UNIVERSITY OF SAO PAULO
SCHOOL OF ARTS, SCIENCES AND HUMANITIES
GRADUATE PROGRAM IN COMPLEX SYSTEMS MODELING

FELIPE DE OLIVEIRA SIMOYAMA

Applications of complex systems science to address public policy issues

SAO PAULO
2018

FELIPE DE OLIVEIRA SIMOYAMA

Applications of complex systems science to address public policy issues

Dissertation submitted to the Graduate Program in Complex Systems Modeling at the School of Arts, Sciences and Humanities at the University of Sao Paulo, as a partial requirement to obtain the Master of Science degree.

Corrected version containing the changes requested by the judging committee on June 21, 2018. The original version is available at the Library of EACH-USP and in the Digital Library of Theses and Dissertations of USP (BDTD), in accordance with CoPGr Resolution 6018 of October 13th, 2011

Concentration area: Complex Systems

Supervisor: Prof. Dr. Flavia Mori Sarti

SAO PAULO

2018

CATALOGUING IN PUBLICATION
(University of São Paulo. School of Arts, Sciences and Humanities. Library)
CRB 8 -4936

Simoyama, Felipe de Oliveira
Applications of complex systems science to address public policy issues / Felipe de Oliveira Simoyama ; advisor, Flavia Mori Sarti. – 2018.
84 p. : il.

Dissertation (Master of Science) – Graduate Program in Complex Systems Modeling, School of Arts, Sciences and Humanities, University of São Paulo.
Corrected version.

1. Public policies - Computer simulation. 2. Complex systems. 3. Regulatory body. 4. Dynamic systems. I. Sarti, Flavia Mori, advisor II. Title

CDD 22.ed.– 320.6011

Name: SIMOYAMA, Felipe de Oliveira

Title: Applications of complex systems science to address public policy issues

Dissertation submitted to the Graduate Program in Complex Systems Modeling at the School of Arts, Sciences and Humanities at the University of Sao Paulo, as a partial requirement to obtain the Master of Science degree

Approved on: June 21, 2018.

Dissertation Committee:

Prof. Dr. Fernando de Souza Coelho
Universidade de São Paulo. Escola de Artes, Ciências e Humanidades

Prof. Dr. Ricardo Luiz Pereira Bueno
Universidade Federal de São Paulo. Escola Paulista de Política, Economia e Negócios

Prof. Dr. Cintia Rejane Möller de Araújo
Universidade Federal de São Paulo. Escola Paulista de Política, Economia e Negócios

ABSTRACT

SIMOYAMA, Felipe de Oliveira. **Applications of complex systems to address public policy issues.** 2018. 84 f. Dissertation (Graduate Program in Complex Systems Modeling) - School of Arts, Sciences and Humanities, University of Sao Paulo, Sao Paulo, 2018. Corrected version.

In public policies, agents are part of an emergent and complex context, reason for which their actions should not be examined in isolation. The state of an agent is influenced by the state of others, in an environment where feedback is continuous and full of interactions. These characteristics result in a system where the total is more unpredictable and dazzling than the mere sum of its parts. As a result, there are a growing number of studies that use typical methods of complex systems to analyze public policies in various areas, such as healthcare, education, crime prevention, energy resources and others. Moreover, such distinct approach allows for more accessible investigations of public policy models, including policies that were not evaluated *ex ante* from the traditional lenses. This research had two main objectives: to verify how complex systems apply to the context of public policies theoretically and to present a practical application of a model, which was built based upon a case study. Since there is not a clear comprehension on how complex systems could benefit policy makers, this study presents, in its first part, a systematic literature review including some existing applications and the benefits of complexity science in the policy arena. On the whole, it can be asserted that there is a strong consensus that complex systems can be highly beneficial for policy makers and, consequently, for the overall population. Researchers perceive different benefits, such as the opportunity of testing policies *a priori*, the possibility of comparing different policies for the same topic, and the contemplation of new ideas and insights for better policy formulation. Although there are several simulations and models proposed for public policies in several areas, it lacks an empirical demonstration that effectively proves the benefits of applying complex systems in public policies, *i.e.*, apparently, there are obstacles that prevent such models from having effects in the real world. In this way, the second part of the research presents an agent-based model that can be applied empirically in a government agency: a regulatory body. Such model allows policy makers to compare different enforcement strategies and anticipate side effects that would be difficult to predict without the use of simulations. In this sense, the objective of the second part of this research was to build an agent-based model of a public policy and for which a practical implementation could be carried out. Therefore, a public policy from a professional regulatory board in the healthcare area was chosen, for which two different strategies were tested, with the objective of comparing their efficiency and effectiveness. Such strategies were modeled and simulated with the use of Netlogo software with different scenarios. Results indicate that agent based models can serve as predictive tools for comparing and improving inspection strategies, and also as source of insights for anticipating unintended consequences that would hardly be noticed ex ante without the use of simulation tools.

Keywords: Agent based model. Healthcare. Regulatory body. Complex systems. Effectiveness of public policies.

RESUMO

SIMOYAMA, Felipe de Oliveira. **Aplicações de Sistemas Complexos para Problemas de Políticas Públicas**. 2018. 84 f. Dissertação (Programa de Mestrado em Modelagem de Sistemas Complexos) - Escola de Artes, Ciências e Humanidades, Universidade de São Paulo, São Paulo, 2018. Versão corrigida.

Em políticas públicas, as ações dos agentes envolvidos não podem ser analisadas de forma isolada. O estado de um agente é influenciado pelo estado dos demais, num ambiente em que o feedback é contínuo e repleto de interações. Essas características resultam num sistema onde o total é mais imprevisível e deslumbrante do que a mera soma de suas partes. Com isso, há um crescente número de estudos que utilizam métodos típicos de sistemas complexos para analisar políticas públicas de diversas áreas, como saúde pública, educação, segurança, recursos energéticos e outros. Além disso, essa forma diferente de abordagem permite que alguns modelos de políticas públicas sejam investigados com mais facilidade, incluindo políticas que sequer eram analisadas pelo prisma tradicional. Esta pesquisa teve dois objetivos principais: verificar como os sistemas complexos se aplicam às políticas públicas no campo teórico e apresentar uma aplicação prática de modelagem dentro do contexto de um estudo de caso. Como ainda não há um entendimento sistematizado sobre como sistemas complexos podem ser úteis em políticas públicas, este estudo apresenta, em sua primeira parte, uma revisão sistemática de literatura para uma melhor compreensão de como essas aplicações ocorrem e de quais benefícios essa ciência, de fato, pode trazer. Em decorrência desse estudo, pode-se afirmar que há consenso, na literatura, de que a teoria da complexidade é benéfica para formuladores de políticas e, consequentemente, para a população em geral. Tais benefícios são vistos de diversas formas pelos pesquisadores, como, por exemplo, a possibilidade de se testar políticas *a priori*, a possibilidade de se comparar diversos tipos de políticas para um mesmo problema e a obtenção de novas perspectivas e ideias para formulação de políticas. Apesar de haver diversas simulações e modelos propostos para políticas públicas em diversas áreas, não foi constatada uma demonstração empírica que comprove efetivamente o benefício de se aplicar sistemas complexos em políticas públicas, ou seja, aparentemente há obstáculos que impedem esses modelos terem efeitos nas políticas *de facto*. Dessa maneira, o objetivo da segunda parte da pesquisa foi o de construir um modelo baseado em agentes relacionado a uma política pública e cuja implementação prática fosse factível. Assim, foi selecionada uma política relacionada a um órgão público de fiscalização do exercício profissional (conselho de classe), especificamente na área da saúde, para a qual foram traçadas duas estratégias diferentes, com o objetivo de compará-las em termos de eficácia e de efetividade. Essas estratégias foram modeladas e simuladas em software específico de modelos baseados em agentes para análise dos resultados considerando diversos cenários possíveis. Os resultados indicam que os modelos baseados em agentes podem auxiliar o formulador de políticas a comparar diferentes estratégias de fiscalização e antecipar efeitos colaterais que dificilmente seriam constatados *ex ante* sem a utilização de simulações.

Palavras-chave: Modelo baseado em agentes. Saúde. Conselhos de fiscalização. Sistemas complexos. Efetividade de políticas públicas.

LIST OF ILLUSTRATIONS

LIST OF TABLES

TABLE OF CONTENTS

1 INTRODUCTION

Public policies have increasingly been recognized as complex systems due to its instability, its capacity of self-organization and the ability of its participating agents to learn and adapt their behavior (Furtado, Sakowski, Tóvolli, 2015). Some tools used in complexity science are being applied to understand consequences of policies in various areas, such as healthcare (Kaplan, Galea, 2014; Zhang *et al.*, 2014), education (Maroulis *et al.*, 2010), employment (Martin, Neugart, 2009), economics (Chernicoff *et al.*, 2014) and others. For instance, simulations can be useful in forecasting unintended consequences of policies that are difficult to be evaluated *ex ante* (Badham, 2014; Chen et al, 2012). In some cases, randomized trials are impracticable due to ethical concerns. Also, such trials are limited to few individuals due to cost and time constraints, whereas simulations are limited to computational power.

Despite the increasing number of studies where public policies are recognized as complex systems, there is still little empirical evidence on how complex systems tools can help policy makers in formulating better strategies, *i.e.*, the existing applications are merely theoretical, which may indicate that there are barriers preventing complex systems to reach practical relevance in public policy area (Zivkovic, 2015; Morçol, 2010).

In this sense, a research was carried out with two main objectives. The first was aimed at identifying how complex systems are being used in public policy research and whether there is empirical evidence of its potential benefits. The second objective was to demonstrate the use of a typical complex systems mechanism in a public policy. Because of the differences and the importance of each objective, this research is presented in two distinct parts.

Part one - A systematic literature review of studies applying complex systems theory to public policies

The first part of the research will present a systematic literature review that was carried out based on PRISMA protocol, in order to address the use of complex systems in public policy. A total of 35 studies were reviewed, and it was found a strong consensus favoring the use of complex systems applications for enhancing public policies. Also, some practical applications were found in the areas of public transport, education, healthcare and others. However, there were found no evidences of the use of complex systems in practical situations, *i.e.*, even though some researchers demonstrate the benefits of complex systems, they were not able to reach street-level bureaucrats and put their theoretical models into practice.

Part two - Effects of disclosing inspection scores of health facilities - an agent based model

On the second part of the research, an agent-based model, a typical complex system tool, was built based on the case study of a Brazilian professional regulatory body. Simulations were run in order to compare two different inspection strategies. The difference between them is that the inspection scores is disclosed to overall population in one strategy, whereas in the other they are not. The strategies are measured by their results on population's health, *i.e.*, does disclosure of inspection scores lead to any difference in policy effectiveness? This dependent variable would be difficult to be measured by traditional means of policy evaluation.

In this manner, the part two of the research helps to fill the gap found on the first part, since the model can be readily used by Brazilian professional regulatory bodies and help them making decisions concerning inspection strategies.

Even though changing the strategy did not result in better policy effectiveness, *i.e.*, disclosing inspection scores had no impact on health, the model can be useful in various ways: help public agencies save their scarce resources by avoiding fruitless strategies, gain insights on how agents behave in each scenario and also to gain insights for strategies that can have better outcomes.

In brief, this research is helpful in understanding how complex systems can be used by policymakers in both theoretical and practical situations, reason for which it is structured in two separated and independent articles. In the first part, theoretical evidences are presented to reinforce the advantages of complex systems approach, while the second part contributes in filling the empirical gap by presenting an off-the-shelf model for regulatory bodies and its corresponding results.

2 A SYSTEMATIC LITERATURE REVIEW OF STUDIES APPLYING COMPLEX SYSTEMS THEORY TO PUBLIC POLICIES[1]

ABSTRACT

A typical public policy environment is composed of self-organizing agents, nonlinear interactions, emergent behavior and a high level of unpredictability. These features are sufficient to define public policies as complex systems, a relatively new field of study that, despite its relevance, is unfamiliar to most of the policy makers and politicians. Even though there is an increasing number of both exploratory and applied research in this area, there is still little use of complex system tools in the process of policy formulation. Traditional methods often generate ill-designed policies, thus leading to catastrophic, unintended consequences. The purpose of this study is to verify whether complexity tools provide a more robust method for policy formulation and the current state of practical approaches of these tools for policymaking. This paper presents the results of a Systematic Literature Review (SLR) of 35 studies on the use of complexity methods and tools in public policy in a range of issues, which can provide useful insights to guide policy formulation. We used a predefined search strategy including multiple databases and a non-strict selection criteria. This study reveals that (a) there is a strong consensus supporting the use of complex system tools for modeling public policies; (b) there are several topics of public policies where complex systems tools have been tested, but mostly theoretical; (c) agent-based modeling is preferred over other complex systems techniques; (d) there are no negative results arising from the use of complex systems approach in public policies in literature, what implies a risk of bias and (e) despite the great deal of theoretical approaches, complex systems have not yet reached policymakers to be put into practice.

Keywords: complex systems, public policy, systematic literature review

---

[1] This article was published on the Journal on Policy and Complex Systems. Available at: http://dx.doi.org/10.18278/jpcs.3.1.6

2.1 INTRODUCTION

Frequently, public policies do not generate the expected results. In fact, despite the best intentions of a policymaker and the consensual nature of interactions between agents, public policies can beget totally opposite outcomes from the initial plans (Fischer, Miller, Sidney; 2007). In some cases, policy analysts detect the errors too late to reverse them. This sort of unintended consequences is notorious in various areas of public policy, such as: employment, healthcare, education and others. In some cases, these consequences could be predicted before policy implementation. In other cases, however, a policy designed for Region A can cause an unforeseen disaster in Region B. Chouvy (2013) distinguishes unintended consequences between direct and collateral. The first type occurs when the unintended consequence is a direct effect of an action, while a collateral consequence emerges when it is a result of an intended consequence of an action.

In fact, Chouvy (2013, p.9) argues that all public policies generate both direct and collateral unintended consequences, and these consequences, in almost all cases, are unmeasured (Reuter, 2009). Such level of unpredictability led to a consensus among researchers and specialists that the public policy process is a complex system (Kay, 2006), and traditional methods are no longer sufficient for estimating its effects, whether they are direct or collateral, beneficial or harmful.

The common properties of a complex system comprise complex collective behavior, signaling and information processing and adaptation (Mitchell, 2009), as detailed in Table 1. The combination of these properties gives rise to a dynamic, hard-to-predict and often chaotic behavior, thus consequences cannot be properly foreseen.

Table 1: Common properties of a complex system

Complex collective behavior	The agents that are potentially affected by a policy take their individual and particular decisions by following simple rules and no central control. One could argue that the government or the state acts as a central control, however, as it will be presented, agents do not always behave as expected by policymakers. In fact, it is the case that agents adapt and create unexpected outcomes in both the short and long terms. For example, when government raises taxes it expects to increase its revenues. But the number of unintended direct and collateral consequences that could arise therefrom is high. Agents could avoid taxes in legal and illegal ways. Firms could dismiss employees to reduce costs, they could leave the market or they could even go bankrupt. Despite the fact that the State is a ruler, it cannot force, or even predict, how the agents will behave precisely.
Signaling and information processing	Agents in a society are constantly being provided with a huge amount of information, and they use it to take and update their decisions all the time. The fact that agents can use the same information in a completely different manner brings even more complexity to the system. New information allows agents to think, learn and evolve.
Adaptation	Adaptation is a concept very well established in biology. By receiving new information, agents will change their behavior in order to reach the best possible outcomes. Environmental changes constantly place new challenges to agents. As they will react in many different ways, chances are some will adapt better than others. In biology, when a species does not adapt to the environment, it can cause extinction. However, in a public policy system, unadapted agents often remain in the system, *i.e.* they do not die or extinguish. This could imply that public policies hold a very high level of complexity.

Source: Felipe de Oliveira Simoyama, 2018.

Increasing complexity created the necessity for new tools, since traditional analyses no longer provided social sciences researchers with reasonable results. In fact, complex systems theory can be seen as a new way of observing the world around us and the social phenomena, and not merely a bunch of tools to improve processes and decision making.

In economics, there has been a long debate. Although economists from the Austrian school argued that statistics and mathematical methods could not provide reliable predictions in the area of social sciences (Mises, 1998), the use of complex systems tools can help detect unforeseen and unintended consequences, allowing policymakers for mitigating or avoiding harmful and perverse consequences of public policies, but it can also help detect unforeseen beneficial consequences in order to enhance its effects. Even Hayek (1945), a renowned Austrian economist, argued in favor of the use of complex systems in economics.

The scenario of the policy context is not much different. Despite the large number of studies reviewed for this paper, the use of complexity tools in public policies is limited and disperse. The so-called evidence-based policy movement, for example, does not consider complexity tools (*e.g.* computer simulations) as a type of evidence for policymaking, not even as a low-rank evidence (DFID, 2014; Nutley, Powelll & Davies, 2012).

However, at the minimum, these tools provide insights that could serve as a good and distinct sort of evidence, offering policymakers a different view, which could anticipate multiple possible scenarios beforehand.

Even though complex systems science is far from being a primary tool for policymakers, we have gathered some sophisticated practical applications of complexity tools in different areas of public policy, such as: public transport, education, healthcare, water and energy resources, employment, immigration, discrimination, climate change and economics, and various others.

In this paper, we have carried out this systematic literature review of studies on complex systems for public policies in both theoretical and experimental approaches. Our primary objective is to verify whether complex systems theory is beneficial in the field of public policies, and our secondary objectives include the analysis of what contexts of public policy has complex system theory been empirically tested, what tools have been used and what are the main results obtained so far.

2.2 METHODS

In this study, we carried out a systematic literature review instead of a narrative text. Such method allows for a more replicable and transparent process, since traditional literature reviews lack criteria for study selection, and thus transparency and replication are not possible. Here, we used a method adapted from Parris and Peachey (2013).

2.2.1 Elegibility

Our primary objectives are to answer how useful complex system tools are useful to the public policy process, and also to detect practical work in this field, identifying the main areas that are benefiting from such approach.

