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Editorial
Public Policy Modeling and Applications

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This special issue brings 18 papers on applied policy modeling where the complex nature of the systems (and intervention techniques) plays a significant role. The issue covers a range of applications from crime, finance and trade, infrastructure, and engineering to health policies. In order to tackle these multifaceted problems, a plethora of methodologies is used: extended econometric approaches, large-scale simulations, and theoretical models for which some results can be derived analytically. This highlights the difficulty of the tasks and the lack of standardized approaches, which also may be seen in a good light as it pinpoints the wide background of the scholars that are approaching these problems. We argue that the current issue gives a good overview of the challenges to be addressed and how the state-of-the-art deals with them. As a final remark, it is worth noticing that the following list of papers is sorted only based on topics—without any underlying judgment.

The special issue opens up with the work by the Guest Editors: "Policy Modeling and Applications: State-of-the-Art and Perspectives." This review focuses on methodologies that are, arguably, at the core of the complex systems science: agent-based modeling, network models, dynamical systems, data mining, and evolutionary game theory. The view of all the chosen methodologies is presented having in mind public policy applications. They illustrate specific experiences of large applied projects in macroeconomics, urban systems, and infrastructure planning.

Two expected results of public policies are fostering economic development and show adaptive capacity in case of disruptions. The latter is linked to the concept of *resilience*. In the research paper by G. Castañeda and O. A. Guerrero, "the Resilience of Public Policies in Economic Development," the authors analyze how the adaptive capacity of the policy-making process generates resilience in the face of disruptions. Further, they develop a computational model, which takes into account different social mechanisms (coevolutionary learning and complex interaction networks) to compute a resilience score against simulated disruptions to the expected evolution. Interestingly, they show that certain policy issues are resilient and others fragile, depending on the context of application.

This special issue also brings two papers that focus explicitly on applied policy from a complex systems perspective. The first—"Infrastructure as a Complex Adaptive System" —by E. J. Oughton et al. advocates the need to coordinate govern planning considering interdependencies among infrastructure sectors. The second paper—"A Case Study of Complex Policy Design"—by Buzuku et al. reinforces the need to integrate policy analysis. The authors of the latter propose methodological steps that should guarantee a systematic analysis that covers the space of possibilities paving optimal paths for policymakers.

The paper by E. J. Oughton et al. makes a case that infrastructure sectors are increasingly becoming more integrated in tandem with advances in digital and technological

enhancements. Further, the authors describe the pervasive effects of the lack of intertwined infrastructure planning over social and economic issues. This description is in tune with the concepts of complex adaptive systems (CAS), mainly, its multitude of decentralized decision-making agents, its emergent phenomena characteristics, and its networked, dynamic connections. The paper then details each feature of systems locking together properties of CAS and infrastructure. Finally, E. J. Oughton et al. illustrate the analysis of the applied version of their system-of-systems to a case study of the United Kingdom. They identify the key decision-makers across government bodies and list four necessary metrics to consider about each sector to foster integration. A family of models under the NISMOD umbrella functions as the coordinator of the systems aiming specifically at long-term planning, risk, and vulnerability analysis and the prevention of cascading failures within extreme events. The paper concludes with a critical review of its contributions and the limitations of the proposal.

The paper by S. Buzuku et al., in turn, advocates systems integrated analysis via creative and analytical methods applied in sequence. The authors claim that so-called wicked problems demand a prior phase of complex understanding before applying optimal analytics. Hence, when the space of possibilities is intractable, systemic methods may contribute to problem-solving. S. Buzuku et al. proposed method combines General Morphological Analysis (GMA) to Design Structure Matrix (DSM) along with an embedded sensitivity analysis and a cross-consistency assessment to enhance goal-oriented policy design. The paper applies the proposed method to a case study of a large industrial wastewater treatment plant in Brazil. The authors claim that the tool systematically served the purpose of guiding and facilitating the process of decision-making among stakeholders and experts. Limitations included the difficult iterative learning process experienced by theme experts and the lack of priority for cluster of resulting policies suggested at the outcome of the process.

The special issue also depicts two agent-based models (ABM) that evaluate details of policy performance features. Both papers try to illuminate and anticipate the response societal groups are more likely to display factoring in internal social mechanisms.

