Macroeconomic simulation models and causal inference: the challenge of complexity

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A major task of macroeconomics is to devise tools to perform policy analysis, and, specifically, to predict the dynamics effects of interventions (e.g., fiscal, monetary or energy policy) on key time series (e.g., GDP, unemployment, inflation, CO2 emissions). Traditionally, this task has been performed using formal economic models, i.e., as Heckman (2000) put it, "logically consistent systems within which hypothetical 'thought experiments' can be conducted to examine the effects of changes in parameters and constraints on outcomes". Large-scale structural models developed in the 1960s have evolved in Dynamic Stochastic General Equilibrium (DSGE) models, built on microeconomic equations in which optimizing behaviour is explicitly formalized. Such models have been under fierce attack, since their behavioural assumptions are disputable and, moreover, there is a critical mismatch between theoretical concepts and empirical stylized facts (see Canova and Paustian 2011, among others). As alternative policy tools, especially in the wake of the financial crisis and the great recession, many scholars have proposed agent-based models (ABMs), which start from more plausible assumptions about individual behaviour. The idea here is to simulate interactions of heterogeneous entities and assessing their effects on the system as a whole. This approach turns out to be particularly well-suited to answering policy questions in settings where complexity, heterogeneity, networks, and heuristics play an important role (Haldane and Turrell 2019).

Policy analysis performed by simulation models (no matter whether DSGE or ABMs) is reliable insofar as the models' causal dynamic structure is "valid", i.e., it adequately represents the structure of the target system. Only under this condition it is possible to robustly predict the effects of interventions or, in other words, to warrant causal claims. Although there might be different views on the meaning of causal inference, it is widely accepted that a causal claim is well-accepted when it accounts for both a probabilistic/counterfactual dependence (e.g., by showing, through an experimental design, that an average difference in outcome between two different treatments can be attributed only to the treatments) and a mechanism that shows the processes, the dispositions of entities and activities, by which the effects are generated or brought about by the causes (see Hall 2004). Implicitly or explicitly, many scholars seem to justify causal inference via simulation models by relying on a sort of abductive argument (or "inference to the best explanation"): the calibrated model replicates so well statistical patterns, the argument goes, that the modelled mechanism should be true (see Manzo 2022, 94).

A major problem with this argument is that it is possible to calibrate different types of models (e.g., ABMs vs. DSGE models) so that, for some configurations of parameters, they both replicate well a given set of stylized facts. There is, in other words, a problem of observational equivalence or, in the econometric jargon, a problem of identification that undermines the abductive justification of causal inference. I argue that the lack of identification is strictly connected with specific features of macroeconomic modelling and macroeconomic time-series data, namely ergodicity, instability under intervention, violations of the stochastic equicontinuity condition, aggregation and heterogeneity. While macroeconomic simulation models tackle some or most of these issues (e.g., ABMs explicitly deal with the problem of heterogeneity and DSGE models with the problem of instability under intervention), these nevertheless create objective difficulties for identification, calibration, and validation.

My claim is that simulation models as policy tool can increase reliability in warranting causal claims by adopting calibration and validation methods that are deliberately designed for the purpose of causal inference. Building on Martinoli et al. (2021), I present a general scheme for calibration and validation of simulation models. The idea of this scheme is to associate to a macroeconomic (simulation) model a causal structure, which can be formalized by a graphical causal model, and to measure its ability of matching the causal structure representing an observed data set. This involves three levels of inference: from the data generated by the simulation model to a model's causal graph, from observed data to a second causal graph, and, finally, from the two inferred causal graphs to a validation measure. Uncertainty associated with these types of inference can be controlled and analyzed from a statistical point of view and I argue that the first two types of inference can be handled in a pragmatic way that avoids the introduction of further a priori assumptions. This is because, for the sake of validation, not the entire causal structure should be unraveled, but only key features of it, namely how shocks affect variables, i.e., what we call the "independent component representations." Some objections that can be raised against the causal inference approach to model validation will be discussed and I contrast this approach with the practice of validating ABMs by matching stylized facts and the practice of evaluating DSGE models by fitting specific statistical properties of (reduced-form) time series models.

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