We did not intend to compare the results of policies formulated with traditional and complex system approaches, because there is not a significant number of studies describing the results of real-world policies formulated with the support of such tools. As secondary objectives, we include the formal comparison of traditional and complex system approaches and the reason why policymakers are not receptive to engaging in complex systems.

We searched studies within a 10-year period (2005-2015) on complex systems and public policies, with two different approaches:

1) those that describe the use of complex system theory in the public policy area.
2) those with the aim of solving a public policy issue with the use of complex system methods and tools.

Also, we used the following inclusion and exclusion criteria:

(a) Include only studies with full text available
(b) Include only studies in English language
(c) Include only studies with one of these components addressed in the abstract, results or discussion: (c.1) the implications of the intersection of public policies and complex systems, or (c.2) an application of complexity theory to the policy context (empirical evidence or simulation).

2.2.2 Search strategy

We have conducted this study based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Moher *et al.*, 2010) following all steps and guidelines. In order to identify papers on complex systems for public policies, we used the following search strategy:

1. Select the primary terms that fit the objectives of this study;
2. Select the secondary terms based divided in two categories: complexity tools and public policy topics;
3. Run iterated searches by doing minor changes in the terms, such as spelling and plurals;
4. Link one of the primary terms with one of the secondary terms using fundamental operators (and, or).

Table 2: The search strings used for this review

Search strategy (1 primary term + 1 secondary term)		
String	Primary terms	"Policy" OR "policies" OR "public policy" OR "public policies"
AND	Secondary terms - complexity tools	"Complex systems" OR "complexity theory" OR "agent-based modeling" OR "ABM" OR "system dynamics" OR "computer simulation" OR "cellular automata" OR "chaos" OR "fractals" OR "nonlinear systems" OR "genetic algorithms"
AND	Secondary terms - public policy topics	"Public transport" OR "traffic" OR "land use" OR "education" OR "healthcare" OR "water resources" OR "energy" OR "employment" OR "labor market" OR "immigration" OR "discrimination" OR "crime" OR "violence" OR "climate change" OR "economics"

Source: Felipe de Oliveira Simoyama, 2018.

We used the library system of the University of Sao Paulo (http://buscaintegrada.usp.br) and the Federal University of Sao Paulo (http://unifesp.summon.serialssolutions.com) to search for articles published in peer-reviewed journals within the period of 2005-2015.

These systems include results arising from the following databases: Art Full Text; EBSCOhost; ECCO - Eighteenth Century Collections Online; Faculty of 1.000 Biology; Hein Online; LSN - Legal Scholarship Network; Modern Language Association (MLA); International Bibliography; MOMW - The Making of the Modern World; Portal de Periódicos

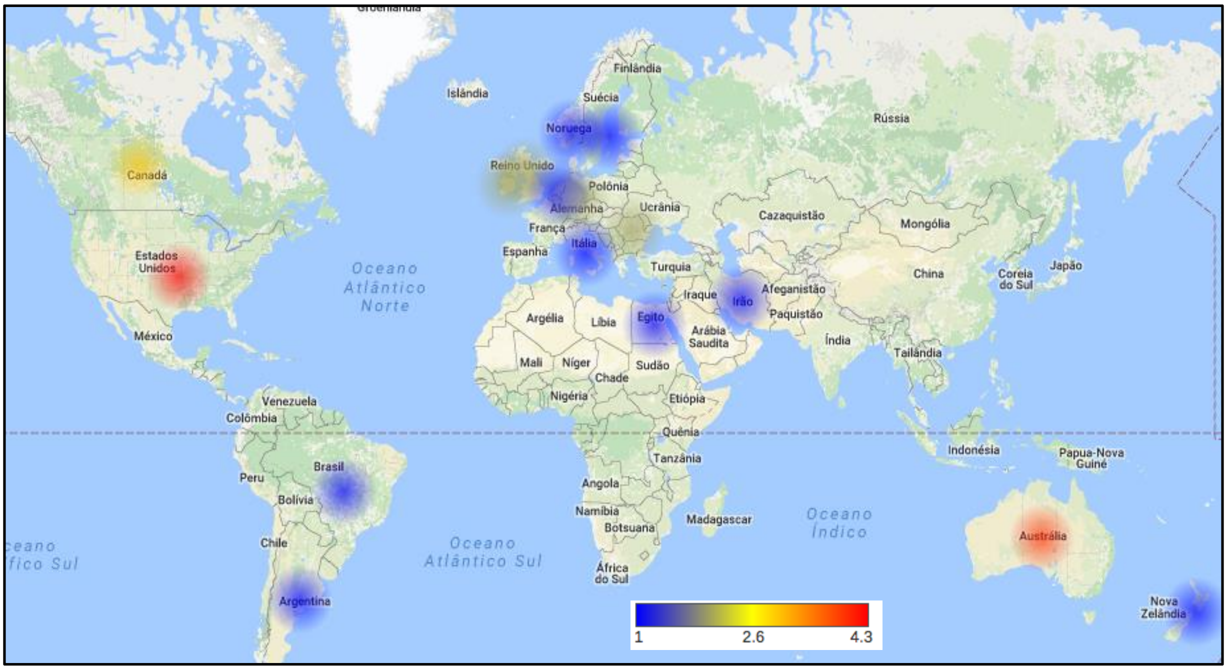
CAPES (Brazil); Scopus; Web of Science and USP internal database (theses, dissertations etc.). We also searched in the Journal on Policy and Complex Systems, which specializes in the applications of complex systems for public policies.

2.3 SEARCH RESULTS

This search strategy resulted in 182 studies. The number of duplicates was low (n=7), due to the fact that we used only 2 different databases (USP and UNIFESP). Next, we read the title, abstract and discussions of all these 175 papers, and then selected those that fit our research questions and the inclusion/exclusion criteria. Then, 133 studies were removed from the final step.

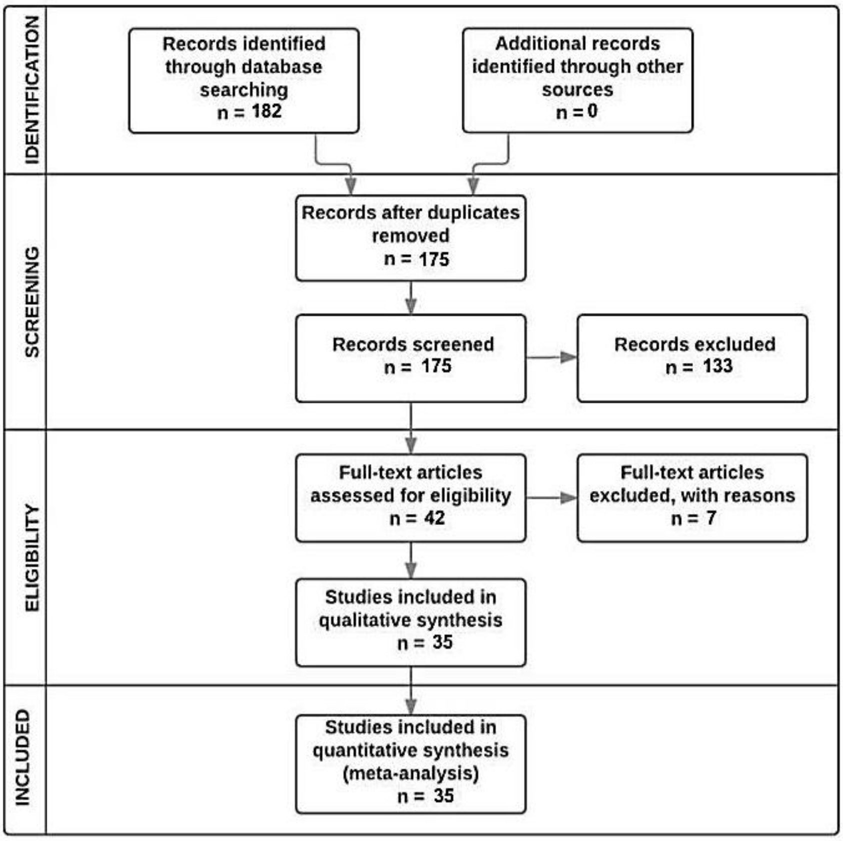
Finally, we did a careful reading of the final sample (n=42), of which 7 were excluded due to inadequacy to our research purposes, and thus reaching the final number of 35 studies, which came from a variety of journals (Table 3) and countries, as shown in Figure 1. Figure 2 represents the PRISMA flow diagram of such results.

Figure 1: Country of origin of the 35 studies



Source: Felipe de Oliveira Simoyama, 2018.

Figure 2: The PRISMA flow diagram



Source: Felipe de Oliveira Simoyama, 2018.

Table 3: Journals included in the SLR

Journal	**Number of studies**
American Journal of Public Health	5
BEPAM	1
Ciência e Saúde Coletiva	1
Comput Econ	1
E-CO	4
Ecol Modell	1
Emergence: Complexity and Organization	3
Environmental Management	1
Health Care Manage Sci	1
International Journal of Health Geographics	1
International Public Management Journal	1
Journal of Coastal Research	1
Journal of Simulation	1
Policy and Complex Systems	7
Policy Sci	1
Public Administration Quarterly	2
Science	1
Water Resource Manage	2
Total geral	**35**

Source: Felipe de Oliveira Simoyama, 2018.

Data Synthesis

We used a spreadsheet to synthesize the information from all the selected papers. Since there are two major objectives in this study, first we separated descriptive (conceptual) studies from applied studies. Here, we considered as “applied” the studies containing models, simulations or even empirical evidence from real-world policies. In both cases, we performed individual critical appraisals of each study, based on an assessment adapted from Mays and Pope (2000), and then we rated the studies as high (A) or low (B) quality, as shown in Table 4.

The assessment of each study is presented in Table 5. Finally, we structured the studies in concept-centric matrixes (Webster, Watson, 2002) and we decomposed the 2 original broad research questions into a topic-specific approach. This method enabled a more intelligible classification of the studies and allowed the researchers to focus on analyzing and discussing the data. Also, this spreadsheet was used to summarize and combine the results of the studies, and thus provided an overall picture of the current state of complex systems for public policies.

Table 4: Critical appraisal tool used in this SLR

Questions (No=0 / Yes=1)	● Relevance / worth of the study (0;1) ● Clarity of research question (0;1) ● Appropriateness of method (0;1) ● Context description (0;1) ● Sampling (0;1) ● Data collection and analysis (0;1) ● Reflexivity by the author (0;1)
Classification	● High quality >= 4 points ● Low quality < 4 points

Source: Felipe de Oliveira Simoyama, 2018.

Table 5: Results from the critical appraisal

Reference	Type of study	Relevance	Clarity	Appropriateness of method	Context description	Sampling	Data collection and analysis	Reflexivity by the author	Total
Thieler et al (2000)	Applied	●	●	●	●	●	●	●	●●●●●●●
Bankes (2005)	Descriptive		●		●				●●
Anderson, Chaturvedi, Cibulskis (2007)	Applied	●	●	●	●	●	●	●	●●●●●●●
Ferrante et al (2007)	Applied	●	●	●	●	●	●	●	●●●●●●●
Meek, De Ladurantey, Newell (2007)	Descriptive	●	●	●	●			●	●●●●●
Rhodes, Murray (2007)	Descriptive	●	●	●	●	●	●	●	●●●●●●●
Mischen, Jackson (2008)	Descriptive	●	●	●	●	●	●		●●●●●●
Mischen, Jackson (2008)	Descriptive	●	●	●	●			●	●●●●●
Cockerill, Daniel, Malczynski, Tidwell (2009)	Descriptive	●	●	●	●	●	●	●	●●●●●●●
Martin, Neugart (2009)	Applied	●	●	●	●	●	●	●	●●●●●●●
Winz, Brierley, Trowsdale (2009)	Applied	●	●	●	●		●	●	●●●●●●
Maroulies et al (2010)	Descriptive		●	●	●			●	●●●●
Morçol (2010)	Descriptive	●	●		●			●	●●●●
Scott Jr. (2010)	Descriptive	●	●	●	●	●	●	●	●●●●●●●
Young, Borland, Coghill (2010)	Applied	●	●	●	●	●	●	●	●●●●●●●
Chen et al (2012)	Applied	●	●	●	●	●	●	●	●●●●●●●
Dearing, Dawson, Puppy (2012)	Descriptive			●	●	●	●		●●●●
MacGillivray, Gallagher (2012)	Descriptive	●	●	●	●			●	●●●●●
Morçol (2012)	Descriptive	●	●	●	●			●	●●●●●
Pinheiro Filho, Sarti (2012)	Descriptive	●	●	●	●			●	●●●●●
Akhbari, Grigg (2013)	Applied	●	●	●	●			●	●●●●●
Badlant et al (2013)	Applied	●	●	●	●			●	●●●●●

(continues)

(continuation)

Reference	Type of study	Relevance	Clarity	Appropriateness of method	Context description	Sampling	Data collection and analysis	Reflexivity by the author	Total
Badham (2014)	Descriptive	●	●		●			●	●●●●
Chernicoff et al (2014)	Applied	●	●	●	●	●	●	●	●●●●●●●
Dombkins (2014)	Descriptive	●	●	●	●				●●●●
Ghorbani et al (2014)	Descriptive	●	●	●	●			●	●●●●●
Inguaggiato, Occelli (2014)	Applied	●	●	●	●	●	●	●	●●●●●●●
Johnston, Matteson, Finegood (2014)	Descriptive	●	●	●	●	●		●	●●●●●●
Kaplan, Galea (2014)	Applied	●	●	●				●	●●●●
McPhee-Knowles (2014)	Applied	●	●	●	●	●	●	●	●●●●●●●
Osman, Nikbakht (2014)	Applied	●	●	●	●	●	●	●	●●●●●●●
Zhang et al (2014)	Applied	●	●	●	●	●	●	●	●●●●●●●
Lyons, Duggan (2015)	Applied	●	●	●	●	●	●	●	●●●●●●●
McClure et al (2015)	Applied	●	●	●	●	●	●	●	●●●●●●●
Zivkovic (2015)	Descriptive		●	●	●				●●●

Source: Felipe de Oliveira Simoyama, 2018.

2.4 FINDINGS

In general, the select studies show how positive can be the connection between public policies and complexity theory. After reading the 35 studies, we did not find significant criticism of the use of complex systems applied to the public policy area. In fact, we found only 1 study (2.86%) in which the author argues that "models are an oversimplification of reality" (Thieler et al, 2000), in a criticism of the models used to predict beach behavior in the United States. In all the other 34 studies (97.14%), the authors argue explicitly in favor complexity theory for public policies. Besides from Thieler *et al.* (2000), other 4 studies present issues in the application of complexity theory to the public policy arena, as shown in Table 6. However, these 4 studies are mostly focused on the benefits of complex systems tools.

Table 6: Main issues in the the application of complexity theory to public policies

Reference	**Main issues**
Ghorbani et al (2014)	Agent-based modeling (ABM) requires enhancement.
Morçol (2010)	Complexity theorists need to incorporate what is already known in public policy. Also, there is not a distinct alternative, as complex adaptive systems (CAS) overlaps with some theories that already exist.
Thieler et al (2000)	Some models are an oversimplification of complex systems that are poorly understood.
Zivkovic (2015)	Complex system approach is difficult to public administrators.
Winz, Brierley, Trowsdale (2009)	It does not provide exact solutions. Also, the likelihood that two individuals will develop the same system dynamics model is small.

Source: Felipe de Oliveira Simoyama, 2018.

To answer our primary research objective, *i.e.*, "Is complexity theory beneficial to public policies?", we divided our answer 7 different topics, since the authors of the 34 "positive" studies provided different rationale to argue in favor of complex systems. Then, we sum the number of authors in favor of each topic and classified such conclusions as a strong (1) or weak (0) evidence. If three or more studies of high quality, as classified in Table 5, supported a given topic, then we assigned 1. In contrast, we assigned 0 to the remaining topics. The results of each topic are presented in Table 7.

Table 7: The benefits of complexity theory to public policies

Topic	**Statement**	**Evidence**	**Reference**
Data aggregation	Do complex systems help to demonstrate how individual decisions relate to group level results?	Strong evidence in favor of statement (1)	Maroulies et al (2010) (A); Ghorbani et al (2014) (A); McPhee-Knowles (2014) (A); Zhang et al (2014) (A); McClure et al (2015) (A); Anderson, Chaturvedi, Cibulskis (2007) (A).
Identification of problems	Do complex systems help to identify problems of public policies in advance?	Strong evidence in favor of statement (1)	Badham (2014) (A); Chen et al (2012) (A); Cockerill, Daniel, Malczynski, Tidwell (2009) (A).
New insights	Do complex systems help to gain new insights of public policies?	Strong evidence in favor of statement (1)	Kaplan, Galea (2014) (A); Chernicoff et al (2014) (A); Dearing, Dawson, Puppy (2012) (A); Scott Jr. (2010) (A); Chen et al (2012) (A).
Government relationships	Do complex systems help to realign government relationships?	Weak evidence in favor of statement (1)	Inguaggiato, Occelli (2014) (A).
Nonlinear systems	Do complex systems help to analyze nonlinear systems of public policies?	Strong evidence in favor of statement (1)	Pinheiro Filho, Sarti (2012) (A); Morçol (2010) (A); Morçol (2012) (A); Lyons, Duggan (2015) (A); Cockerill, Daniel, Malczynski, Tidwell (2009) (A); Rhodes, Murray (2007) (A).
Testing of policies	Do complex systems help to test policies *a priori*?	Strong evidence in favor of statement (1)	Ferrante et al (2007) (A); Badlant et al (2013) (A); Akhbari, Grigg (2013) (A); Anderson, Chaturvedi, Cibulskis (2007) (A).
Complex problems require complex system	Do complex problems, such as public policies, require complex systems?	Strong evidence in favor of statement (1)	Dombkins (2014) (A); Zivkovic (2015) (B); Johnston, Matteson, Finegood (2014) (A); Winz, Brierley, Trowsdale (2009) (A); Lyons, Duggan (2015) (A); Osman, Nikbakht (2014) (A); Meek, De Ladurantey, Newell (2007) (A); Mischen, Jackson (2008) (A); Mischen, Jackson (2008) (A); MacGillivray, Gallagher (2012) (A); Martin, Neugart (2009) (A)

Source: Felipe de Oliveira Simoyama, 2018.

