Agent-Based Models for Economic Policy Design

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Abstract: *Agent-based simulation models are used by an increasing number of scholars as a tool for providing evaluations of economic policy measures and policy recommendations in complex environments. Based on recent work in this area we discuss the advantages of agent-based modelling for economic policy design and identify further needs to be addressed for strengthening this methodological approach as a basis for sound policy advice.*

Economic policy advice requires a thorough understanding of the relevant economic mechanisms that are responsible for the (overall) effects of policy measures in the economy. Policy advice based on models where aspects, that crucially affect real world effects of the considered policy measures, are missing might be flawed and result in misleading recommendations. Theoretical work based on certain model structures accompanied by empirical evidence aims at giving us guidance on the causal relationship of key economic variables. Methods for the analysis of such relationship within established classes of (typically equilibrium) models, by means of analytical, numerical or econometric approaches are well developed and continuously improving. However, a key challenge, when providing policy advice, is that we have to select among the various explanations for certain economic phenomena. It is hardly the case – maybe never – that only a single school of thought or an exclusive methodological approach is able to explain a set of observable economic relationships. There are different explanations for business cycle fluctuations, the distribution of income or the role of human capital investments for economic growth just to name a few topics that policymakers care about. However, the choice of the modeling approach (which aspects are in, which are out) and the tools of analysis might crucially influence the predictions of effects of policy measures and even the set of questions about policy effects that can be sensibly addressed in the framework of the model.

Obviously, the assertion which aspects of the economic environment have to be captured in order to provide meaningful policy advice on a certain issue is highly subjective – a prime example of differing subjective viewpoints in this respect is the controversial debate about the appropriate modeling strategy in macroeconomics and financial economics in the aftermath of the 2008/09 economic crisis (see Colander et al. 2009, or Schneider and Kirchgässner 2009) – and we will not attempt to resolve the issue of how to select among different modeling approaches. Rather we would like to make a few points how a fairly new protagonist in the area of model-based economic policy advice - agent-based models – can enrich the possibilities of a modeler to capture economic phenomena that seem relevant to policy makers and extend the set of questions that can be asked about policy effects. Also, we briefly point to

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several issues that need to be addressed in order to make the approach even more useful and applicable for the economic policy analysis.

Agent-based modeling is a strongly micro-founded approach to studying economic dynamics. It is interested in the emergence of patterns at aggregated levels of analysis that origin from the interaction of agents, who follow particular behavioral rules and may be constrained in their choices by various institutional arrangements. Within the last decade or so many scholars have made important contributions to the area demonstrating the value added that can be derived from agent-based modeling for a better understanding of economic and more broadly speaking social phenomena. A large part of these contributions is documented in the special issues in the Journal of Economic Dynamics and Control, Computational Economics and IEEE Transactions in Computational Economics all edited by Tesfatsion (2001a, 2001b, 2001c), a special issue in Advances in Complex Systems edited by Contini et al. (2004) and the Handbook of Computational Economics edited by Judd and Tesfatsion (2006). Particular emphasis on the use of agent-based models for economic policy design has been put in special issues in the Journal or Economic Behavior and Organization edited by Dawid and Fagiolo (2008) and in the Journal of Economics and Statistics edited by LeBaron and Winker (2008). Apart from these collections numerous articles were published in various economics journals including the Eastern Economic Journal.

The purpose of this paper is not to review the existing published work on agent-based models for policy advice, but to try an assessment of the merits and problems of agent-based models as a solid basis for economic policy advice that is mainly based on the work and experience within the recently finished project EURACE ('An Agent-based Software Platform for European Economic Policy Design with Heterogenous Interacting Agents: New Insights from a Bottom-Up Approach to Economic Modeling and Simulation') which was carried out 2006-2009 in the framework of the European 6th framework programme by a consortium of economists and computer scientists (see e.g. Deissenberg et al. 2008). The agenda of this project was to develop an agent-based closed macroeconomic model with strong empirical grounding and micro-foundations that provides a uniform platform to address issues in different areas of economic policy. Particular emphasis was put on the possibility to generate an implementation of the model that allows for scaling of simulation runs to large numbers of economic agents and to provide graphical user interfaces that allow researchers not familiar with the technical details of the implementation to design (parts of) the model as well as policy experiments and to analyze simulation output.

Analytical models often require a restricted analysis for reasons of tractability. This is even true for general equilibrium models that lump together various factor and output markets and their interactions via prices and quantities. Although these models already go a long way and are by no means easy to handle and solve, policymakers have more ambitious problems to address. Just think about a constituency that is populated with heterogeneous households that differ in their skill endowment across space. Typically a policymaker will want to know how a particular policy measure, as for example how to improve the acquisition of general skills, will impact the distribution of household income over time and space. In the EURACE project topics like these have been dealt with. While the primary aim of this endeavor was to show that it is technically feasible to program a software platform that allows the study of emergent phenomena including a spatial dimension and heterogeneous groups of society as an

agent-based model, we were already able to show that an approach like ours can go beyond existing models used for policy advice and give additional insights.

