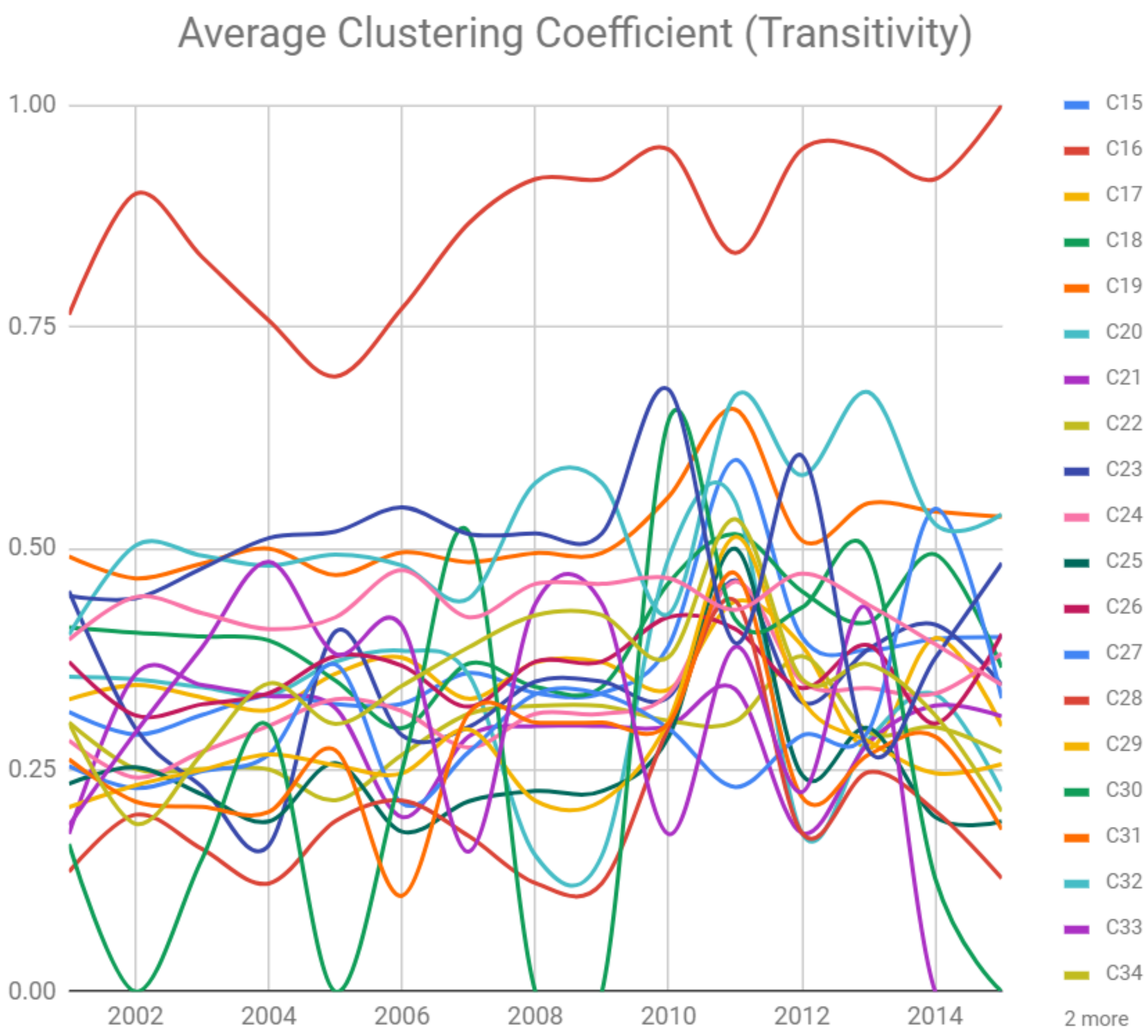
Source: Author's elaboration.

Chart 12: Average Path Length, 2000 - 2015



Source: Author’s elaboration.

Chart 13. Average Clustering Coefficient, 2000 - 2015



Source: Author's elaboration.

Table 9: Metrics for Year 2001

Economic Activity	u	v	c	d	e	s	l	t
15	699	2548	7.29	11.51	0.01	11	3.71	0.32
16	13	28	4.31	2.18	0.18	2	1.62	0.76
17	183	323	3.53	3.79	0.01	13	4.37	0.33
18	324	651	4.02	4.89	0.01	17	5.41	0.41
19	316	2359	14.93	18.47	0.02	10	2.88	0.49
20	212	331	3.12	2.71	0.01	13	4.79	0.36
21	85	99	2.33	2.54	0.01	7	4.05	0.18
22	111	223	4.02	5.14	0.02	7	3.3	0.3
23	47	78	3.32	3.68	0.04	5	2.64	0.45
24	202	421	4.17	5.32	0.01	13	4.63	0.28
25	166	176	2.12	1.57	0.01	8	5.74	0.23
26	174	259	2.98	3.03	0.01	9	6.12	0.37
27	83	123	2.96	2.32	0.02	6	3.89	0.25
28	142	150	2.11	1.96	0.01	8	3.51	0.14
29	244	414	3.39	3.44	0.01	17	4.71	0.21
30	17	16	1.88	0.86	0.06	3	3.17	0.17
31	59	67	2.27	2.29	0.02	7	3.67	0.26
32	57	149	5.23	4.68	0.05	6	2.89	0.4
33	24	21	1.75	1.03	0.04	2	1.65	0.19
34	102	189	3.71	3.63	0.02	10	3.73	0.3
35	27	36	2.67	2.15	0.05	4	2.43	0.45
36	222	376	3.39	3.54	0.01	7	4.78	0.4

Source: Author’s elaboration.

Table 10: Metrics for year 2011

Economic Activity	u	v	c	d	e	s	l	t
15	483	8995	37.25	53.02	0.039	6	2.34	0.6
16	8	10	2.5	1.41	0.179	2	1.13	0.83
17	123	320	5.2	4.91	0.021	11	3.87	0.44
18	91	221	4.86	6.34	0.027	10	3.24	0.52
19	115	888	15.44	17.83	0.068	8	2.59	0.66
20	55	70	2.55	2.02	0.024	1	2.52	0.55
21	89	177	3.98	4.93	0.023	7	3.24	0.34
22	79	112	2.84	3.65	0.018	1	3.79	0.3
23	47	147	6.26	6.05	0.068	7	2.72	0.46
24	174	652	7.49	9.67	0.022	8	3.02	0.46
25	170	426	5.01	5.75	0.015	11	3.78	0.5
26	104	194	3.73	3.96	0.018	9	3.88	0.41
27	52	67	2.58	1.67	0.025	9	5.52	0.23
28	195	436	4.47	4.13	0.012	12	4.54	0.44
29	272	1245	9.15	12.11	0.017	8	3.14	0.51
30	11	14	2.55	1.97	0.127	4	2.11	0.42
31	70	223	6.37	7.18	0.046	7	2.71	0.47
32	35	120	6.86	7.55	0.101	5	2.34	0.67
33	18	17	1.89	1.13	0.056	1	1.89	0.39
34	129	873	13.53	14.43	0.053	6	2.46	0.53
35	16	29	3.63	3.58	0.121	4	2.5	0.39
36	144	346	4.81	5.55	0.017	8	4.25	0.43

Source: Author’s elaboration.

Figure 11. Clustering Methods by parameters, 2000