How do public policies benefit from complexity?

There is a strong evidence in favor of the application of complexity theory to public policies. However, the reasons vary. Since complex collective behavior and interactions among heterogeneous agents are in the core of public policy implementation, policymakers are unable to foresee all the consequences of their actions, and thus some tools used by complexity researchers comes handy.

In some sense, some of the topics presented in Table 7 could be assembled, but it is important to note how the authors approach the coming of such theories and tools. For example, 6 different authors argue that complex system tools, specially agent-based modeling (ABM), can help to aggregate data from the individual level (agents) and then relate such data to the outcomes from the group level (Maroulies et al (2010); Ghorbani et al (2014); McPhee-Knowles (2014); Zhang et al (2014); McClure et al (2015); Anderson, Chaturvedi, Cibulskis (2007)). In their turn, Badham (2014); Chen et al (2012); and Cockerill, Daniel, Malczynski, Tidwell (2009), argue that complex systems can help to identify problems of public policies in advance.

In a slightly different perspective, there are those authors that recommend the use of some tools to gain insights (Kaplan, Galea (2014); Chernicoff et al (2014); Dearing, Dawson, Puppy (2012); Scott Jr. (2010); Chen et al (2012)) and those that recommend such tools to simulate and test policies *a priori* (Ferrante et al (2007); Badlant et al (2013); Akhbari, Grigg (2013); Anderson, Chaturvedi, Cibulskis (2007)), mainly comprised of ABM, system dynamics and simulations. Pinheiro Filho & Sarti (2012); Morçol (2010, 2012); Lyons & Duggan (2015); Cockerill, Daniel, Malczynski & Tidwell (2009); and Rhodes & Murray (2007) argue that complexity theory can help in the analysis of nonlinear systems, which is the case of public policies.

What are the issues in approaching public policies with complexity lenses?

Modeling is an important aspect of complex systems. In this way, criticism of modeling and simulation techniques are also applied to complexity theory. Thieler *et al.* (2000) argues against models that are merely an oversimplification of reality, and then recommends different approaches that, in his view, are better than usual modeling.

Also, Morçol (2010) reasons that complex system researchers need to incorporate what is known in public policy. Other critics are made by Ghorbani *et al.* (2014) and Zivkovic (2015), however, the most strong evidence comes from Winz, Brierley, Trowsdale (2009), who say that models do not provide exact solutions, and that it would be almost impossible for two researchers to build similar models. However, they argue that the use of system dynamics can help in the comparison of different policies *a priori*.

In what contexts was complexity theory explored in public policies?

Even though complexity theory can be applied in a variety of policy areas, we have found the predominance of studies on healthcare policies (Table 8), considering only those applied in a specific area.

There are 13 studies (28.89%) that are not topic-specific, *i.e.*, they rather focus on the use of complexity applied to public policies generically, or on the use of specific tools of complex systems. It should be noted that there are 2 studies that focus on two topics each: Pinheiro Filho, Sarti (2012) (economy; healthcare) and McClure et al (2015) (land use; healthcare).

Table 8: Covered topics in the included studies

Covered topics	Number of studies
Economy	1
Economy; Healthcare	1
Education	1
Employment	1
General	13
Healthcare	8
Hydrology	3
Land use	1
Land use; Healthcare	1
Models	1
Urban issues	4
Total	**35**

Source: Felipe de Oliveira Simoyama, 2018.

What are the main complex system tools recommended for policymakers?

To answer this question, we used two different approaches. First, we analysed only the tools used in the 17 applied studies, *i.e.*, those that present an empirical evidence, a model or a simulation (Table 9). Second, we read the 18 conceptual studies and analyzed whether there was a recommendation of a complex system tool (Table 10). In this sense, we can see a predominance of agent-based modeling (ABM) in both Tables 9 and 10. Considering only the applied studies, ABM represents 47.06% of the total. System dynamics were used in 23.53% of the studies.

When it comes to the conceptual studies, 11 out of 18 recommended one or more tools for the use in public policies. Of these 11, ABM was cited in 8 (72.7%) studies. There can be many reasons that makes ABM so predominant. For instance, Kaplan & Galea (2014) cite one of the advantages of ABM over other techniques: that the modeler needs to specify anticipated relations, leading to a higher level of transparency and documentation.

Also, Badland et al (2013), say that ABM helps to examine systems of autonomous individual agents that, programmed with simple rules, enables the researchers to analyze the system as a whole, in a bottom-up approach.

Table 9: List of applied studies and tools used

Reference	**Covered topics**	**Tools used**
Inguaggiato, Occelli (2014)	General	Social network analysis
Kaplan, Galea (2014)	Healthcare	ABM
McPhee-Knowles (2014)	Healthcare	ABM
Chernicoff et al (2014)	Economy	System dynamics
Zhang et al (2014)	Healthcare	ABM
McClure et al (2015)	Land use; Healthcare	System dynamics
Ferrante et al (2007)	Healthcare	Simulation
Young, Borland, Coghill (2010)	Healthcare	Actor network
Thieler et al (2000)	Land use	Mathematical modeling
Badland et al (2013)	Urban issues	ABM
Chen et al (2012)	General	ABM
Winz, Brierley, Trowsdale (2009)	Hydrology	System Dynamics
Akhbari, Grigg (2013)	Hydrology	ABM
Lyons, Duggan (2015)	Healthcare	System Dynamics
Osman, Nikbakht (2014)	Urban issues	Game theory
Anderson, Chaturvedi, Cibulskis (2007)	Healthcare	ABM
Martin, Neugart (2009)	Employment	ABM

Source: Felipe de Oliveira Simoyama, 2018.

Table 10: List of conceptual studies and recommended tools

Reference	**Recommendation of tool**
Maroulies et al (2010)	ABM
Dombkins (2014)	Systems thinking; Multiple views; Technical Enterprise Readiness Index; ABM; WAVE Modeling
Ghorbani et al (2014)	ABM
Badham (2014)	Concept mapping, soft systems, flowcharts, causal loop diagrams, social network analysis, games, state transition, microsimulation, system dynamics, discrete event simulation, ABM
Pinheiro Filho, Sarti (2012)	ABM, Cellular automata
Morçol (2010)	ABM
Bankes (2005)	No
Dearing, Dawson, Puppy (2012)	ABM, Cellular automata
Scott Jr. (2010)	No
Morçol (2012)	ABM
Zivkovic (2015)	New tool
Johnston, Matteson, Finegood (2014)	Systems science
Cockerill, Daniel, Malczynski, Tidwell (2009)	System dynamics. Collaborative modeling
Meek, De Ladurantey, Newell (2007)	No
Mischen, Jackson (2008)	No
Mischen, Jackson (2008)	No
MacGillivray, Gallagher (2012)	No
Rhodes, Murray (2007)	No

Source: Felipe de Oliveira Simoyama, 2018.

2.5 LIMITATIONS

In this study, we tried to compile studies relating complex systems to public policies in the most systematic manner possible. However, the available studies vary significantly, which certainly makes assessments and classifications more difficult. In order to reach our objectives, we needed to combine different assessment tools for systematic literature review, coming close to the creation of a new method of SLR.

Another important issue is that some studies from the grey literature, or not published in peer-reviewed journals, were excluded, amounting to 20 studies. Other 13 studies were excluded due to date of publication (before 2005). In this manner, some important aspects of the relation between complex systems and public policies could have been lost due to these reasons.

Also, our search strategy was limited to published materials written in English language. For example, a search in the library system of the University of Sao Paulo (buscaintegrada.usp.br) for the terms "*des systèmes complexes*" AND "*politiques*" (French) resulted in 6 more articles, while a search for "sistemas complejos" AND "políticas" (Spanish) resulted in 21 articles in the same library system.

Finally, it is important to note that the quality assessment of individual studies, as presented in Table 4, was carried out by the researcher, but some aspects of the methods were subjective, *i.e.*, a different researcher could come to a different conclusion using the same methods.

2.6 CONCLUSION

This SLR is the first synthesis of studies exploring the use of complex systems in public policies. Also, this study enabled the use of a hybrid method for assessing studies in a SLR, specially for social sciences, where studies on the same topic can be very distinct. This SLR shows that there is a strong evidence in favor of the application of complexity theory to the public policy area. For instance, all of the descriptive studies (100%) argued in favor of such use, whereas only 1 of the applied studies presented an explicit criticism, but not directly related to the purpose of this study, but rather related to the use of models in general. Also, it seems that researchers from different parts of the world are concerned with the current methods in public policies, since the studies included in this review are from 13 different countries on 5 continents.

However, there seems to be a distance separating research from practice, *i.e.*, even though we have found some applied research in the area, none of them presented a case-report of an application where complexity theory helped policy formulation and/or implementation. Even though Zivkovic (2015) argued that complexity theory is difficult to public administrators, this bridge needs to be given priority, because, as we have seen, there is a very strong consensus that there are many benefits in such application.

In our analysis of the applied studies, we found a major concern in the areas of healthcare and even more to discuss the policy process itself. One manner of “building the bridge” between researchers and policymakers is to help solving real-world problems and thus arouse in them more interest in complex systems. A policymaker might not be interested in how to formulate a policy (the process), but rather on how to solve the problem he needs to solve. In this sense, more applied studies on the areas of education, employment and urban issues are needed. Also, from the applied studies, we can observe that ABM is certainly the preferred tool used by researchers. Public policies is an area where decentralization is important, and this may lead to the success of ABM.

The excitement around complexity theory also brings concerns. Complex systems is a relatively new area in science. Despite the increasing number of researchers in many areas, such as public policies, economics and physics, the applied studies are conducted by complex system researchers, who may be biased towards their own field of research, called “Myside

Bias” (Stanovich, West, Toplak, 2013; Baron, 1995). Other types of bias that can be directly related to complex systems are the “Optimism Bias” (Weinstein, 1980), the “pro-innovation bias” (Rogers, Shoemaker, 1971), “system justification” (Jost, Banaji, 2004) and “self-serving bias” (Miller, Ross, 1975), since most of the studies included in this review were carried out by complex system researchers, and not policymakers, that could have a more critical view of this approach.

At the outcome level, the complex systems approach for public policies is in its early stages and there is no debate between conventional and complex systems. Unlike medicine and related sciences, the number of SLRs in social sciences is low, as well as the number of randomized controlled trials (PARRIS, PEACHEY; 2012), what led us to include a high number of descriptive studies combined with the applied ones.

There are many opportunities for future studies. For instance, we did not find studies to measure the level of complexity of public policies' environment, which could be done through the quantity of information of a given situation or by the entropy increase of a system. Also, as already mentioned, there are few real-world applications of complex systems to public policies. In this manner, good models and simulations are as important as the ability to pass on the information until it reaches policymakers, who in fact have the power to implement them and make them useful.

2.7 FUNDING

The research did not receive any fundings.

2.8 REFERENCES

STUDIES INCLUDED IN SYSTEMATIC REVIEW

Akhbari, M., & Grigg, N. S. (2013). *A framework for an agent-based model to manage water resources conflicts*. Water resources management, 27(11), 4039-4052.

Anderson, J., Chaturvedi, A., & Cibulskis, M. (2007). *Simulation tools for developing policies for complex systems: Modeling the health and safety of refugee communities.* Health care management science, 10(4), 331-339.

Badham, Jennifer. (2014). Functionality, Accuracy, and Feasibility: *Talking with Modelers*. Policy and complex systems. Volume 1, Number 2.

Badland, H., White, M., MacAulay, G., Eagleson, S., Mavoa, S., Pettit, C., & Giles-Corti, B. (2013). *Using simple agent-based modeling to inform and enhance neighborhood walkability.* International journal of health geographics, 12(1), 1.

Bankes, S. C. (2005). *Robust policy analysis for complex open systems.* Emergence: Complexity & Organization, 7(1), 2-10.

Chen, X., Lupi, F., An, L., Sheely, R., Vina, A., & Liu, J. (2012). *Agent-based modeling of the effects of social norms on enrollment in payments for ecosystem services.* Ecological modelling, 229, 16-24.

Chernicoff, William; Naumov, Sergey; Shahryar, Sarkani; Holzer, Thomas. (2014). *Modeling Market Dynamics in a Super Octane Ethanol Fuel Blend-Vehicle Powertrain System: Understanding the role of consumer perception in ethanol market growth.* Policy and complex systems. Volume 1, Number 2.

Cockerill, K., Daniel, L., Malczynski, L., & Tidwell, V. (2009). *A fresh look at a policy sciences methodology: collaborative modeling for more effective policy.* Policy Sciences, 42(3), 211-225.

Dearing, J. A., Bullock, S., Costanza, R., Dawson, T. P., Edwards, M. E., Poppy, G. M., & Smith, G. M. (2012). *Navigating the perfect storm: research strategies for socialecological systems in a rapidly evolving world.* Environmental Management, 49(4), 767-775.

Dombkins, D. H. (2013). *Realizing Complex Policy: Using a Systems-of-Systems Approach to Develop and Implement Policy*. Editor's Introduction, 2(5), 22.

Emison, G. A. (2008). *Complex adaptive systems and unconventional progress for the national air quality management system.* Public Administration Quarterly, 393-414.

Ferrante, D., Levy, D., Peruga, A., Compton, C., & Romano, E. (2007). *The role of public policies in reducing smoking prevalence and deaths: the Argentina Tobacco Policy Simulation Model.* Revista Panamericana de Salud Pública, 21(1), 37-49.

Ghorbani, A., Dechesne, F., Dignum, V., & Jonker, C. (2014). *Enhancing ABM into an inevitable tool for policy analysis.* J Policy Complex Syst, 1(1), 60-76.

Inguaggiato, Claudio, Occelli, Sylvie. (2014). *Policymaking in an Information Wired Environment: Realigning Government and Governance Relationships by Complexity Thinking.* Policy and Complex Systems. Volume 1, Issue 1.

Johnston, L. M., Matteson, C. L., & Finegood, D. T. (2014). *Systems science and obesity policy: a novel framework for analyzing and rethinking population-level planning.* American journal of public health, 104(7), 1270-1278.

Kaplan, George A. Galea, Sandro. (2014). *Bridging complexity science and the social determinants health.* Policy and Complex Systems. Volume 1, Number 2.

Lyons, G. J., & Duggan, J. (2015). *System dynamics modelling to support policy analysis for sustainable health care.* Journal of Simulation, 9(2), 129-139.

MacGillivray, A. E., & Gallagher, K. G. (2012). *A Policy Paradox: Social Complexity Emergence Around An Ordered Science Attractor.* Emergence: Complexity and Organization, 14(4), 67.

Maroulis, S., Guimera, R., Petry, H., Stringer, M. J., Gomez, L. M., Amaral, L. A. N., & Wilensky, U. (2010). *Complex systems view of educational policy research.* Science, 330(6000), 38-39.

Martin, C. W., & Neugart, M. (2009). *Shocks and endogenous institutions: an agent-based model of labor market performance in turbulent times.* Computational Economics, 33(1), 31-46.

McClure, R. J., Adriazola-Steil, C., Mulvihill, C., Fitzharris, M., Salmon, P., Bonnington, C. P., & Stevenson, M. (2015). *Simulating the Dynamic Effect of Land Use and Transport Policies on the Health of Populations.* American journal of public health, 105(S2), S223-S229.

McPhee-Knowles, Sara. (2014). *What's On the Menu: Assessing Manufactured Risk in Restaurant Inspection Systems Using Agent-Based Models.* Policy and Complex systems. Volume 1, Number 2.

Meek, J. W., De Ladurantey, J., & Newell, W. H. (2007). *Complex systems, governance and policy administration consequences.* Emergence: Complexity and Organization, 9(1/2), 24.

Mischen, P. A., & Jackson, S. K. (2008). *Connecting the dots: Applying complexity theory, knowledge management and social network analysis to policy implementation.* Public Administration Quarterly, 314-338.

Morçöl, G. (2010). *Issues in reconceptualizing public policy from the perspective of complexity theory.* Emergence: Complexity and Organization, 12(1), 52.

Morçöl, G. (2012). *Urban Sprawl And Public Policy: A Complexity Theory Perspective.* Emergence: Complexity and Organization, 14(4), 1.

Osman, H., & Nikbakht, M. (2014). *A game-theoretic model for roadway performance management: A socio-technical approach.* Built Environment Project and Asset Management, 4(1), 40-54.

Pinheiro Filho, F. P., & Sarti, F. M. (2012). *Falhas de mercado e redes em políticas públicas: desafios e possibilidades ao Sistema Único de Saúde*. Ciência and Saúde Coletiva, 17(11), 2981-2990.

Rhodes, M. L., & Murray, J. (2007). *Collaborative decision making in urban regeneration: A complex adaptive systems perspective.* International Public Management Journal, 10(1), 79-101.

Scott Jr, R. J. (2010). *The science of muddling through revisited.* Emergence: Complexity and Organization, 12(1), 5.

Thieler, E. R., Pilkey Jr, O. H., Young, R. S., Bush, D. M., & Chai, F. (2000). *The use of mathematical models to predict beach behavior for US coastal engineering: a critical review.* Journal of Coastal Research, 48-70.

Winz, I., Brierley, G., & Trowsdale, S. (2009). *The use of system dynamics simulation in water resources management.* Water resources management, 23(7), 1301-1323.

Young, D., Borland, R., & Coghill, K. (2010). *An actor-network theory analysis of policy innovation for smoke-free places: understanding change in complex systems.* American Journal of Public Health, 100(7), 1208-1217.

Zhang, D., Giabbanelli, P. J., Arah, O. A., & Zimmerman, F. J. (2014). *Impact of different policies on unhealthy dietary behaviors in an urban adult population: an agent-based simulation model.* American journal of public health, 104(7), 1217-1222.

Zivkovic, S. (2015). *A complexity based diagnostic tool for tackling wicked problems.* Emergence: Complexity & Organization, 17(4).