In Dawid et al. (2009a) a scenario of an economy consisting of two ex-ante symmetric regions is considered, where consumption goods can be transferred between the regions without costs whereas movement of workers between regions is associated with commuting costs. A policy maker plans to invest effort to increase the general skills of workers and it is examined how the spatial allocation of this policy measure (i.e. whether general skills are symmetrically upgraded in both regions or all upgrading is concentrated in one region) affects the economic dynamics in both regions, their relative performance and the dynamics of total output. It is shown that the effects of the two considered policies with respect to macro variables like (regional) GDP depend crucially on the spatial frictions on the labor market. A careful examination of the interplay of dynamics of various micro level variables like (skill) specific worker flows between regions, production costs, prices, sold quantities and investment exposes the causal chains of effects leading to the differences in policy effects under different spatial frictions on the labor market. In a nutshell, under asymmetric skill upgrading policies labor market frictions lead to temporary differences in production costs between the two regions, which induce demand shifts towards producers located in one region and, because physical capital is immobile, induces a strong demand for new capital goods in that region. In the EURACE model, as in the real world, investment of production firms in new capital goods is the key driver for diffusion of new technologies in the economy and therefore the large investments of production firms in one region induces a fast increase of productivity in that region, which in turn reinforces the relative cost advantages. This analysis highlights the economic mechanisms responsible for the positive effects an asymmetric skill upgrading policy has relative to a symmetric one in the scenario where spatial frictions on the labor markets are positive, but not so large that movement of labor between regions is excluded.

In general terms we have demonstrated how temporary imbalances generated by spatial frictions induce long term effects through the dynamic interaction of different markets – labor, consumption goods and capital good markets – and spatial flows. Furthermore, the spatial flows are not uniform across skill groups and therefore generate dynamic changes of the (relative) skill distributions in the different regions. Although this pattern is far from trivial the use of a micro-founded agent-based model allowed us to clearly highlight the reasons for the observed path dependency.

As usual for theoretical models our claim is not that our model and hence the identified causal chains capture all aspects relevant in the real world. Rather, we provide insights into the effects of the considered policy measures within the context of a model that, although not all encompassing, is able to capture institutional aspects, like different degrees of frictions on different markets, and spillovers through labor flows. An additional point to be highlighted is that the use of an agent-based simulation model allows us to distinguish between short- and long run effects of policies, which might substantially differ even in qualitative terms. This point has been stressed even more in Dawid et al. 2009b, where the implications of different patterns of labor market integration between regions with asymmetric local endowments with skills and physical capital has been examined within the framework of the EURACE model.

Agent-based models, as we were trying to illustrate also with our previous example, are strong in providing a testbed for the study of policy questions targeting the medium and long run by basing the analysis on economic mechanism that may unfold as a response to a policy intervention. Although a large amount of data is typically produced by theses models – in the extreme every agent with all his characteristics can be traced over time – and progress has been made in the calibration of agent-based models (see, e.g., Windrum et al. 2007,) a quantitative application of agent-based models for forecasting seems for us, at least currently, not feasible. Agent-based models can do well in replicating stylized facts but are at least currently not well suited for forecasting the business cycle. They have the ability to give meaningful insights on the effect of policy measures for the medium and longer run. This stems from the deliberate modeling of the heterogeneous agents' interaction in a spatial context with the inclusion of various factor and product markets. Only if this kind of economic structure is included in a model we will be able to study economic phenomena following policy interventions kicking in as feedback processes unfold. Even if it is at the current stage difficult or not yet feasible to quantify effects on output, growth or distribution measures, the possibility to at least qualitatively study the consequences of policy measures should be highly valued.

It also occurs to us that many economic phenomena relevant for a sound policy advice cannot be captured with representative agents or mean field approximations appropriately. Let us exemplify this point by looking again into a modelling structure akin to the previously sketched one. In a growth context, one could postulate that the adoption of new technologies on the firm level is a function of the specific skills of workers, which may adapt faster to the technological frontier with higher general skills endowments of workers. Modeling carefully the time path of specific skills adoption requires the investigation of employment and unemployment patterns, as on the job learning will be the driver of the adaption of the specific skills as individuals are confronted with the more advanced technology at the firm level. Thus, a careful analysis should not only take into account the differences in specific skill upgrading between employed and unemployed, but also the fact that transitions into and out of unemployment systematically depend on workers' specific skill levels (workers with higher specific skills on average have shorter durations of unemployment). An explicit consideration of these dynamic implications of agents' heterogeneity contributes to a better understanding of the effects of policy measures targeting the general skill level of labor market transitions. The general point that explicit consideration of agents' heterogeneity might indeed lead to qualitatively different policy recommendations compared to a model where only dynamics of 'average' agent characteristics are captured has recently been clearly made in Arifovic et al. (2010) in the context of a standard policy commitment problem.