A. Székely et al. present "Countering Protection Rackets Using Legal and Social Approaches: An Agent-Based Test," in which they balance benefits of strong legal measures against coordinated social approaches but also a combination of both. In fact, the authors claim to consider and integrate influence from *Homo Sociologicus* and *Homo Economicus* alike. In the model, the notion of the 'salience of a norm' and its measurement along with a calibration process help make it more theoretically and empirically grounded. In short, the agents of the model are the State (implementing legislation) and the NGO (fostering social norms) acting upon the core, complex-behavior duet of entrepreneur and consumers within the Mafia influence. Validation is achieved via participatory modeling but also through comparative historical data analysis. Although not definitive, results suggest

that a combination of legal and social approaches is socially preferable.

H. I. Brugger et al. also investigate features of alternative policy scenarios within (income) groups in "Equity of Incentives: Agent-Based Explorations of How Social Networks Influence the Efficacy of Programs to Promote Solar Adoption." Rather than observing overall increase in solar photovoltaic (PV) adoption, the paper emphasizes unequal distribution of adopters given by segregated network effects. The model theoretically tests different structures of influence on the next adopter. Thus, four alternatives of incentives are tested against extreme levels (low and high) of network segregation. Feed-in tariff keeps fixed rates for energy that is fed into the grid; leasing equipment comes from third parties; and seeding supports initial adopters in given neighborhoods. Alternatively, there is also a comparison with zero incentives. Among the tested cases, feed-in tariffs were the one found to produce larger inequalities among consumers, whereas leasing is in pair with the scenario with no incentive. The author strengthens the argument that underlying network structures may be relevant when designing policy.

The work by R. Azghandi et al., "Minimization of Drug Shortages in Pharmaceutical Supply Chains: A Simulation-Based Analysis of Drug Recall Patterns and Inventory Policies," studies, using a mathematical model, the pharmaceutical supply chain in order to understand the behavior of the drug shortages under different disruption patterns. This problem is of relevance to public policy as it must, in principle, ensure that any drug is available to patients at healthcare centers. This is a problem that official healthcare administrators and other stakeholders of supply chains continue to face. The authors use a mix of simulation modeling and data envelopment analysis approaches.

From a policy and regulatory point of view, understanding the characteristics and instabilities brought by the financial interrelations between variegated actors is fundamental. These interrelations can be represented in terms of a *financial network*. Contrary to stylized models in the former literature, such networks exhibit a nontrivial topology. Their characterization is fundamental, as it is the study of economic processes over them. In Y. Tang et al., "Complexities in Financial Network Topological Dynamics: Modeling of Emerging and Developed Stock Markets," the authors study the interplay between the topological structure of the price correlation network and the emergent market behavior. In their paper, they analyze the stock markets of the two largest world economies (China and USA), unveiling fundamentally different properties in the two stock markets, as also revealed by price movements. While the paper discusses portfolio applications, the authors call for the interpretation from the policy-making point of view.

In this special issue, another agent-based model is introduced to study a specific financial network: that of the interbank exposures. In this setup S. Davidovic et al., in "Liquidity Hoarding in Financial Networks: The Role of Structural Uncertainty," study the dynamics of confidence in the presence of different kinds of shocks. The model is microfounded including the balance sheet of the bank. Interestingly, the authors study the spreading of local impacts

in confidence in cases such as sudden shocks, leading to the system breakdown. With respect to policy-making, the results suggest the importance of rapid bailouts and the need for regulation designed to improve overall transparency in the financial system.

In a similar direction, the problem of fund investment is tackled by X. Yue and X. Sue, in "A Novel Decision-Making Approach to Fund Investments Based on Multigranulation Rough Set." In this paper, a multigranulation rough set decision method is used to construct the fund investment decision information system; then, the fund investment decision information system is reduced at different thresholds, the decision rules are extracted by reduction and the rules are analyzed, and finally the decision rules are given using fund investment.

In a somewhat different venue of research, G.-Y. Shi et al. analyze the stable marriage problem (SMP) and propose a theoretical generalized form for SMP, along with average happiness achieved. Indeed, the paper "Instability in Stable Marriage Problem: Matching Unequally Numbered Men and Women" focuses on the application of GSMP for unequal sized matching groups. The GSMP could be applied to any matching problems such as clients and servers, peers in a P2P network or, more generally, allocation of limited resources across interested users. Their results suggest that the advantages of the active side are typically observed on the Gale-Shapley algorithm reverses on the GSMP when the active side has a higher number of individuals. Further, GSMP suggests that results are highly sensitive to group size.