OTHER STUDIES

Baron, Jonathan. (1995). *Myside bias in thinking about abortion.* Thinking and Reasoning, 1, 221–235.

Chouvy, Pierre-Arnaud. (2013). *A Typology of the Unintended Consequences of Drug Crop Reduction.* Journal of Drug Issues, SAGE Publications.

DFID - Department For International Development. (2014). *Assessing the Strength of Evidence.* Retrieved from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/291982/HTN-strength-evidence-march2014.pdf

Fischer, F., Miller, G.J., & Sidney, M.S. (2007). *Handbook of Policy Analysis: Theory, Politics and Methods.* Boca Raton, FL: CRC Press.

Hayek, F.A. (1945). *The Use of Knowledge in Society.* Menlo Park, CA: Institute for Humane Studies. Print.

Kay, Adrian. (2006). *The Dynamics of Public Policy: Theory and Evidence.* Cheltenham: Edward Elgar Publishing

Mays, N., & Pope, C. (2000). *Assessing quality in qualitative research.* British medical journal, 320(7226), 50.

Mises, L.V. (1998). *Human Action: a Treatise on Economics.* Scholar's Edition. Ludwig Von Mises Institute.

Mitchell, Melanie. (2009). *Complexity: A guided tour*. Oxford, UK: Oxford University Press.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group. (2010). *Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement.* International journal of surgery, 8(5), 336-341.

Nutley, S.M., Powell, A., Davies, H.T.O., 2012. *What Counts as Good Evidence?* Retrieved from: http://www.nesta.org.uk/library/documents/A4UEprovocationpaper2.pdf.

Parris, D. L., & Peachey, J. W. (2013). *A systematic literature review of servant leadership theory in organizational contexts.* Journal of business ethics, 113(3), 377-393.

Reuter, Peter. (2009). *The unintended consequences of drug policies.* A Report on Global Illicit Drug Markets 1998-2007.

Rogers E M & Shoemaker F F. (1971). *Communication of Innovations: a cross-cultural approach.* New York: Free Press. 476 p.

Stanovich, Keith E., Richard F. West, and Maggie E. Toplak. (2013). *Myside bias, rational thinking, and intelligence.* Current Directions in Psychological Science 22.4.

Webster, J. and Watson, R.T. (2002). *Analyzing the Past to Prepare For the Future: Writing a Literature Review.* MIS Quarterly, 26 (2), xiii-xxiii.

3 EFFECTS OF DISCLOSING INSPECTION SCORES OF HEALTH FACILITIES - AN AGENT BASED MODEL

ABSTRACT

In most countries, health services are highly regulated and go through in-depth inspections by government officials, whose aim is to protect patients from malpractice or unethical professionals. In Brazil, inspection of regulated professions costs an amount of 3.3 billion of Reais every year, including professions out of the health area, and are financed by taxes paid by the professionals themselves. Despite such significant cost, little attention has been given to the quality of this public expenditure. There are no studies regarding the impact of these inspections on the health of the population, which is certainly difficult to unveil. In the Brazilian case, each professional regulatory body can adopt its own strategy of inspection, making it even more challenging to account for the effectiveness of regulation and bodies in charge of inspections. Since public policies are influenced by a variety of factors and different patterns can emerge from the bottom-up, such strategies can be analyzed through a complex systems approach. In this study, an agent-based model developed in Netlogo is presented, with the objective of observing the phenomena resulting from these interactions. Two variations of the model were designed: one of which representing an approach from an actual regulatory body and the second includes the disclosure of inspection scores to consumers. The agent-based model simulations indicate that transparent inspection scores had no significant impact either on patients' health or on the level of compliance by clinics. Conclusions are drawn in the light of public policy effectiveness.

Keywords: agent-based modeling; inspection scores; health facilities

3.1 INTRODUCTION

In Brazil, the healthcare sector is composed of 19 professional categories, such as physicians, nurses, physiotherapists, nutritionists and others. 13 of these categories are highly regulated and continuously inspected by their respective regulatory bodies, which are created by law as independent governmental agencies. Such agencies are composed of a superior (federal) board and their respective regional boards, which represent States or Regions. Altogether there are 27 federal boards which are decentralized in 535 regional offices. As of 2013, these agencies collected tax revenues that amounted to 3.3 billion of Reais (TCU, 2016). Most of these revenues are comprised of mandatory annual fees that are updated according to monetary inflation, as defined by Federal Law no. 12.514. In order to reflect the magnitude of these values, the total revenues of these boards reached 2.92% of the total governmental tax revenues in 2013, which amounted to 1.13 trillion of Reais (G1, 2014).

These amounts are significant to the Brazilian economy by all means. However, such revenues are not part of the national budget, *i.e.*, these boards do not obtain from or transfer funds to the government, what gives them more autonomy in budgetary terms. However, such bodies cannot be considered as private companies - they must follow the same rules of any public body. For example, bids must be made for almost all purchases and personnel are recruited mainly through competitive open exams. Such a paradigm turns professional regulatory bodies into *sui generis* autarchies, since they have budgetary autonomy, but with the same restrictions applied to any governmental agency.

Due to this trait, the public administration debates often disregard the professional regulatory bodies. For instance, there are no studies on the quality of public spending made by these Brazilian agencies. Such topic has already been broadly researched in the areas of healthcare (Andrade *et al.*, 2017; Borges *et al.*, 2014), education (Brunet, Bertê, Borges, 2009; Diaz, 2012) and others (Coelho, Campos, 2015; Leão *et al.*, 2015), but never reached the areas of professional regulation or professional supervision. When looking at the quality of public spending according to professional regulatory bodies in Brazil, through internet search engines, only one study was found, as shown in Table 11, which is a term paper, where the author (student) interviewed some professionals to inquiry about a new method of inspection. The objective of the present study, however, is not to analyze the impact of inspections on the professionals, but the effects of the inspections on the general public (patients) whom the regulatory bodies should protect.

Table 11: Literature search on quality of public spending in Brazilian regulatory bodies (August 23, 2017)

Keyword	**And**	**References found**
“Qualidade do gasto público”	“Conselho” OU “Conselhos”	0
“Eficiência” OU “Eficácia”	“Conselho de Fiscalização” OU “Conselhos de Fiscalização”	1(*)

Source: Felipe de Oliveira Simoyama, 2018.
(*) Marcos, 2017. Research on a new method of electronic inspections implemented by the Accountancy Regulatory Body of the State of Santa Catarina.

Even though the professional regulatory bodies have some degree of autonomy, their main activity is to inspect the professionals under their jurisdiction - so it is expected that a significant ratio of their revenues should be invested in inspection services (*e.g.*, inspection personnel, vehicles, etc.). However, there is a lack of studies concerning the inspection methods used by the regulatory bodies, or in the case of health professionals, its impact in the public health. In Brazil, these bodies are responsible for the inspection of more than 4 million professionals (Table 12).

Table 12: Number of registered professionals in Brazil according to each category as of 2018

Category	**Registered professionals**	**Source**
Biomedicina	54.700	CFBM
Educação Física	170.000	CONEF*
Enfermagem	1.997.814	COFEN
Farmácia	195.022	CFF
Fisioterapia	243.644	COFFITO
Fonoaudiologia	41.718	CFFA
Medicina	443.369	CFM
Medicina Veterinária	142.900	CFMV
Nutrição	140.038	CFN
Odontologia	280.306	CFO
Psicologia	299.962	CFP
Radiologia	107.094	CONTER
Terapia Ocupacional	18.852	COFFITO
Total	**4.135.419**	

Source: Felipe de Oliveira Simoyama, 2018.
*Estimates based on CONFEF revenues and the annual fee per professional.

3.2 OBJECTIVES

Even though there are studies on the efficiency of other government inspection services in Brazil (sanitary inspection, internal revenue services, labor audits etc.), the topic is only superficially approached. In addition, there are studies concerning the regulatory bodies, but in most cases they discuss just legal issues of the regulatory bodies and the professions they are responsible for. For example, there are only few studies concerning performance indicators and the effectiveness of the regulatory bodies and their services. More importantly, there are no studies to identify the impacts of health professional regulatory bodies on population welfare and health.

In this sense, the main objective of this study is to discuss the effectiveness of professional regulatory bodies as they function under the Brazilian legislation. Data from a midsize professional regulatory body from the State of Sao Paulo were obtained to build an agent-based model comparing two different inspection strategies, one of which represents the status-quo and the other includes disclosing inspection scores to the public. It will be discussed whether simulations can be used in inspection services and other types of public policies, where *ex-ante* evaluations and randomized trials can be too expensive or even impracticable.

3.3 LITERATURE REVIEW

3.3.1 Regulatory bodies

The professional regulatory bodies emerged in Brazil in the 1930s, when the government granted some professional categories the responsibility to control their own activities (Garcia, 2012). They were created in the form of boards composed of elected professionals from the same area. For this reason, these boards can be considered as self-regulation entities (Girardi, Fernandes, Carvalho, 2000), being responsible for technical and ethical regulation in their area of activity. Besides, the boards are accountable for the inspection and disciplinary actions of the registered professionals.

Also, the boards can enact regulation concerning the technical and ethical aspects of their respective professional area, as well as issue documents, such as licenses, certificates, notifications and others (Neto *et al.*, 2015). Such permissions are derived from the decentralization principle, since these are typical governmental roles that would naturally belong to the Ministry (Department) of Labor. And the similarities end there.

Each professional regulatory body is provided with a certain degree of autonomy. For instance, there are not inspection standards determined by the central government that all the boards should follow. In fact, each federal board can determine the inspection procedures in their respective professional category. Moreover, in some cases the federal boards fail to establish such rules, providing the regional offices with even more autonomy. As a result, professional categories undergo different inspection methods depending on board decisions. That is, some professions can be inspected austerely, while others can be more flexible. Even in the same professional category it is possible that a regional board from one state is more strict than others and vice-versa. Hence, it is almost impossible to plan an inspection model that could serve all these categories and their respective boards.

These factors would make it arduous to analyze all the aspects of the professional inspections in only a single study. In this sense, a case study of one professional regulatory body was performed in order to attain the research objectives.

3.3.2 Legal nature of professional regulatory bodies

In Brazil, the regulatory bodies arose out of an extension of the Ministry of Labor, which delegated licensing and inspection functions to these agencies. In 1998, the Federal Law nº 9.649 was intended to break the ties that anchored the boards to the Ministry, and they would turn into private entities with the right to inspect the professionals and collect fees in their area of jurisdiction. According to this Law:

> *Article 58. Inspection of regulated professions must be carried out by private entities delegated by the government and through legislative authorization.*
> *Paragraph 2. Professional regulatory bodies, endowed with private rights, are not subordinate to the government or its ministries*.[2] (Author's translation).

This impasse lasted until 2002, when the Supreme Federal Court of Brazil declared such Law as unconstitutional (Direct Action of Unconstitutionality - ADI number 1.717-6), and as a result the professional regulatory bodies turned out to be public entities again. As stated in the ADI report:

> *...through the interpretation of our Constitution, it does not seem possible to delegate public services, such as police force, tax collections and imposition of penalties, to a private entity...*[3] (Author's translation).

This sort of debate prevails in the available literature concerning professional regulatory bodies. Researchers focused on the legal nature of these entities, *i.e.*, whether they are of private or public right. This issue was only closed after ADI nº 1.717. In view of this, the

[2] Art. 58. Os serviços de fiscalização de profissões regulamentadas serão exercidos em caráter privado, por delegação do poder público, mediante autorização legislativa. §2o Os conselhos de fiscalização de profissões regulamentadas, dotados de personalidade jurídica de direito privado, não manterão com os órgãos da Administração Pública qualquer vínculo funcional ou hierárquico.

[3] "... não parece possível, a um primeiro exame, em face do ordenamento constitucional, mediante a interpretação conjugada dos artigos 5º, XIII, 22, XVI, 21, XXIV, 70, parágrafo único, 149 e 175 da C.F., a delegação, a uma entidade privada, de atividade típica de Estado, que abrange até poder de polícia, de tributar e de punir , no que tange ao exercício de atividades profissionais".

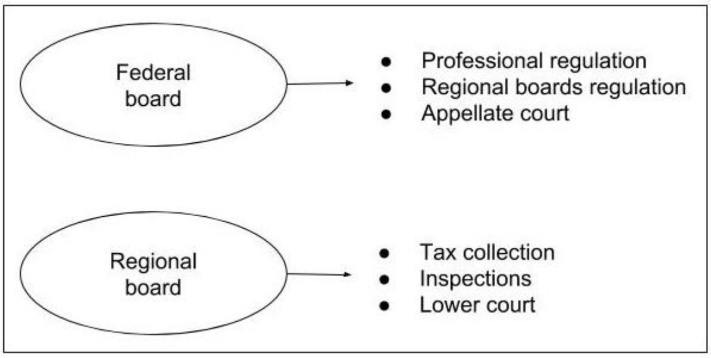
literature on other technical and specific aspects of the regulatory bodies is little. Also, so far these entities did not have a place in the public administration or in the public policy literature.

3.3.3 Regulatory bodies' structure

In Brazil, there are 27 regulated health professions that are under the jurisdiction of a regulatory professional body, and they are organized similarly. In general, there is one federal body, which is responsible for the general rules of each profession and the regulation of their own system, while the regional offices are responsible for tax collections, inspection services and also function as first instance courts of professional conduct - the Federal boards serve as second instance courts in case of dispute or appeal. Examples can be found in Federal Law nº 3.268 (Articles 5 and 15), Law nº 3.820/1960 (Articles 6 and 10) and Law nº 6.316/1975 (Articles 5 and 7)

A part of the revenues obtained by the regional offices are transferred to their respective federal body, which is called “quota”, with a rate that is determined by the Law that created each category body. Also, it is up to the federal bodies the role of determining the structure of the regional offices, according to each specific situation. The division of roles between the federal and regional boards is presented in Figure 3.

Figure 3: Duties of federal and regional boards of health professionals in Brazil



Source: Designed by the author, based on legal documents.

In other countries, the inspection of regulated professions can occur differently. For example, in the United States each State defines how the inspections and regulations should take place. Therefore, there are States where each profession is structured in a specific body that is tied to the Department of Consumer Affairs, such as California. In others, such as Indiana and Colorado, regulated professions are under supervision of a Secretary Office. In New Zealand inspections and regulations of healthcare professionals are duties of the Ministry of Health, which in its turn delegates part of this work to special committees of each area. A similar structure is also found in Australia. In its turn, Sweden groups many different professions under one board (National Board of Health and Welfare). Additionally, inspection power can vary according to a country's legislation. In Brazil, for example, no complaint is required prior to conducting an inspection, but nominated complaints are prioritized over routine inspections. In this sense, with such different models and structures, without good information an effective benchmarking is impossible (Massheder, Finch, 1998).

3.3.4 Regulatory Bodies' Spending

Even though the tax revenues from the professional regulatory bodies are significant, for a long period they were not even obliged to render their accounts to the TCU (Federal Court of Accounts) - this took place between 1996 (TCU Normativa Instruction nº 42 of 1996) and 2012 (TCU Judgement nº 2666 of 2012), *i.e.*, a 16-year gap.

Since the reinstatement of the professional regulatory bodies under the TCU jurisdiction, the Court has carried out sporadic audits and provided them with specific guidance, *e.g.*, the Guide for Professional Regulatory Bodies (TCU, 2014) and the audits to check their compliance with the Access to Public Information Act (Federal Law nº 12.527).

Such audit occurred in 2016 and revealed that 80% of the regulatory bodies did not present details of their expenditures on their websites. This condition makes it even more difficult to verify how their resources are used. Besides, given the autonomy enjoyed by them, it is not possible to know how much of the revenues is spent with inspection services (TCU Judgement nº 96 of 2016).

3.3.5 Quality of regulatory bodies' spending

The rendering of accounts process has been modernized by the TCU in the past recent years. For instance, it is demanded that the entities under their jurisdiction present data on the effectiveness and quality of spending. However, the professional regulatory bodies still focus their communication on licensing and permission services, skipping out on their role of protecting consumers from unprofessional workers. This could be caused by the existing conflicts of interests in professional regulatory bodies, a topic on which little has been studied (Cohen, 1980).

Some examples are the regulatory bodies from the healthcare area. Little is known about the impact of their services on the health and wellness of the patients they should cover. They are not required to release any information on these aspects, and thus such measurement cannot be achieved by the general public. Though Brazilian public agencies are required to present information on performance, they are free to choose which indicators will be disclosed. As can be seen in TCU Norm nº 63 of 2010, this requirement is generically approached.

Moreover, in order to measure the efficiency of the inspection services made by the boards, it would be vital to know its costs. However, according to Nascimento *et al.* (2015), 72% of the professional regulatory bodies not even know the cost of their services.

Due to the difficulties related to the information on cost and results achieved by the boards, in order to attain the objectives of this research a case-study was carried out in professional regulatory body of the health area in the State of Sao Paulo, as well as an agent-based model to simulate the results of two different inspection strategies.

3.3.6 Limitations imposed on the regulatory bodies

On the one hand, regulatory bodies are assigned to regulate their own professional areas, but on the other hand they cannot expand or limit the rights, but rather should concern only the ethical and technical aspects of the areas under their jurisdiction (Finger, 2007). For instance, a regulatory body is not given the right to close premises, even in the case of serious infringements. In such situations, it is a practice of some bodies to partner with other public bodies, such as the National Sanitary Surveillance Agency.

Although the inspection and regulatory capabilities of the bodies can impose restrictions to their registered professionals, their activities are limited and public interest should always be above any corporate concerns, *i.e.*, their target audience are the general public (Costa, Valente, 2008).

3.3.7 Performance indicators

According to Mitchell *et al.* (1995), performance indicators are ways to verify what cannot be measured directly. Also, indicators are a useful means of gaining comprehension of complex systems, such as public policies.

Parmenter (2015) categorizes indicators in 4 groups: key result indicators, result indicators, key performance indicators and performance indicators. Key result indicators (KRI) synthesize the results of actions carried out by many teams, whereas result indicators are related to financial information, but less global and less important than KRIs. Performance indicators are nonfinancial and measure the activities of an organization. On its turn, key performance indicators are those vital to an organization and are linked to a critical success factor.