A particular obstacle for selling sound economic policy advice to the policymaker is often that our addressees are not used to think in economic models or, more generally, the principle of abstraction for doing thought experiments. As they do not see a model which reflects their perception of the world advice based on highly abstract vehicles of thinking is likely to be rejected. Agent-based models may be less prone to be rejected by policymakers as they usually are characterized by a lot more economic structure. This is not to say that an agent-based modeler would choose any other general approach of building his model than a more orthodox economist. It is rather the larger toolbox that agent-based

models offer which allows him to bring into the picture features of the system that policymakers may find more convincing. Agents can for example be endowed with different behavioral rules which policy makers recognize from own experience. It is feasible to model an economy along its spatial dimension, and institutions can be incorporated in a much more fine-grained way as in more traditional approaches. As the policy-makers part is usually about deciding on the institutional environment and possible changes of that, having a more accessible model in that respect may be of great value for a fruitful interaction between policy advisers and policymakers.

While most of our discussion so far focused on how to write down an agent-based model that brings into the picture a simultaneous analysis of various non-negligible institutional, spatial or economic features for a better policymaking, an underdeveloped branch of agent-based modeling is certainly the positive analysis of economic policy making. Early work by Kollman et al. (1997) already showed the way how to study the variance in economic policy choices when individual preferences are aggregated up under different voting mechanisms. It occurs to us that agent-based models are far from being fully exploited as a means of positive policy analysis. More should be done to bring together a meaningful economic model with an equally meaningful political model that does justice to the intricate rules which characterize democratic societies and shape policy outcomes.

Admittedly most of our selling points had the flavor of “we – the agent-based modelers - can do more”. This should not be misunderstood as an argument that in general bigger models are better. Quite on the contrary, it seems crucial to us, that, regardless whether analytical or simulation methods are employed, models are carefully built in a way that only those aspects of the economic environment which seem directly relevant for the policy question at hand are modeled in some detail. A closed macroeconomic agent-based model has to contain all relevant market, but this does by no means imply that all these markets have to be modeled with identical granularity and institutional richness. Nevertheless, closed macroeconomic agent-based models typically are quite large and building big models requires big computing power. But machines that potentially can do the job exist and are used by other professions like meteorologists or physicists. However, a lesson learned from our EURACE project was that running economic models on parallel machines brings up new and non-trivial problems. The reason behind these technical issues is quite intuitive: parallelization requires the slicing up of a big task into digestible smaller chunks. The question becomes how to cut through an economic system. An obvious candidate is the spatial dimension of an economic model, i.e. to allocate the computing to be done for a particular region to a particular processor. However, as there is considerable interaction between regions as in economic models factor and product markets are typically highly interdependent across regions via the flows of worker, capital, intermediate or final goods, a lot of communication between processors has to be organized which can considerable slow down the computing. In order to be able to use agent-based models for economic policy advice in a way we sketched it, problems of parallelizing code or in general computing issues need to be resolved. In addition and coming back to our argument of convincing policymakers of the appropriateness of the framework on which the policy advice is based, easy to use and intuitive graphical user interfaces (GUIs) need to be developed. Ideally, at some point these GUIs would be so user-friendly that any interested person would be able to run his own simulations.

Another issue down the road, which we find important as we want to proceed to using agent-based models for economic policy advice, are the behavioral foundations of the (heterogeneous) agents that populate our models. Once we deviate or even abandon the perfectly rational agent there are many degrees of freedom on what to assume for the behavior of an agent, may it be a worker, firms or a government agency. In the EURACE project we followed the modeling philosophy to apply management rules for modeling firm behavior. For most decision problems firms face the management literature offers standard procedures (which are often heuristic methods). Examples are specifications on how firms plan their production volume or replenish their stocks. Some of these suggestions are even implemented in standard software that is purchased by firms to automatize on these operational management decisions. As we want to base the policy advice on models where firm behavior is as close as possible to the performance of real world firms it seems natural and also for outsiders convincing to rely on such standard rules where available. For the modeling of the behavior of individuals a promising approach seems to be incorporate findings from experimental studies. These findings make a strong point for the existence of heterogeneous types of agents in a population (see, e.g., Plott and Smith, 2008). We need to link to these research outcomes more closely to our agent-based models. It will not only strengthen the scientific foundations of the models but also make them for outsiders a more convincing tool for policy advice. After all, how reliable, for example, is a model as a basis for pension policy recommendations, if it does not take into account that people look forward differently when deciding on old-age savings rather than on other economic issues?

We believe that in many circumstances agent-based models have a menu to offer that allows us to incorporate into our models economic, institutional and behavioral structure. This provides a sound starting point for economic policy advice and allows to address issues and phenomena that can hardly be captured by alternative approaches. Nevertheless, as is the case with other methodological choices, there are limitations involved and these should be clearly communicated when putting forward agent-based policy analyses to avoid misunderstandings. We expect that future work in this area will reduce the limitations of the approach and make it an even more appealing tool.

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