In a related research line, Y.-X. Kong et al. in "Competition May Increase Social Utility in Bipartite Matching Problem" study again the stable marriage problem and in the context of competition (instead of random matching, as in the original Gale-Shapley formulation). In this context, they introduce a global measure for the social utility. Interestingly, they find that, under this condition, competition increases the overall social utility. They also show imbalances in the size of the two groups can change dramatically with respect to the symmetric case.

In "Congenital and Blood Transfusion Transmission of Chagas Disease: A Framework Using Mathematical Modeling" E. Ramalho et al. study the dynamics of Chagas disease in cases where there is no vector. The importance of this case can be understood in the mobility from places with such vectors, for example, Latin America, to places like Europe. The authors use a ODE-model in order to evaluate the epidemiological effect of control measures. It was applied to demographic data from Spain and sensitivity analysis was performed on model parameters associated with control strategies.

N. M. R. Ahmad et al., in "Analyzing Policymaking for Tuberculosis Control in Nigeria," study one of the major causes of death by an infectious disease worldwide. The authors focus on the tuberculosis control in Nigeria. Using a sophisticated mathematical model they aim to analyze effective strategies that could be used in policy-making to effectively reduce Tuberculosis.

M. Jovanovic et al. in "SOSerbia: Android-Based Software Platform for Sending Emergency Messages" present a platform used in smartphone devices to be used in emergency situation. This platform is experimentally used as a part of the emergency response center at the Ministry of Interior of the Republic of Serbia. In their work they empirically demonstrate how the treatment of complex information in coordination with public forces can be of use in order to be more effective when applying public policy.

K. Yoo and S. Blumsack analyze "the Political Complexity of Regional Electricity Policy Formation." The authors focus on a very important aspect of energy supply: any technological change in electric power systems required from one part physical systems adapts to integrate new technologies and market players but also policies and rules adapt to support that technological integration.

The products produced, imported, and exported by a given country determine its profile. Different representations are possible of this world trade network. It found in the last decade that such profile largely determines the development of nations. Conversely, the set of nations that produce, import, or export specific products are indicators of the complexity involved in its production. In the last years, a wealth of studies has delved into this research direction. In policy-making, prediction is helpful as it can help practitioners to solve practical problems and advise meaningful strategies for the future. In the special issue, H. Liao et al. "Enhancing Countries' Fitness with Recommender Systems on the International Trade Network" analyze the export data of countries within the World trade. They introduce a methodology akin to recommender systems to identify products that correspond to the production capacity of countries, which are however overlooked by them. By a minimalistic modeling they simulate the evolution of country's fitness if changes in the product profile of the country are changed, following the policy recommendation. Interestingly, the recommendation seems to capture the countries' technological evolution by making correct out-of-sample predictions of different economic indicators.

In a related line of research, M.-Y. Zhou et al., in "Quantifying the Robustness of Countries' Competitiveness by Network-Based Methods," deal with quantifying the robustness of countries to fluctuating economic conditions. The long-term aim is to provide policy-makers with indicators of fragility that allow for construction of efficient policies to overcome it. Specifically, the authors develop indicators to characterize the robustness (or stability, as they frame it) of countries against unexpected economic recessions. They resort to different approaches (the celebrated Fitness-Complexity approach and a method of reflections). Interestingly, they find that the characterization through Fitness-Complexity yields countries which have strong robustness against economic crises.

We—as Editors—are glad to have been able to put together a relevant number of papers, from a wide spectrum of disciplines—from economics to sociology and from physics to medicine and engineering—and traditions to a united core of applied policy modeling environment. Clearly, network, agent-based modeling, and mathematical simulations come to fore as preferable tools of the craft. Much is yet to be discussed, mainly, from our perspective, validation,

replication, and comparative studies. We hope you enjoy the diverse contents and methods that are represented in the following collection.
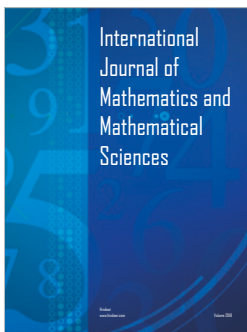
Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper. The editors declare that they have no conflicts of interest regarding the publication of this special issue.

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