When it comes to the Brazilian public sector, indicators are often classified in 3 groups: result, efficiency and effectiveness. Result indicators inform whether a given policy has reached its objectives. Efficiency indicators present the amount of resources to obtain an objective. Finally, effectiveness indicators measure the impacts in a broad sense (da Costa, Castanhar, 2003). The latter is certainly the most difficult to assess. As shown by the Independent Evaluation Group (2008) of the World Bank, the macro-level results are influenced by many variables, which encumbers the analysis of the net benefits of regulatory policies.

In the case of the regulatory bodies, 3 types of evaluation could be implemented, as shown in Table 13.

Table 13: Main measurements of regulatory activities

Type of evaluation	**Description**	**Example of indicators**
Regulatory administration	Evaluates how well the regulation is implemented	Number of inspections, number of fines, number of judgements.
Behavioural compliance	Evaluates if regulation is complied with	Number of violations, compliance rate.
Outcome performance	Evaluates if regulation produces the intended results	Number of contaminations, number of patients harmed due to malpractices.

Source: Reproduced from Coglianese (2012).

It should be stressed out that indicators should be selected carefully, especially in the area of healthcare, where some important aspects cannot be controlled by regulatory bodies. As an example, Giuffrida, Gravelle and Roland (1999) have shown that morbidity, socioeconomic characteristics, and secondary care supply represent significant confounding factors in this area.

3.3.8 The importance of inspection services

Despite the absence of effectiveness indicators in professional regulatory bodies in Brazil, the importance of regulation and inspection services is corroborated in literature from different areas. Martin, Davis and Downe (2001) argue that inspections are important in promoting service improvement. Also, some empirical evidence is provided by Lindell (1997), who has shown that inspection scores in the area of occupational safety could predict the number of injured workers in United States Navy shore facilities.

Although it is true that Brazilian regulatory bodies dismiss effectiveness indicators, it is also true that measuring macro-level results empirically is challenging, especially in the area of healthcare, because it is influenced by countless variables.

The traditional approach to regulation and enforcement is based on the importance of mandatory requirements from the government, as opposed to the voluntary approach, in which the government acts as a facilitator. Even though both the risk perception and the sense of duty are important for compliance, when considering the two approaches separately, the first one has proven to be more effective (May, 2005). Mandatory requirements are generally enforced by inspections that can take many different forms. In this sense, inspectors, who work as street-level bureaucrats, translate policy directives into real public policy (Meyers, Vorsanger, 2007). In order to demonstrate the importance of this type of policy, Winter and May (2001), for instance, have shown that different enforcement styles can result in different compliance rates (Winter, May, 2001).

3.3.9 Complex systems

There does not seem to be a widely accepted definition of what a complex system is. However, such systems often have a set of features in common. The idea of interacting parts that lead to a not reducible macro result, self-organization of the system (without central control), signaling and feedback are common properties of complex systems. In this sense, public policies can easily be defined as complex systems (Furtado, Sakowski, Tóvolli, 2015).

3.3.10 Agent-based modeling

An agent based model is a form of computer simulation where agents interact with other agents and with the environment by following a set of rules. These agents can be of various different types, who might take different decisions according to individual level behavior (Farmer, Foley, 2009). Such decisions can result in unexpected macro-level outcomes.

As shown by Gentile, Glazner and Koehler (2015), ABMs are useful in modeling complex systems for public policy analysis. Economic policy makers, for example, often base their decisions on common sense (Farmer, Foley, 2009), an area where ABMs could also be used.

3.4 METHODS

In complex systems, it is deemed impracticable to perform simulations fully based in quantitative models. In these cases, researchers can benefit by integrating quantitative and qualitative methods, especially when their main interest is to observe phenomena in its broad sense, or its essential aspects (Yan *et al.*, 2013).

Qualitative research is often more flexible (Marshall, Rossman, 2014). It normally begins with merely vague and imprecise information, which can be better drawn as more data is obtained during the research (Taylor, Bogdan, Devault, 2015). Besides, according to Bryman (2015), a research plan is composed of seven main elements:

(a) General research questions
(b) Selecting relevant site sand subjects
(c) Collection of relevant data
(d) Interpretation of data
(e) Conception and theoretical work
(f) Writing up findings and conclusions

According to Bryman, social science research is motivated by gaps or inconsistencies in the existing literature, when researchers reflect on a specific topic of the social life.

One of the most used methods in qualitative research is the case study, which corresponds to a detailed and intensive analysis of a single case - that can be a person, an organization, a community or an event. Therefore, the main objective of a case study is not to obtain external validity or an extrapolation, but rather to gain understanding on the chosen case.

On its turn, modeling is a technique aimed at representing the functioning of a system through simplification and abstraction, and it is often achieved using computer simulations. For example, simulations are highly used to reduce risk of failures in a system or to predict unintended consequences (Maria, 1997).

In this study, a single case of a professional regulatory body is presented with the objective of building an agent-based model (ABM) to compare two different inspection strategies. As

Bryman (2015) presents, a case study can be seen as an example to be analyzed in details of a given category, but should not be considered generalizable. That is, a case study is not a sample of one.

Here, the ABM will be used to analyze the macro-level results arising from the inspection strategies, in order to check for effectiveness of inspection services carried out by regulatory bodies. It will be measured the consequences of adding transparency to such inspections as a public health concern, *i.e.*, how can inspection strategies impact public health, for it should be the main goal of the regulatory bodies of the health professions. As shown by Louie and Carley (2008), ABM is a useful tool for such type of studies, where real experiments could be deemed unethical.

Unlike other simulation models, ABM is able to describe the heterogeneity of individuals and the interactions between individuals, so that at sector level patterns and overall behavior emerge that are not explicitly modeled in advance. Certain behavior can sometimes and sometimes do not occur, or a certain combination of parameters suddenly results in a turning point in behavior. This is very relevant for situations where not all assumptions are known and in which randomness can play a role (such as everyday life). Without having to run the system 'in reality', we can still see what could happen.

An example of an ABM with a surprising conclusion is the description of group behavior during evacuation in the event of a fire alarm. This showed that placing a pillar diagonally in front of the emergency exit ensured optimal flow, so that after 45 seconds all people could leave the room unharmed. Without a pillar, only 60% of the people had been evacuated at the same time, 10% of whom had been injured. This simulation was also tested in a practice room and the predictions proved to be in line with reality (Helbing *et al.*, 2000).

The agent based model was built based on the ODD (Overview, Design Concepts and Details) protocol developed by Grimm *et al.* (2012), which allows for a clearer reading of the agents and other components of the model. This simulation was programmed in Netlogo, a free tool with a user-friendly interface and provides a simple and plain visualization of the agents, the environment and their interactions (Allen, 2011).

3.4.1 Model overview, design concepts, and details

The model was named simply "Inspections". Even though the model was built to simulate the conditions of the case presented in this study, its principles can fit the needs of most inspection agencies or audit bodies by merely adjusting some parameters. It will be used the ODD protocol to describe the model.

The Inspections model was built in the version 6.0.1 of Netlogo (Wilensky, 1999), a software for simulation of agent-based models specially suited for complex systems. The models are programmable by the modeler, who can give instructions to agents of many different types that are independent of each other. This allows for observing macro-level outcomes that arise from individual agents, especially in systems where "the whole is more than the sum of its parts".

Agents in Netlogo are called turtles, patches and links. Turtles are mobile agents whereas patches are stationary (turtles move over the patches). Links are agents that connect turtles to form networks. In the present model, turtles are the consumers (patients) and the inspectors. Patches are the health facilities, which can be hospitals, clinics and others. Links were not needed to this study.

3.4.1.1 Purpose

The main objective of this study is to compare the results of two different inspection strategies. The first one simulates the status-quo, *i.e.*, the current strategy adopted by the regulatory body under study. In this strategy, the regulatory body allocates inspectors according to their range, the inspection capacity (number of inspections that each agent can perform per year) and the number of inspectors available.

The inspectors impute a grade to each clinic varying from 1 (good) to 3 (bad) after each inspection. All clinics start with grade 1, but when they are caught non-compliant, the inspector changes its grade to 2 and, in case of recidivism, it goes to 3 (limit). The opposite also applies, that is, if a clinic is compliant during an inspection, its grade is lowered by one point until the limit of 1. But in this first simulation the grades barely affects the results. In the second strategy, however, the grades of the clinics are disclosed to all consumers (patients), who will decide the place of treatment based on these scores.

3.4.1.2 Entities, state variables and scales

The model is composed of three entities: consumers, inspectors and clinics. The variables describing consumers behavior are:

- Their range (how far they travel in order to obtain treatment)
- Choice of next destination
- Memory (a list of clinics that did not help cure them)
- Whether they are healthy
- Their number of visits
- Their number of bad visits

The way consumers choose their next destination is what differs the first scenario from the second one. In the second scenario consumers are aware of the inspection scores, that is, they know how the clinic was evaluated by the inspection authority. When they encounter a clinic with a bad score, the higher are the chances of wandering and searching for another clinic.

The variables of inspectors are their range (inspection area), their inspection capacity (how much they can inspect per year) and their destination, which is based both on their range and their inspection capacity.

Finally, clinics are patches, *i.e.*, stationery agents, which have the following variables:

- Clinic - whether the patch is a clinic or empty
- Rating - score assigned during an inspection
- Compliant - whether the clinic complies with regulation at a given time step.
- Compliance rate - the chance of being compliant at a given time step.
- Knowledge of rules - how much the clinics know the rules they must follow
- Imitation probability - the chance a clinic has to imitate behavior of their closest neighbors

The world size, *i.e.*, the number of patches in the Netlogo environment was set up to a 65x65 grid, which is almost the double of the standard 33x33, as seen in most Netlogo models. This was due to a need of scaling up the model, since the number of consumers to simulate the case was much higher than the standard world size could fit.

3.4.1.3 Process overview and scheduling

In the first scenario, agents inspect health facilities, but they do not disclose information to the public, that is, there is no transparent information to the consumers on the inspection outcomes. This implies that the inspections do not affect the way consumers choose the place of treatment. But in the second scenario the results from the inspections are public for both compliant and non-compliant clinics, and this helps consumers choosing their place of treatment by avoiding risky facilities.

The processes of this simulation take place as follows:

To comply: clinics will choose to comply with regulation according to 5 variables, which are:

<u>Their inspection score</u> - when clinics are assigned a low score during an inspection, the chance of being compliant increases in the next time step. This occurs because clinics “feel” more at-risk and because fines and penalties are generally higher for recidivists.

<u>Knowledge of rules</u> - the less one know the rules, the lesser are the chances to comply. This parameter was set to 90% due to empirical evidence from the case study, but it can be set differently from the Netlogo user interface.

<u>Risk perception</u> - The risk perception is based on the number of inspectors and the inspection capacity.

<u>Imitation probability</u> - The behavior of neighbor clinics influences the behavior of others, *i.e.*, the more compliant neighbors a clinic has, the higher the chances it also complies with regulation.

Sanction severity - when penalties are more severe, the chances of being compliant increases proportionally.

To find clinic: a consumer action. Consumers choose their destination based on their range (how far they can go) and on their memory. They keep a list of clinics that did not help cure them, which lasts for 15 time steps. After that, the consumer “removes” this experience from his memory and it returns to be a potential destination. This is in accordance with Beck's shifts from hysteria to indifference (Beck, 1992) and with Bocker (2000).

In the second scenario, the inspection scores are disclosed and it influences how consumers make their choices. If a clinic has a good score, then he chooses it for treatment. In the case of a medium score, there is a 50% chance of going for treatment and 50% chance of wandering and searching for a clinic in the next time step. And if the score is bad, the chance of choosing if for treatment lowers to 20%.

Only unhealthy consumers go look for clinics (all of them starts unhealthy). In case they are treated and become healthy, they are hidden from the system and do nothing else.

To inspect clinic: an inspector procedure. Agents go out for inspections on their inspection days. The number of inspection days is determined by the inspection capacity, which is initially set to 216 according to empirical evidence from the case study. It means that each agent inspects 216 clinics during the 365 days of the year. The days they go out are randomly assigned.

The process of choosing clinics is mainly associated with the inspection range. This parameter is settled according to the world size and the number of inspectors, and thus creating a radius (range) for each inspector. Then the inspector checks whether the clinic is compliant. In case it is, the clinic score is raised by one point, otherwise it is decreased by one. In both cases, there is a limit of 1 and 3.

Consumer care: a consumer procedure. After choosing a clinic for treatment, the consumer can become healthy or remain unhealthy. This result is based on whether the clinic chosen is compliant or not at that given time step. In case it is compliant, there is a 98% chance of becoming healthy; otherwise, the chance is reduced to 90%, 80% and 70%. Then, the consumer updates its memory (lists of bad clinics) if necessary.

3.4.1.4 Design concepts

Most of the design of this simulation is based upon empirical evidence obtained through the case under study.

Basic principles

The table of eleven

Table of eleven (T11) is a heuristic device which presents components that influence behavior towards compliance with regulation, based on some psychological aspects from the theory of reasoned action (Azjen, Fishbein, 1988).

It was developed by a number of researchers from Netherlands and was adopted in studies of compliance behavior towards insurance and social benefit legislation, law on consumer durables and others. However, as mentioned by Elffers, Van der Heijden and Hezemans (2003), the T11 can be adapted, according to research needs.

The components of the T11 are divided in two groups. The first one (T1-T5) is called spontaneous compliance, *i.e.*, the factors that affect behavior but are not under the public agency control. The other elements (T6-T11) cover the activities of the agency, and is called induced compliance factors. A version of the T11 is presented in Table 14.

Table 14: Components of T11

Spontaneous compliance dimensions	
T1 - Knowledge of rules	Familiarity and clarity of legislation among the target group
T2 - Costs and benefits	The tangible/intangible advantages and disadvantages of breaking or complying with the rule, expressed in time, money and effort
T3 - Acceptability	The degree to which the target group regards the policy and the rules as acceptable
T4 - Respect for authority	The extent to which the target group is willing to respect governmental authority
T5 - Social control	The risk, as estimated by the target group, of positive or negative sanctions on their behaviour other than by the authorities
Enforcement dimensions	
T6 - Risk of reporting	The risk, as estimated by the target group, of a violation detected by others than the authorities being reported to the authorities
T7 - Risk of inspection	The risk, as estimated by the target group, of being inspected by the authorities for possible violations
T8 - Risk of detection	The risk, as estimated by the target group, of a violation being detected if the authorities inspect
T9 - Selectivity	The perceived increased risk of inspection and detection of a contravention resulting from selecting the businesses, persons, actions or areas to be inspected
T10 - Risk of sanction	The risk, as estimated by the target group, of a sanction if a violation is detected in an inspection
T11 - Severity of sanction	The severity and type of sanction associated with the violation and additional disadvantages of being sanctioned

Source: Adapted from Azjen and Fishbein (1988).

Professional regulatory bodies

Professional regulation can take different forms, according to country legislation. In this study, it is presented the case of a Brazilian professional regulatory body from the area of healthcare. Therefore, specific concerns of regulatory bodies from other countries will be disregarded.

In Brazil, professional regulatory bodies are independent public agencies (autarchies) created by federal law with administrative and financial autonomy. In general, there is one public agency for each regulated profession. These agencies are responsible for professional licensing, accepting complaints concerning technical or ethical aspects of their licensed professionals and take disciplinary actions when necessary (Valente, 2002). Licensed professionals are required to pay annual fees directly to the regulatory body, and these resources are used to maintain the agencies, *i.e.*, the agencies do not receive from or transfer funds to the government. The boards are composed of members elected by the licensed professionals. Such elections occur each 4 or 5 years, depending on the law that originated the board.

The typical services carried out by the boards are the licensing itself, regulatory and inspection services and sanctions. Professionals are subject to present their diploma or course certificate in order to obtain a license. Some regulatory bodies also might require a professional exam. Inspection services, in general, are not regulated by Law, providing each board with a certain degree of autonomy to determine how the inspections should take place. The sanctioning often occurs through letters of reprimand, notifications, revoking of licenses and ethical judgements.

Risk aversion

The concept of risk aversion is incorporated to the model in a way similar to the restaurant inspection model by McPhee-Knowles (2014). That is, even though consumers avoid risks, for example avoiding clinics or hospitals that did not help cure them, they may be indifferent after some time, what Beck (1992) called "shifts from hysteria to indifference and vice versa".

However, the model presented in this study differs from the former by including a risk perception parameter in order to adjust compliance rate according to one of the components of T11.

Inspection scores

Inspection scores are grades assigned by an inspector to a place (hospital, restaurant, hotel etc.) according its compliance with regulation. When such scores are disclosed to the public, it can be seen as a strategy to improve compliance, since it can affect consumers' choice, thus it could work as an incentive to comply with regulation. However, literature on this topic can be inconsistent.

For instance, Jin and Leslie (2003) showed that displaying grade cards in the windows of restaurants in Los Angeles resulted in an increase in the inspection scores, a change in consumer demand after its implementation and a decrease in the number of foodborne illness. In other words, the implementation was successful.

On the other hand, similar strategies applied to hospitals showed distinct outcomes. Romano and Zhou (2004) found that the effects of hospitals' report cards on market share were not significant, a result similar to Mennemeyer *et al.* (1997). On the other hand, Cutler *et al.* (2004) showed that hospitals that receive a bad score had a decrease in the number of patients when compared to other hospitals. Jin and Sorenson (2006) found that ratings of health insurance plans had a great impact on consumers' choice.

Moreover, Dranove and Sfekas (2008) presented a stylized model which incorporates the idea of prior beliefs, on which the strategy had a significant impact only when the report cards differ from patients' prior beliefs.

Some agent-based models regarding inspection services have already been published. For instance, the restaurant inspection model by McPhee-Knowles (2014) suggest that disclosing inspection scores did not lead to more healthy consumers, even though variation was affected considerably. The agent-based model from Van Asselt *et al.* (2012) did not take into consideration the inspection scores, but, as opposed to the restaurant inspection model, it included some aspects of the T11.

