Exploration of the Parameter Space in Macroeconomic Models

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Abstract

The global economy can be described as a complex adaptive system where large numbers of heterogeneous agents interact in parallel. The evolution of this system gives rise to emergent phenomena such as business cycles, inequality or even crises and crashes. Agent-based models (ABMs) are computational devices for simulating artificial economies that generate these emergent phenomena. This makes ABMs excellent *scenario-generators* that can be used to understand the spectrum of possible paths for the economy. Unfortunately, the versatility of ABMs means that they suffer from the "wilderness of bounded rationality" both due to the large number of parameters and the different choices of behavioral rules. They have been described as "black boxes" able to generate any phenomena. Consequently, it is imperative to understand the full set of possible generated phenomena how robust they are to changes in parameters.

Our research provides a first answer to the question of *what are the different types of dynamics that an agent-based model can generate?* In the present paper, we establish which parameter combinations are most influential on observed dynamics. We find that across models, only few parameter combinations matter. Using this, we develop an algorithm to systematically uncover the set of possible dynamics that an agent-based model can generate, and apply this to a medium-sized ABM. Our method is able to recover the full set of dynamics in only a few steps.

Research by Gutenkunst et al. (2007) has shown that there are generally only a few *stiff* directions in the parameter space that significantly change the observable dynamics. Conversely, there are many *sloppy* directions in which there are no significant changes in the model dynamics. We apply this idea to six macroeconomic models including a medium-sized ABM and five Dynamic Stochastic General Equilibrium (DSGE) models. All models are sloppy: their observable dynamics change significantly only in a handful of directions. These stiff directions are not aligned with the bare parameter axes, suggesting they may be missed by one-parameter-at-a-time variations.

In the DSGE models, the key directions are dominated by the parameters governing the exogenous shock processes, while deeper economic parameters typically have little influence. In the ABM, the stiffest directions are dominated by parameters relating to *phase transitions* in the model. We study the medium-scale Mark-0 ABM of Gualdi et al. (2015), which has several phase transitions between different dynamics in the model's output. Focusing on the dynamics of unemployment, in the two-dimensional case the stiffest parameter combinations point towards the nearest phase transition. In the presence of multiple close transitions, they point towards these directions sequentially according to the distance of the transition. Exploiting this idea, we build an algorithm to step along these stiff directions to systematically explore the phase space within a given computational budget. In the case of the Mark-0 model, we show that this approach can efficiently recover all possible dynamics for the unemployment rate for both the low-dimensional and high-dimensional cases. Our method therefore provides a useful tool to navigate the space of parameters to find abrupt changes of behavior and their parameter dependencies.

Our approach is exploratory and agnostic, with no prior assumptions about the dynamics we are seeking, such as to provide an understanding of the full set of possible phenomena that can be generated by the model. We do this through intelligent sampling of the parameter space by exploiting the stiffest directions. An agnostic approach is crucial when some emergent behavior is truly unexpected, as is indeed often the case. Our method complements existing meta-modeling approaches, as the discovery of different phases can facilitate a more precise

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criteria for the classification of parameters by the meta-model. In this way, one could identify new phases using our algorithm, and determine the phase transitions using a meta-model to get a full picture of a macroeconomic model.

References

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