3.4.2 Case study

For this study it was selected the case of a professional regulatory body from the healthcare area located in the State of Sao Paulo. There are more than 70,000 registered professionals in this board (and growing), plus more than 10,000 registered companies (hospitals, clinics and others). Its office is located in the city of Sao Paulo with branch offices in the interior of the State.

The model was built mostly based on actual data provided by this regulatory body. Therefore, it is important to present some of its main characteristics:

(a) There are 30 inspectors that work for the board distributed in its 10 branches. They average 18 inspections per month which are carried out according to their operational range. The inspectees are mainly clinics (most of which are sole proprietorships) and hospitals, amounting to more than 10,000 facilities. There is not an equal allocation of inspectees per inspectors, due to demographic variations - the density of clinics is highly unequal between the cities where office branches are located. So each inspector is responsible for 333 places in average, with significant deviations.

(b) According to the inspection capacity, each employee would take 18 months to complete inspections in their area, in average. Again, for modeling simplification purposes, it will be considered that each clinic has the same chance of being inspected.

(c) On the basis of Brazilian legislation, it will be considered that each clinic can see 5 patients per day. This is due to the fact that the professionals can work no more than 6 hours per day, and they can see only one or two patients at a time, depending on the type of treatment that is required for each patient. Also the model considers that the clinics do not work at full capacity all the time, reason for which the number of 5 patients per day shall be considered.

(d) The total number of inspections in 2017 reached 7,662, while the number of notifications amounted to 4,280, resulting in a notification rate of 55.86%. Taking into consideration that notifications are issued only in case of irregularities, it can be said that the compliance rate for the year 2017 was 44.14%.

Emergence

The main objective of the model is to verify whether disclosing inspection scores of clinics to the public results in more healthy patients. This will be tested by comparing the current inspection strategy adopted by a regulatory body and a new one, in which the inspection scores are disclosed to and used by the public when choosing where they are going to be treated. In other words, it will be ascertained if and what pattern emerges from patients after a change in the board's inspection strategy.

Adaptation, learning, sensing and prediction

Patients have a memory in which they keep a list of their last 15 visits to clinics. When looking for a treatment, patients randomly choose a clinic within their range (selected by a slider) and, in case it is in the list as a “bad visit” (patient not recovered), it will be avoided. In the second scenario, patients also have access to the inspection scores, which they also use in the process of choosing a clinic. When grading is good (A) and the clinic is not in memory as a bad visit, patient chooses it for treatment immediately. However, when grading is moderate (B) or bad (C), the chance of choosing the clinic for treatment corresponds to 50% and 20%, respectively.

In their turn, patches also have adaptation capabilities. Clinics choose whether or not to comply with regulation based on 5 factors, 2 of which make clinics adapt. First, they have a risk aversion parameter based on the score assigned by the inspector. When moderate (B) or bad (C) scores are assigned by inspectors, their risk aversion parameter goes to 60% and 90%, respectively. This is based on the fact that sanctions and penalties are often more severe for recidivists (Moffatt, Poynton, 2007), and also that bad scores can deteriorate a clinic’s reputation. Also, clinics can imitate the behavior of their closest neighbors. At each time step, they look for clinics within a range (which is equal the inspectors’ range) and check whether they are compliant (1) or not (0) and then take the neighbors’ compliance average. This result is then multiplied by the imitation probability (set by a slider) and the imitation parameter is obtained: the higher the value the higher are the chances of complying.

Interaction and signaling

There are three types of interactions possible. Turtles with turtles, turtles with patches, and patches with patches. Inspectors have no direct interactions with other inspectors or with patients. Patients also have no interactions with themselves.

However, both inspectors and patients interact with patches (clinics), and even patches interact with themselves. Inspectors can assign a grade according to each clinic's compliance and influence their behavior, as previously stated.

As a matter of fact, even the number of inspectors affects patches, since the more inspectors in the system, the higher the risk perception is. Also, even though they do not interact directly with patients, they can signal to patients which clinics are not compliant, and thus influence their behavior as well, but it only occurs in the second scenario of the model.

Patches also interact with patient. Their decision of whether or not to comply with regulations is directly related to patients' recovery condition. When patients go to a compliant clinic their chances of recovering are 98%, whereas in noncompliant clinics it is reduced to 90%, 80% and 70%.

Stochasticity

Stochasticity was embodied in the model in many different forms. The days the inspectors go out to inspect clinics are random, though the number of inspections is fixed. This is in accordance with empirical data from the case study, since the number of inspections is determined by the board, however, inspectors have some degree of autonomy in choosing which days they go out and what clinics they will inspect. For this reason, they choose clinics to inspect randomly, as long as they are within their operating range.

Patients arrive at each time step according to a Poisson process with rate $\lambda = 5{,}000$. All of them begin unhealthy and choose a clinic randomly according to their range. In case they do not find a clinic in a given time step, they wander randomly and try to find another place for treatment in the next time step. In addition, the chances of recovery are also random. When they choose a compliant clinic this chance corresponds to 98%, while 90% in noncompliant clinics.

Patches (clinics) also have random parameters. First, they begin compliant or not based on a random Boolean of 0 (noncompliant) or 1 (compliant). After the first time step, clinics choose to comply or not based on several random parameters, as it will be shown in the initialization section. Finally, all of the agents are placed randomly in the system on setup.

Collectives

In this model, agents are not aggregated in groups.

Observation

The main objective of the model is to compare the two scenarios measured by the number of bad visits. In the first scenario, inspection scores are not disclosed to patients, whereas in the second scenario they are disclosed and affect patients' choice.

The experiments were carried out with the use of BehaviorSpace, an integrated Netlogo extension. This tool runs the simulation many times according to the settings and variables defined by the user, and results are recorded in a CSV file.

In this study, one experiment stops when it reaches 100,000 patient treatments with 5,000 patients per step, while the other stops with 5,000,000 treatments with 2,000 patients per step. The tested values are presented in Table 15.

Table 15: Experiments run in Behaviorspace

Variable	Tested values
Number of clinics	1,000
Inspection capacity	216
Number of consumers	5,000
Sanction severity	1; 3 and 5
Knowledge of rules	0.1; 0.5 and 0.9
Non-compliant recovery rate	0.9; 0.8 and 0.7
Compliant recovery rate	0.98
Inspection scores	True; False
Imitation probability	0; 0.5 and 1
Consumer range	5
Number of inspectors	1; 3; 10; 50 and 100
Refresh consumers (Poisson mean of new consumers)	5,000
Generate random seed	True
Model stops at	100,000 visits ($\sim 20\ steps$)

Source: Felipe de Oliveira Simoyama, 2018.

The reporters used were the number of bad visits and the proportion of compliant clinics in the system. The data was recorded in CSV format and then analyzed in SPSS. Alternative scenarios were also modeled and analyzed to evaluate the robustness of the model. However, it should be noted that these scenarios are not proportional to the values from the case study. In these scenarios, the number of clinics and consumers was reduced, on the other hand, the total number of visits was increased to 500,000.

Table 16: Alternative scenarios tested in Behaviorspace

Variable	Tested values
Number of clinics	500
Inspection capacity	216
Number of consumers	2,000
Sanction severity	1 and 5
Knowledge of rules	0.9
Non-compliant recovery rate	0.7 and 0.9
Compliant recovery rate	0.98
Inspection scores	True; False
Imitation probability	0 and 1
Consumer range	5
Number of inspectors	1; 3; 10 and 50
Refresh consumers (Poisson mean of new consumers each step)	2,000
Generate random seed	True
Model stops at	500,000 visits (~ 230 steps)

Source: Felipe de Oliveira Simoyama, 2018.

3.4.3 Details

Initialization

The model is initialized with 3 inspectors, 1,000 clinics and 5,000 people (consumers), all of them are randomly distributed on the grid. The quantities of inspectors and clinics were scaled based upon the information from the case[4]. The number of consumers was not obtained, however, such quantity was not arbitrarily chosen. In fact it is plausible when taken into consideration that each professional can care of 1 or 2 patients per hour, depending on the type of treatment.

Also, for the professionals registered in the regulatory body under study, they are allowed to work 6 hours per day, which gives a maximum of 12 patients per day. In this case, for 1,000 clinics, there should be 12,000 people[5], but we are considering that the professionals are not working at their full capacity and that some treatments require that only 1 consumer can be accepted at a time, which results in the approximate number of 5,000 people. But it is important to notice that the number of clients does not substantially affect the objective of this study.

At each time step, a mean of 5,000 new consumers are added to the grid following a Poisson process, and they follow the same rules as the initial consumers: they start unhealthy and find a clinic for treatment. Those that healed in the previous timestep are hidden and do not participate any longer. In their turn, those that did not heal remain in the system and look for treatment again until they are healed.

Simultaneously, the inspectors choose clinics to inspect in their operating range according to their capacity. It is important to notice that, for the regulatory body under study, inspectors do not go out every working day, since part of their job must be carried out internally (*e.g.* write notifications, register the processes in the organization's information system etc.). The range depends upon the jurisdiction size (in terms of space) and the number of inspectors. In this model, the range is determined by a formula [1].

---

[4] The factual numbers from the case study are 30 inspectors and 11,000 clinics.
[5] Most of the clinics registered in the regulatory body under study have only 1 practitioner.

$$[1] \quad \sqrt{\frac{\frac{h \times w}{num-inspectors}}{\pi}}$$

Considering that the inspector range corresponds to a circumference for which the area is given by πr^2, in order to determine the radius the result is divided by π and then the square root is obtained. Hence the inspector range is implemented in netlogo by using the in-radius argument with the value obtained through the formula.

The Netlogo's world size was set with a width and height of 65, resulting in 4,225 patches. The number of clinic-patches is initially set to 1,000, which are randomly placed on the grid and are colored green. The other patches are empty. Clinics may comply or not with regulation according to a formula [2].

$$[2] \quad c = \frac{r + k + p + i + s}{5}$$

Where r corresponds to the clinic's rating, k corresponds to the degree of knowledge of rules, p is the risk perception, i is the imitation probability and s is the sanction severity.

All the clinics start with a rating of A (good score). The rating drops by one point (B) when a clinic is caught noncompliant during a visit by an inspector, and the patch turns to yellow, and it goes on up to the limit of C (bad score), when the patch becomes red. The inverse also applies, *i.e.*, if a clinic has a B or C rating and is compliant during a visit, its rating is increased by one point, up to the limit of A.

The variable "knowledge of rules" is set to 0.9 for all clinics, according to empirical evidence from the case study. However, simulations will also be run with values of 0.7 and 0.8. There is an opportunity for improvement in this variable, since it is unlikely that all participants have the same degree of knowledge, so the model allows for the implementation of more complex implementation of this variable.

The risk perception is also set equally for all clinics. However, the value depends on the number of inspectors and the number of clinics, as shown in the formula [3], where i denotes the number of inspectors, μ is the inspection capacity (number of inspections that can be carried out in a year by each inspector) and n is the number of clinic-patches.

[3] $$r = min(1; \frac{i \times \mu}{n})$$

Each clinic can have a different imitation probability, since it is dependent on how their closes neighbors behave. It is given by a formula [4]. The value m ($0 \leq m \leq 1$) is defined globally by a slider in Netlogo, and was set to 0.75, while y is the average compliance of the clinic's closest neighbors. The neighbor can be compliant (1) or noncompliant (0), so y is the arithmetic mean of the neighbors within a range that is equal to the inspectors' range.

[4] $$p = m \times \overline{y}$$

Finally, the sanction severity (s) is a value from the set {0.1,0.3,0.5,0.7,0.9}, which is chosen by a slider in Netlogo interface that corresponds to {1,2,3,4,5} to facilitate interpretation.

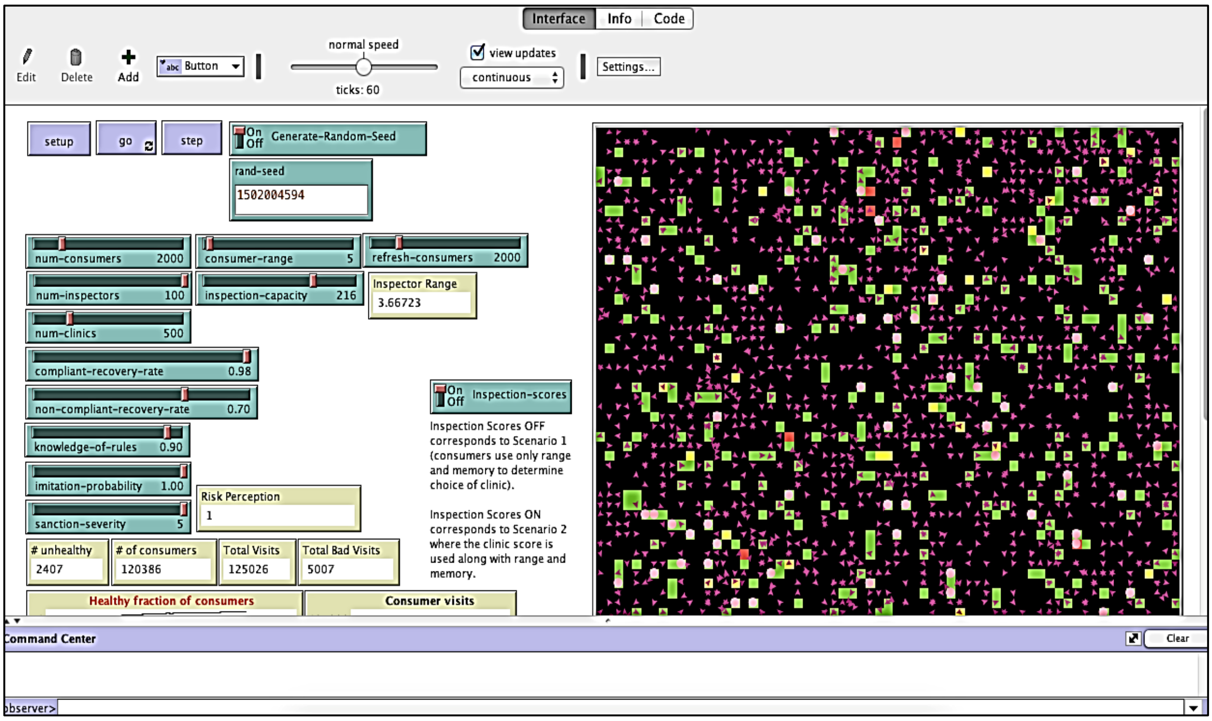
Input data

The model does not use input data from external sources to represent time-varying processes.

Submodels

The model was implemented in a manner that the user can easily change the main parameters through the Netlogo interface, as seen in Figure 4.

Figure 4: Netlogo interface of the inspections model



Source: designed by the author.

The full code is available at http://openabm.org under the tag “inspection model”.

<u>Subprocesses</u>

The subprocesses of this model are discussed in the process overview and initialization sections.

3.5 RESULTS

The descriptive statistics of the data obtained in Behaviorspace are presented in Table 17. A total of 810 simulations were run with an average of 20 steps each - each simulation stops when approximately 100,000 visits are reached and a mean of 5,000 consumers arrive at each time step. Histogram and quantil-quantil plots for the number of bad visits are presented in Figures 5, 6 and 7.

The number of bad visits varied significantly from 3,873 (min) to 27,871 (max). The initialization setup of both the best and worst scenarios are shown in Table 18. Similarly, the ratio of compliant clinics ranged from 13,20% (worst scenario) to 81.20% (best scenario), for which the initialization setup is provided in Table 19. Two simulations resulted in 81.20% of compliant clinics, and they differ only in the number of inspectors (50 and 100), *i.e.*, doubling the number of inspectors did not generate effects between these two runs in terms of compliance.

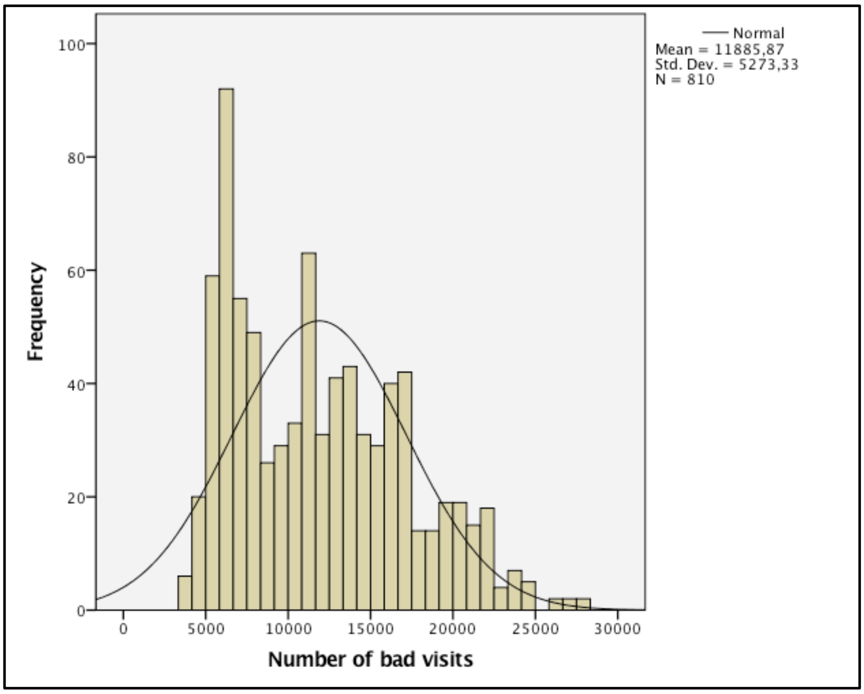
Table 17: Descriptive statistics of results obtained in the model

Variable	Range	Minimum	Maximum	Mean	SD	Skewness		Kurtosis	
						Stat	SE	Stat	SE
Sanction severity	4.00	1.00	5.00	3.00	1634.00	0.00	0.09	-1502.00	0.17
Non-compliant recovery rate	0.20	0.70	0.90	0.80	0.08	0.00	0.09	-1502.00	0.17
Knowledge of rules	0.80	0.10	0.90	0.50	0.33	0.00	0.09	-1502.00	0.17
Inspection scores	1.00	0.00	1.00	0.50	0.50	0.00	0.09	-2005.00	0.17
Compliant recovery rate	0.00	0.98	0.98	0.98	0.00				
Imitation probability	1.00	0.00	1.00	0.50	0.41	0.00	0.09	-1502.00	0.17
Nr of inspectors	99.00	1.00	100.00	32.80	38052.00	0.87	0.09	-0.84	0.17
Nr of bad visits	23998.00	3873.00	27871.00	11885.87	5273330.00	0.54	0.09	-0.56	0.17
Total visits	6610.00	100002.00	106612.00	102642.52	1725948.00	0.20	0.09	-1248.00	0.17
Compliant clinics (%)	0.68	0.13	0.81	0.47	0.14	0.00	0.09	-0.32	0.17
Bad visits (%)	0.22	0.04	0.26	0.12	0.05	0.52	0.09	-0.60	0.17
N				810					

Obs.: SD = standard deviation; Stat = statistic; SE = standard error.

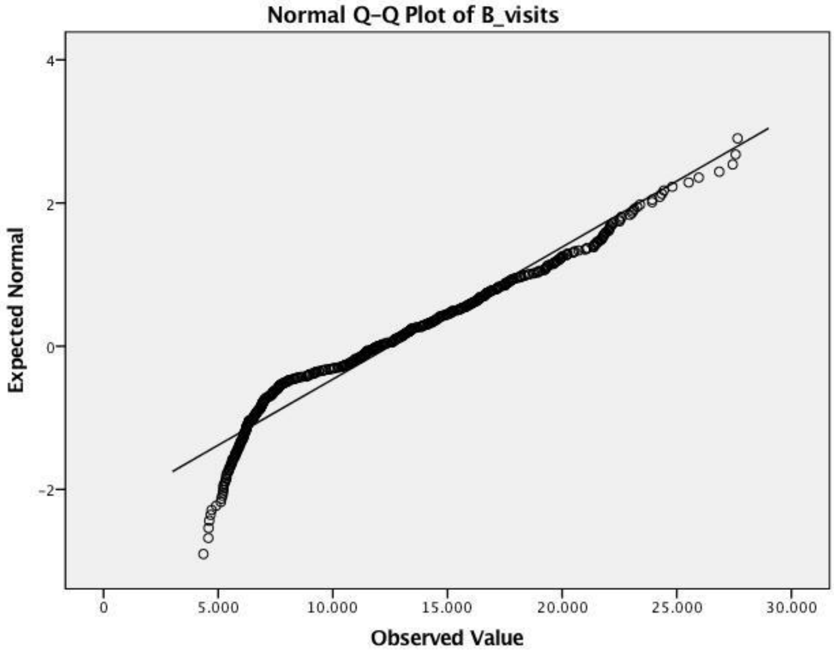
Source: Felipe de Oliveira Simoyama, 2018.

Figure 5: Histogram of the number of bad visits



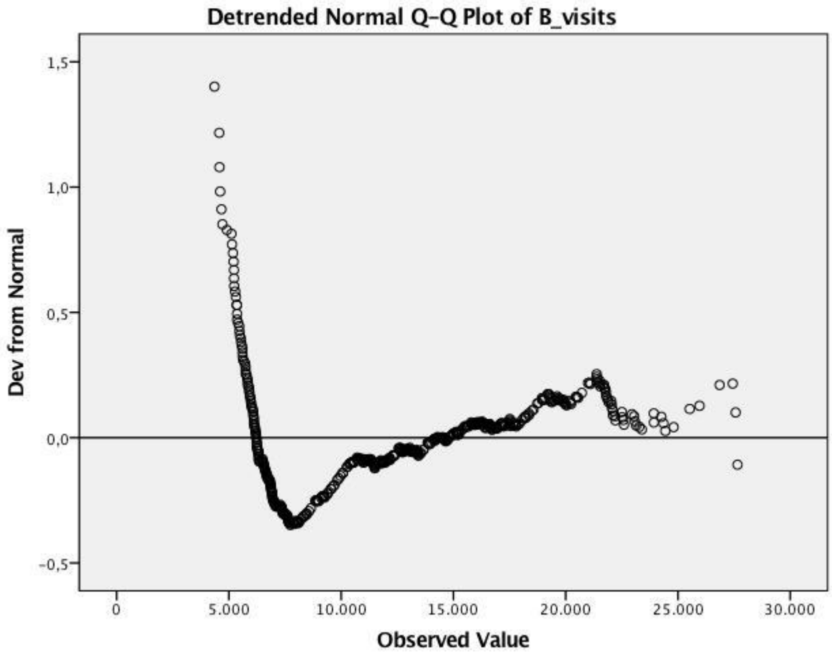
Source: designed by the author.

Figure 6: Normal Q-Q plot of bad visits



Source: designed by the author.

Figure 7: Detrended Q-Q plot of bad visits



Source: designed by the author.

Table 18: Best and worst scenarios possible in terms of bad visits

Variable	Best scenario	Worst scenario
[run number]	734	76
num-clinics	1000	1000
inspection-capacity	216	216
num-consumers	5000	5000
sanction-severity	5	1
knowledge-of-rules	0.9	0.1
non-compliant-recovery-rate	0.9	0.7
inspection-scores	1	0
compliant-recovery-rate	0.98	0.98
imitation-probability	1	0
consumer-range	5	5
num-inspectors	50	1
refresh-consumers	5000	5000
generate-random-seed	1	1
rand-seed	640238611	640238611
[step]	20	16
bad-visits	3873	27871
total-visits	103517	106401
pctcomp	0.785	0.144
pctbad	0.03741414454	0.2619430269

Source: Felipe de Oliveira Simoyama, 2018.

Table 19: Best and worst scenarios possible in terms of compliance levels

Variable	Best scenario 1	Best scenario 2	Worst scenario
[run number]	780	750	16
num-clinics	1000	1000	1000
inspection-capacity	216	216	216
num-consumers	5000	5000	5000
sanction-severity	5	5	1
knowledge-of-rules	0.9	0.9	0.1
non-compliant-recovery-rate	0.8	0.9	0.9
inspection-scores	0	0	0
compliant-recovery-rate	0.98	0.98	0.98
imitation-probability	1	1	0
consumer-range	5	5	5
num-inspectors	100	100	1
refresh-consumers	5000	5000	5000
generate-random-seed	1	1	1
rand-seed	640238611	640238611	640238611
[step]	19	20	19
bad-visits	6033	3910	9109
total-visits	100853	103746	103075
pctcomp	0.812	0.812	0.132
pctbad	0.05981973764	0.03768820003	0.08837254426

Source: Felipe de Oliveira Simoyama, 2018.

In order to assess the effects of inspection scores on the policy outcomes, the mean number of bad visits (patients not recovered) was compared for inspection strategies 1 and 2 - inspection scores are not disclosed to patients in strategy 1, but they do in the second. An independent samples t-test was performed to compare both strategies.

The outcome variable (number of bad visits) was found to be normally distributed and equal variances are assumed based upon Levene's test (p=0,899). There was no significant difference in scores for strategy one (M=11,872.51, SD=5,256.36) and strategy two (M=11,871.98, SD=-5,268.28); t=-0,002, p=0,899. The magnitude of the difference in the means (mean difference = -0.532, 95% CI: -513.42 to 512.36, Table 20) and variances in the number of bad visits cannot be accounted for by the inspection scores (eta squared = 0, Table 21).

Table 20: Independent samples test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	SE Difference	95% CI of Difference	
									Lower	Upper
Nr bad visits	Equal variances assumed	0.016	0.899	-0.002	1618.000	0.998	-0.532	261.487	-513.421	512.356
	Equal variances not assumed			-0.002	1617.992	0.998	-0.532	261.487	-513.421	512.356

Obs.: SE = standard error; CI = confidence interval.

Source: Felipe de Oliveira Simoyama, 2018.

Table 21: Measures of association

	Eta	Eta Squared
Number of bad visits * Inspection Scores	0.000	0.000

Source: Felipe de Oliveira Simoyama, 2018.

A Pearson correlation test was performed to establish the relationship between the number of bad visits and the other parameters that were parameterized in Behaviorspace. Results are shown in Table 22. As can be seen, the independent variable "inspection scores" is the most weakly correlated with the number of bad visits.

Table 22: Pearson correlation between number of bad visits and 6 model parameters

	Variable	Number of bad visits
Pearson Correlation	Number of bad visits	1.000
	Sanction severity	-0.256
	Knowledge of rules	-0.256
	Non-compliant recovery rate	-0.854
	Inspection scores	-0.002
	Imitation probability	-0.151
	Number of inspectors	-0.164

Source: Felipe de Oliveira Simoyama, 2018.

The same Pearson correlation test was performed for dependent variable "percentage of compliant clinics" (Table 23) for the same 6 independent variables. Again, the inspection scores strategy had no effects in improving clinics' compliance. However, sanction severity and knowledge of rules had a moderate positive (0.533) relationship with compliance, whereas the number of inspectors and imitation probability presented a weak, but significant positive correlation with compliance.

Table 23: Pearson correlation between percentage of compliant clinics and 6 model parameters

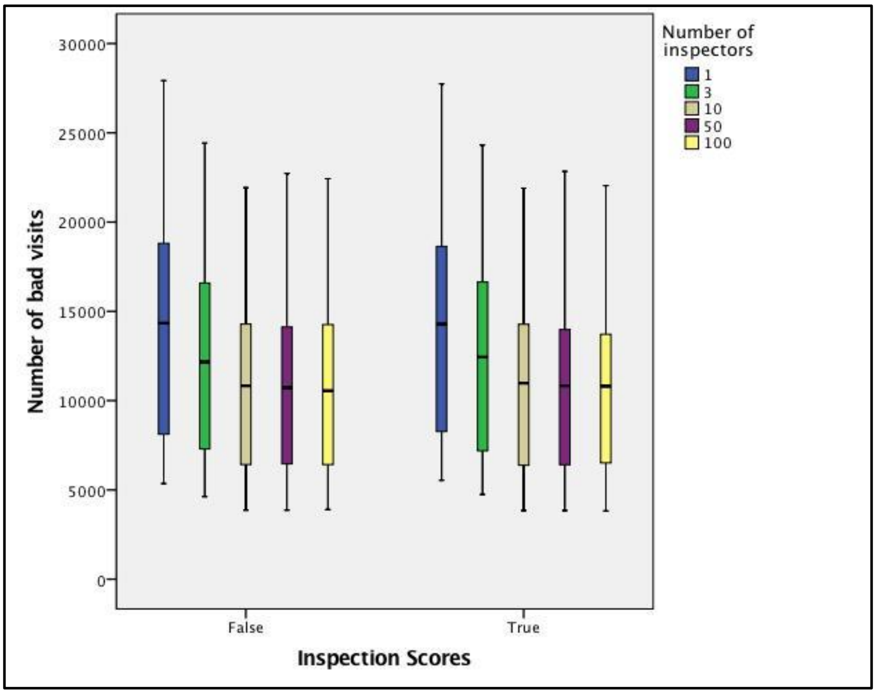
		Percentage of compliant clinics
Pearson Correlation	Percentage of compliant clinics	1.000
	Sanction severity	0.533
	Knowledge of rules	0.539
	Non-compliant recovery rate	0.000
	Inspection scores	0.000
	Imitation probability	0.316
	Number of inspectors	0.369

Source: Felipe de Oliveira Simoyama, 2018.

An analysis was performed to check for a dose-response relationship between the two target variables (mean number of bad visits and percentage of compliant clinics) and the number of inspectors. The results are shown in figures 8 and 9. In both cases, the effects of adding inspectors to the systems seem to have saturated at 10.

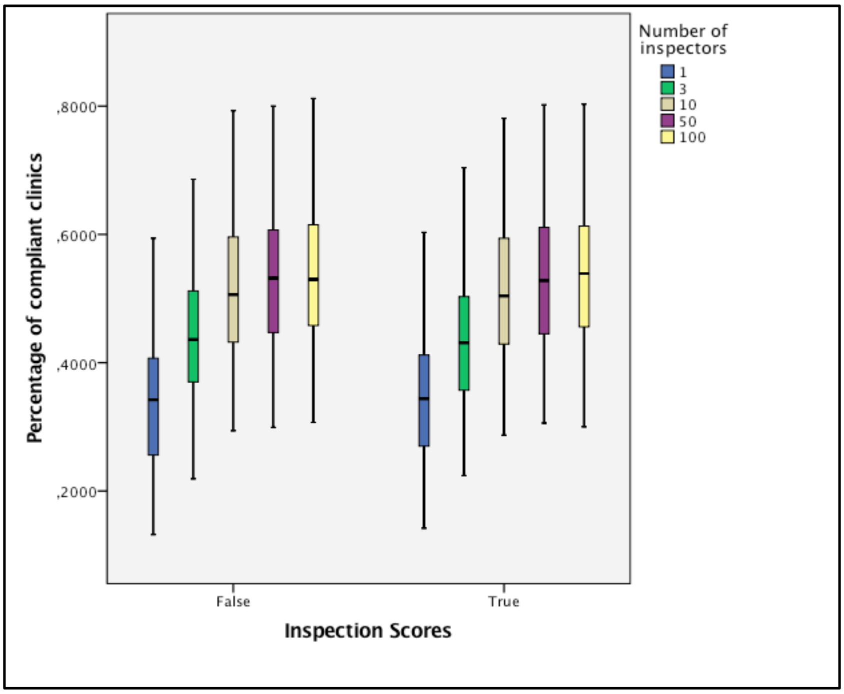
The differences between scenarios with 10, 50, and even 100 inspectors are negligible. On the other hand, increasing sanction severity resulted in a corresponding increase in compliance, as can be seen in Figure 10.

Figure 8: Number of bad visits grouped by inspection scores and number of inspectors.



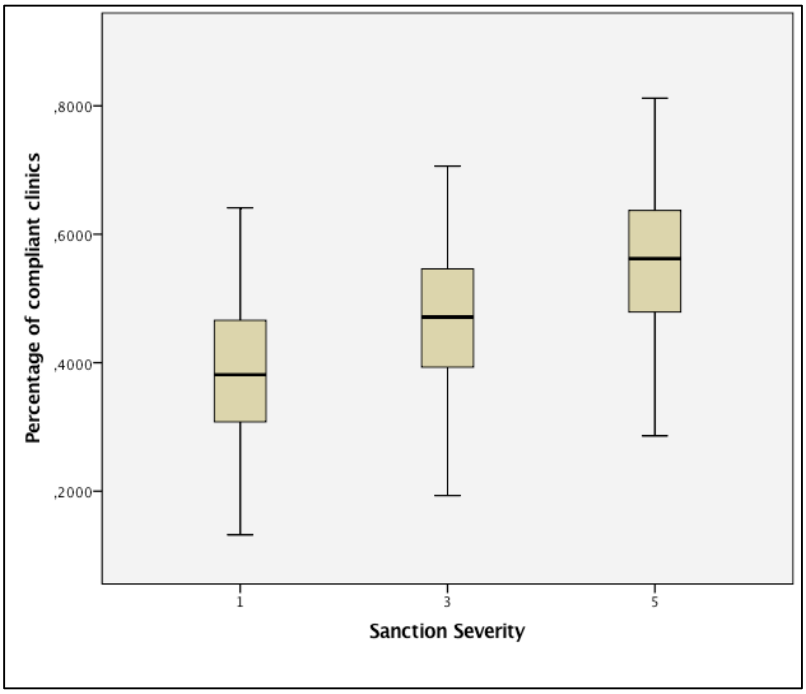
Source: designed by the author.

Figure 9: Percentage of compliant clinics grouped by inspection scores and number of inspectors



Source: designed by the author.

Figure 10: Correlation between compliance and sanction severity.



Source: designed by the author.

For calibration purposes, 27 of the 810 Behaviorspace initializations were proportionally matched to data from the case study. The proportion of compliant clinics are close, which contributes to validate the model, as shown in Table 24.

A similar comparison is not possible for the target variable "number of bad visits", due to the fact that it is not measured by the regulatory body under study. However, the model can be conveniently calibrated according to different public bodies' indicators and rules.

Whereas the percentage of compliant clinics can be considered as a result indicator for a regulatory body, the effectiveness of an inspection policy should be measured by its impact on population's health (*e.g.* number of bad visits, number of medical errors etc.).

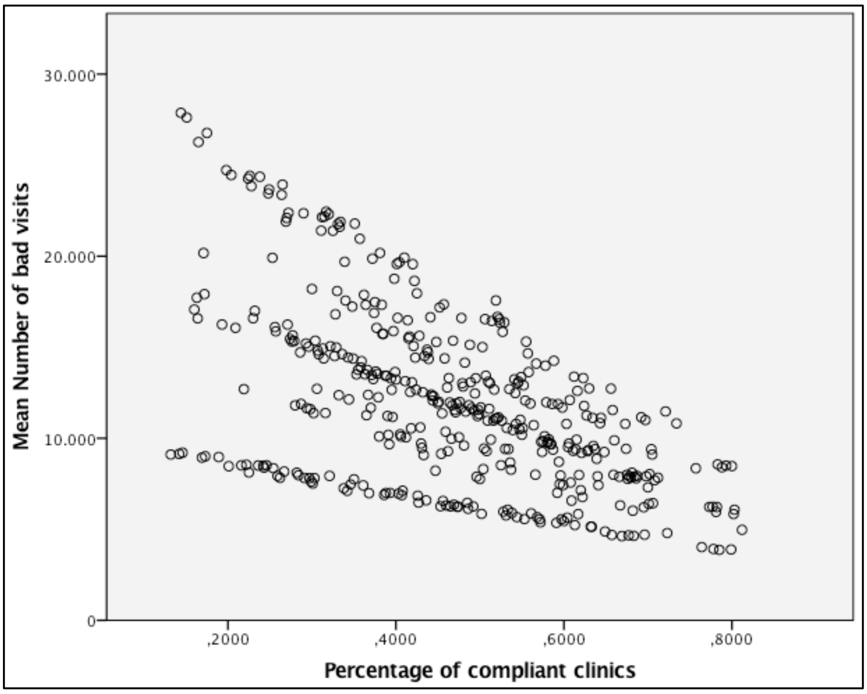
Though this information is not precisely available for most professional regulatory bodies in Brazil, the relationship between compliance and the number of bad visits obtained through the model is presented in Figure 11.

Table 24: Comparison of data from case study and simulation model

Variable	**Case study (regulatory body)**	**Behaviorspace initialization (27 cases)**
Number of clinics	~10,000	1,000
Number of inspectors	30	3
Inspection capacity	216	216
Knowledge of rules	~0,9	0,9
Inspection-scores	False	False
Number of consumers (Poisson mean)	5,000	5,000
Percentage compliant	55,58% (as of 2017)	52,40%

Source: designed by the author.

Figure 11: Relationship between compliance and policy effectiveness



Source: designed by the author.

Finally, the results obtained from the alternative scenarios (Table 16) were similar, *i.e.*, the inspection scores had no impact on both the number of bad visits and the number of compliant clinics. Such results are presented in Tables 25 and 26. The number of visits and steps tested in the alternative scenarios were considerably higher, which also increases the number of inspections. However, the difference in the results between inspection scores (true and false) were not statistically significant as well.

Table 25: Average number of bad visits - alternative scenarios

Inspection-scores	non-compliant-recovery-rate	**Number of inspectors**			
		1.00	**3.00**	**10.00**	**50.00**
false	0.70	82,612.00	63,844.00	61,983.00	60,476.50
	0.90	30,643.25	25,295.00	24,781.25	24,359.75
true	0.70	82,989.50	64,168.25	63,096.25	61,194.25
	0.90	30,674.50	25,509.50	25,189.50	24,653.75

Source: Felipe de Oliveira Simoyama, 2018.

Table 26: Average compliance rate - alternative scenarios

Inspection-scores	non-compliant-recovery-rate	**Number of inspectors**			
		1.00	**3.00**	**10.00**	**50.00**
false	0.70	0.51	0.63	0.64	0.64
	0.90	0.50	0.62	0.64	0.63
true	0.70	0.47	0.63	0.64	0.65
	0.90	0.48	0.64	0.62	0.64

Source: Felipe de Oliveira Simoyama, 2018.

3.6 CONCLUSION AND DISCUSSIONS

The main objective of this study was to compare two different inspection strategies, where the only difference between them was the disclosure of inspection scores to consumers, which could reduce asymmetry of information and allow them to make better choices by avoiding clinics with bad scores. Surprisingly, disclosing inspection scores had no impact on consumers' health.

The available agent-based models regarding the disclosure of inspection scores are focused on food safety area, *i.e.*, they concern the inspection of restaurants. However, even in this area there is not a consensus on whether such strategy is effective in reducing contamination. The Mcphee-Knowles (2014) model, for example, resulted in a slightly increase in the number of sick consumers. However, Jin & Leslie (2003) and Simon *et al.* (2005) had the opposite findings in an empirical study of the Los Angeles transparency system, and concluded that disclosing inspection scores was highly effective by reducing foodborne diseases.

The present study is unprecedented by studying the effects of inspection scores in the healthcare area and its impact on patients' health through an agent-based model, and due to its flexibility it also has the potential to reach regulatory bodies of other areas, such as engineers, lawyers, and other regulated professionals, should an effective calibration be performed according to each case study.

The main result of this research was that disclosing inspection scores to patients is an ineffective strategy for improving patients' health and clinics' compliance. This is in conformity with a study carried out by Weil *et al.* (2006), who reviewed several disclosure policies of various areas, including restaurants, corporate finances, nutritional labeling and patient safety. They concluded that the adoption of hospital and physicians report cards was ineffective.

In addition, the present model is in accordance with Van Asselt, Osinga & Bremmers (2016), who showed that increasing number of inspectors and sanction severity are effective to increase compliance. However, in their model the number of inspectors was not extrapolated to higher levels. Here, it was concluded that there is not a dose-response relationship after a certain number of inspectors is reached. In fact, when doubling the number of inspectors from

50 to 100 the effects were null. Even though Lindell (1997) showed that, in occupational safety area, inspection scores alone are not sufficient for predicting effectiveness of this policy, a result also seen in Lee *et al.* (2012), in the present model inspection scores had null effects regardless of other system variables.

Incidentally, such result can be the response to why the inspection scores strategy was not effective. It was noted that, in order to inspection scores for having some impact on the model, a higher number of inspectors was needed. This is due to the fact that clinics can only have an inspection score after the first inspection. However, increasing the number of inspectors is a mixed blessing, while it displays more scores for consumers, it automatically increases risk perception, which in turn makes clinics become more compliant, then better scores are displayed and it reduces the impact of the inspection scores, because consumers only avoid clinics with moderate and bad scores (50% and 80% chance of avoidance, respectively). Such result would hardly be noticed without the aid of an agent-based model.

In conclusion, the agent-based model developed in this research is a powerful tool and can be calibrated according to the rules and data of each regulatory body. It can assist policy makers by providing scenarios that would be intricate through traditional means. The model has a great potential to be refined by adding psychological and economic inputs, such as cost-benefit evaluations and more complex models of decision making, allowing policy makers to foresee unintended consequences of their strategies and design the best possible scenarios according to empirical data. Also, compliance does not follow a Boolean logic (yes/no). There are many different types of regulatory offence, each with different impact on patients' health, so more complex details on compliance behavior can be implemented.

3.7 REFERENCES

Ajzen, I., & Fishbein, M. (1988). *Theory of reasoned action - Theory of planned behavior*. Tampa, USA: University of South Florida.

Allen, T. T. (2011). *Introduction to Discrete Event Simulation and Agent-based Modeling: Voting Systems.* Health Care, Military, and Manufacturing, Springer Publishing Company, Incorporated.

Andrade, B. H. S., Serrano, A. L. M., Bastos, R. F. S., & Franco, V. R. (2017). *Eficiência do Gasto Público no Âmbito da Saúde: uma análise do desempenho das capitais brasileiras.* Revista Paranaense de Desenvolvimento-RPD, 38(132), 163-179.

Beck, U. (1992). *Risk society: Towards a new modernity* (Vol. 17). Sage.

Böcker, A., & Hanf, C. H. (2000). *Confidence lost and—partially—regained: consumer response to food scares.* Journal of Economic Behavior & Organization, 43(4), 471-485.

Borges, R. N., Bontempo, P. C., Wander, A. E., & Najberg, E. (2014). *Qualidade do gasto público em educação e saúde: uma análise microrregional em Goiás.* Revista Brasileira de Planejamento e Desenvolvimento, 2(2), 30-42.

Brunet, J. F. G., Bertê, A. M. D. A., & Borges, C. B. (2009). *Qualidade do gasto público em educação nas redes públicas estaduais e municipais.* Presented at II Congresso Consad de Gestão Pública.

Bryman, A., & Bell, E. (2015*). Business research methods.* Oxford: Oxford University Press.

Coelho, I. B. V. I., & Campos, P. V. (2015). A *qualidade do gasto público como ferramenta de enfrentamento à crise hídrica de 2015 em Minas Gerais.* Presented at VIII CONSAD - Congresso de Gestão Pública

Coglianese, C. (2012). *Measuring Regulatory Performance evaluating the impact of regulation and regulatory policy.* Paris: OECD.

Cohen, H. S. (1980). *On professional power and conflict of interest: state licensing boards on trial.* Journal of Health Politics, Policy and Law, 5(2), 291-308.

Costa, B. R. M., & Valente, M. A. L. (2008). *Responsabilidade social dos conselhos profissionais.* Brasília: Câmara dos Deputados.

Cutler, D., Huckman, R., Landrum, M.B., 2004. *The role of information in medical markets: an analysis of publicly reported outcomes in cardiac surgery.* American Economic Review 94, 342–346.

da Costa, F. L., & Castanhar, J. C. (2003). *Avaliação de programas públicos: desafios conceituais e metodológicos.* Revista de Administração Pública, 37(5), 969-992.

Diaz, M. D. M. (2012). *Qualidade do gasto público municipal em ensino fundamental no Brasil*. Revista de Economia Política, 32(1), 128-141.

Dranove, D., & Sfekas, A. (2008). *Start spreading the news: a structural estimate of the effects of New York hospital report cards*. Journal of health economics, 27(5), 1201-1207.

Elffers, H., Van Der Heijden, P., & Hezemans, M. (2003). *Explaining regulatory non-compliance: A survey study of rule transgression for two Dutch instrumental laws, applying the randomized response method.* Journal of Quantitative Criminology, 19(4), 409-439.

Farmer, J. D., & Foley, D. (2009). *The economy needs agent-based modelling.* Nature, 460(7256), 685.

Finger, A. C. (2007). *Limites à competência regulatória dos conselhos profissionais.* A&C-Revista de Direito Administrativo & Constitucional, 4(15), 183-191.

Furtado, B. A., Sakowski, P. A. M., & Tóvolli, M. H. (2015). *A complexity approach for public policies*. Brasília: IPEA.

G1 (2014). *Arrecadação federal soma R$ 1,13 trilhão e bate recorde em 2013.* Available at http://g1.globo.com/economia/noticia/2014/01/arrecadacao-federal-soma-r-113-trilhao-e-bate-recorde-em-2013.html).

Garcia, C. L. L. M. (2012). *Conselhos profissionais em tempos de Educação Continuada: a proposta do Conselho Federal de Enfermagem-COFEN.* Tese de Doutorado – Universidade do Estado do Rio de Janeiro. Faculdade de Educação.

Gentile, J. E., Glazner, C., & Koehler, M. (2015). *Simulation models for public policy.* Modeling Complex Systems for Public Policies, 73.

Girardi, S. N., Fernandes Jr, H., & Carvalho, C. L. (2000). *A regulamentação das profissões de saúde no Brasil.* Espaço para Saúde, 2(1).

Giuffrida, A., Gravelle, H., & Roland, M. (1999). *Measuring quality of care with routine data: avoiding confusion between performance indicators and health outcomes.* BMJ, 319(7202), 94-98.

Grimm, V., Berger, U., Bastiansen, F., Eliassen, S., Ginot, V., Giske, J., ... & Huth, A. (2006). *A standard protocol for describing individual-based and agent-based models.* Ecological modelling, 198(1), 115-126.

Independent Evaluation Group (2008). *Doing Business: an Independent Evaluation. Taking the Measure of the World Bank-IFC Doing Business Indicators*, The World Bank, Washington.

Jin, G. Z., & Leslie, P. (2003). *The effect of information on product quality: Evidence from restaurant hygiene grade cards.* The Quarterly Journal of Economics, 118(2), 409-451.

Jin, G.Z., Sorenson, A.T., 2006. *Information and consumer choice: the value of publicized health plan ratings.* Journal of Health Economics 25, 248–275.

Helbing, D., Farkas, I., & Vicsek, T. (2000). *Simulating dynamical features of escape panic.* Nature, 407(6803), 487.

Leão, G. D. A., Silva, J. S., Diniz, L. C., & Kinoshita, M. M. R. (2015). *A experiência de minas gerais na gestão do insumo energia elétrica com foco na sustentabilidade e na qualidade do gasto público.* Presented at VIII CONSAD - Congresso de Gestão Pública

Lee, J. E., Nelson, D. C., & Almanza, B. A. (2012). *Health inspection reports as predictors of specific training needs.* International Journal of Hospitality Management, 31(2), 522-528.

Lindell, M. K. (1997). *Occupational safety and health inspection scores predict rates of workers' lost-time injuries*. Accident Analysis & Prevention, 29(5), 563-571.

Lopes Neto, D., Chamy Dib, K. J., Almeida, C., Oliveira Barreto, D. M., & da Silva Lopes, M. S. (2015). *Poder De Polícia Administrativa Na Fiscalização Dos Conselhos Regionais De Enfermagem.* Direito UNIFACS–Debate Virtual, (183).

LOUIE, M. A. and Carley, K. M. (2008). *Balancing the criticisms: Validating multi-agent models of social systems.* Simulation Modelling Practice and Theory, 16 (2), 242-56. [doi:10.1016/j.simpat.2007.11.011]

Marcos, F. C. (2017). *As implicações geradas e principais mudanças proporcionadas pela fiscalização eletrônica do CRCSC nas organizações contábeis: um estudo de caso realizado no município de Içara-SC.*

Maria, A. (1997, December). *Introduction to modeling and simulation.* In Proceedings of the 29th conference on Winter simulation (pp. 7-13). IEEE Computer Society.

Marshall, C., & Rossman, G. B. (2014). *Designing qualitative research.* Sage publications.

Martin, S. J., Davis, H., & Downe, J. D. (2001). *External inspection of local government: Driving improvement or drowning in detail?*

Massheder, K., & Finch, E. (1998). *Benchmarking methodologies applied to UK facilities management.* Facilities, 16(3/4), 99-106.

McPhee-Knowles, Sarah. (2014). *What's On the Menu: Assessing Manufactured Risk in Restaurant Inspection Systems Using Agent-Based Models.* Journal on Policy and Complex Systems. Volume 1, Number 2. Fall 2014.

May, P. J. (2005). *Regulation and compliance motivations:* Examining different approaches. Public administration review, 65(1), 31-44.

Mennemeyer, S.T., Morrisey, M.A., Howard, L.Z., 1997. *Death and reputation: how consumers acted upon HCFA mortality information.* Inquiry 34 (2), 117–128.

Meyers, M. K., & Vorsanger, S. (2007). *Street-level bureaucrats and the implementation of public policy.* The handbook of public administration, 153-163.

Mitchell, G., May, A., McDonald, A., 1995. *PICABUE: a methodological framework for the development of indicators of sustainable development.* International Journal of Sustainable Development and World Ecology 2, 104–123.

Moffatt, S., & Poynton, S. (2007). *Deterrent Effect of Higher Fines on Recidivism: Driving Offences*, The. BOCSAR NSW Crime and Justice Bulletins, 15.

Nascimento, J. O., Silva, L. C., Zittei, M. V. M., Arnosti, J. C. M., & Lugoboni, L. F. (2015). *Implantação de Sistema de Custos nos Conselhos de Fiscalização Profissional.* In Anais do Congresso Brasileiro de Custos-ABC.

Parmenter, D. (2015). *Key performance indicators: developing, implementing, and using winning KPIs.* John Wiley & Sons.

Romano, P.S., Zhou, H., 2004. *Do well-publicized risk-adjusted outcomes reports affect hospital volume?* Medical Care 42 (4), 367–377.

Simon, P. A., Leslie, P., Run, G., & Jin, G. Z. (2005). *Impact of restaurant hygiene grade cards on foodborne-disease hospitalizations in Los Angeles County.* Journal of environmental health, 67(7), 32.

Taylor, S. J., Bogdan, R., & DeVault, M. (2015). *Introduction to qualitative research methods: A guidebook and resource.* John Wiley & Sons.

TCU (2014). *Guide for professional regulatory bodies.* Available at http://portal.tcu.gov.br/lumis/portal/file/fileDownload.jsp?fileId=8A8182A253D4239E0153F62AA3F46EA6

TCU (2016). *Judgement number 96 of 2016.* Available at http://www.tcu.gov.br/Consultas/Juris/Docs/judoc/Acord/20160204/AC_0096_02_16_P.doc

Valente, M. A. L. (2002). *Sobre a natureza jurídica dos conselhos de fiscalização de profissões regulamentadas.* Revista de informação legislativa, 151-155.

van Asselt, E., Osinga, S., Asselman, M., & Sterrenburg, P. (2012). *Agent Based Modeling: het simuleren van nalevingsgedrag*. Beleidsonderzoek Online, November, 1-8.

van Asselt, E., Osinga, S., & Bremmers, H. (2016). *Simulating compliance behaviour for effective inspection strategies using agent based modelling.* British Food Journal, 118(4), 809-823.

Weil, D., Fung, A., Graham, M., & Fagotto, E. (2006). *The effectiveness of regulatory disclosure policies.* Journal of Policy Analysis and Management, 25(1), 155-181.

Wilensky, Uri, NetLogo (and NetLogo User Manual), *Center for Connected Learning and Computer-Based Modeling*, Northwestern University. http://ccl.northwestern.edu/netlogo/

Winter, S. C., & May, P. J. (2001). *Motivation for compliance with environmental regulations*. Journal of Policy Analysis and Management, 20(4), 675-698.

Yan, X., Zhou, Y., Wen, Y., & Chai, X. (2013). *Qualitative and quantitative integrated modeling for stochastic simulation and optimization.* Journal of Applied Mathematics, 2013.

4 CONCLUSIONS

In this research, it was shown how public policies can be thought and studied as complex systems. Such approach allows for new policy insights and helps predict unintended consequences, which could benefit policymakers and the public at large. This study presented both theoretical and applied applications of complex systems in the public policy area. The first part of which consists of a systematic literature review that focus on complex systems theory applied to public policies, whereas the second part puts it into practice.

In the first part, it was shown that there is a consensus that public policies can benefit from the use of complex systems tools. Even though some authors are wary of using such approach, the systematic literature review showed that the majority of researchers are strongly in favor of this way of studying public policies. Also, it was shown that agent-based models were preferred over other complex systems tools.

Additionally, the systematic literature review presented a gap between policymakers and complex systems researchers. In this manner, researchers should build models that communicate better with policymakers and help solve real-world problems and focus on applied studies instead of theoretical ones.

Moreover, the second part of this study presents an example of agent-based model of a public policy in the regulatory inspection area. This model was built to compare the results of two different inspection strategies through computer simulations. Results show that agent-based models can help predict unintended consequences for different strategies and help policymakers to gain insights for new policy ideas, which corroborates the relevance of complex systems in the area, as shown in the systematic literature review.

Ex ante assessments of public policies can be difficult and expensive, and resources are scarcely available for policy experiments. Therefore, policymakers should consider the use of complex systems techniques, such as agent based models, which could provide new insights, save important resources and significantly improve policy outcomes.