Analyzing the Macroeconomy: Dynamic Stochastic General Equilibrium Modeling versus Agent-Based Modeling

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Dynamic Stochastic General Equilibrium (DSGE) models have become one of the main work-horses of macroeconomic analysis. Their impact has been particularly strong within the central banking community, where policy analysis, policy simulation as well as forecasting are based on this class of models. More recently, these models have received a fair amount of criticism both from within and from outside the academic community. In this debate, agent-based models have frequently been discussed as potential competitors to DSGE models for modeling the macroeconomy. Like DSGE models, agent-based models describe economic behavior at the individual level; unlike DSGE models, agent-based models use the simulation capacity of modern computing technology to analyze the aggregate implications of individual behavior, enabling the analysis of a wide range of behavior, the description of fairly complex institutions as well as the study of system dynamics both out of and in equilibrium. In a research workshop held at OeNB on June 15 and 16, 2011, these competing modeling strategies were contrasted with each other to contribute to the discussion about the relative merits and problems of both approaches.

When economists try to understand phenomena like growth, unemployment, distribution, inflation and financial stability – in short the macroeconomy – they try to do so using models and abstractions that try to see through the stunning complexity of economic reality. Within the social sciences, this use of formal modeling is with few exceptions quite unique to economics. It has given the field a fairly technical nature, and thinking in terms of formal models has become a proudly cherished skill of many economic researchers. The traditional models used by economists have recently become contested by alternative approaches that rely very much on computer simulations and that have their origins in research on complexity and complex systems mainly in the field of physics, biology and other sciences. From the perspective of these contestants, the economy is very much like a living system in general: It is a complex, dynamic, adaptive system. According to Gintis (2009)[2], such a system "consists of a large population of similar entities who interact through regularized channels (e.g. networks, markets, social institutions) with significant stochastic elements, without a system of centralized organization and control. A complex system is adaptive if it undergoes an evolutionary process of reproduction, mutation and selection." At this level of abstraction, many economists would recognize their modeling efforts as trying to achieve a deeper understanding of exactly these kinds of systems. The debate then seems to deal with the question of which modeling tools are likely to be most effective at making a complex system like the economy comprehensible. To focus the debate, the workshop tried to shed light in particular on models of the macroeconomy that would roughly fit into the framework of so-called dynamic stochastic general equilibrium (DSGE) models – a model class particularly popular among central banks – and papers that take an agent-based approach to macroeconomic modeling.

In his opening remarks, *Peter Mooslechner, Director of the Economic Analysis and Research Department of OeNB,* tried to put the debate into perspective by framing the issues along the lines of microfoundations and equilibrium analysis. For reasons that are arguably quite intrinsic to the theoretical features of general equilibrium modeling, the DSGE models used in practice end up in a form where the macroeconomy is explained as the result of the solution to a very complex decision problem in a very simple economic environment. Agent-based models, while also building on descriptions of individual behavior, end up at the other end of the spectrum: In an agent-based model, individuals solve very simple decision problems in a very complex environment that no individual understands in its entirety. In his view, general equilibrium analysis has become particularly popular in macroeconomics because it is one of the few system theories that economics has developed. Clearly, the simultaneous interaction of many key markets rather than the partial analysis of single markets in isolation are at the heart of the key problems in macroeconomics. Moreover, general equilibrium theory offered the attractive feature of linking economic aggregates to theories of individual behavior at a time when the economics community no longer accepted the modeling of economic aggregates without so-called microfoundations. Using a framework that was dynamic rather than static, stochastic rather than deterministic and based on general rather than partial equilibrium analysis was clearly attractive for researchers. As became clear in the discussion at the workshop, the agent-based models seem, however, to be haunted by some old problems economists have been struggling with in their models for a long time; most im-

portantly the question of what could be a useful and coherent theory of expectations.

On the issue of equilibrium thinking, Mooslechner pointed out that equilibrium analysis in economics comes from the attempt to have a parsimonious description of system behavior that takes human reasoning into account. While DSGE models provide a sophisticated and elaborate description of equilibrium, they have never been able to develop this theory into a dynamic process description of how equilibrium is reached and how the system behaves out of equilibrium. Agent-based models, by simulating the full system dynamics, show the full system behavior. If there is an equilibrium state in an agent-based model, the simulation shows how the equilibrium is reached and allows the analysis of adjustment and of out-of-equilibrium behavior. The system dynamics are endogenously driven by agent behavior and do not simply rely on exogenous shocks. In this respect, agent-based models seem to take up some themes that were of crucial importance in earlier macroeconomic analysis, in particular in Keynesian macroeconomics, where distinctions between the short, medium and long run played an important role. While it is true that agent-based models describe the full system dynamics, the presentations showed that their very complexity also makes it difficult to understand at a deeper level how the system works.

Obviously, both approaches have a few open questions. What, then, were the answers given at the workshop?

The Diversity of Agent-Based Models

The first day of the workshop gave the floor to some prominent researchers from the agent-based modeling com-

munity, with discussants coming mainly from more mainstream economic research. While three papers presented gave a more general methodological perspective on what agent-based models are and what they look like, one paper took up some more specific research questions from financial economics which could be contrasted with a traditional macro paper studying financial crisis and macroprudential policies.

The presentations made clear that agent-based modelers are not working within a single model class. Researchers seem to be using agent-based models with quite different goals in mind. The presentations by *Herbert Dawid, University of Bielefeld* ("Agent-Based Computational Modeling and Macroeconomics") and *Domenico Delli Gatti, University of Milan* ("Macroeconomics from the Bottom Up"), suggested, for instance, that the main aim is the construction of models that, in contrast to models commonly used in economics, incorporate more institutional details, more detailed descriptions of individual behavior up to even realistic spatial and topographical structures that act as constraints for trading relationships, in short: More detailed and thus (hopefully) more realistic models of the economy.

J. Doyne Farmer, Santa Fe Institute, suggested in his presentation that traditional economic models were not good enough to lead to a correct qualitative understanding of economic interactions, to reproduce stylized facts in the data and to be useful in time series forecasting. Despite some past achievements, according to Farmer, the agent-based models are not yet particularly good enough, either, along all of these dimensions, but hold out the promise of eventually leading to better models than those that have been used so far in

traditional economics. His overview presentation was colored by the competitive ambition to make agent-based models part of the standard tool kit of economic modelers. This spirit of a modeling contest should be attractive to the economists who frequently lecture about the socially beneficial role of competition.

Finally, *Quamrul Ashraf, Williams College,* presented a paper coauthored with Boris Gershman and Peter Howitt ("Banks, Market Organization and Macroeconomic Performance") that was geared strongly to the better understanding of a traditional and deep problem in economic theory, namely: Which process and what institutional structure would be able to bring about equilibrium prices? The agent-based approach allows for describing and simulating such a process and for studying its properties in specific applications.

How Do Equilibrium Prices Come About?

Given its close relation to models used in the DSGE tradition, the paper by Ashraf, Gershman and Howitt is thus perhaps most suitable for a direct comparison at a methodological level with the DSGE paper about "Financial Crisis and Macroprudential Policies" presented by Gianlucca Benignio from the London School of Economics. Both papers deal with aspects of the financial system and financial crisis.

Benignio's paper is a good representative of how economists traditionally set up their models. The research question asked in the paper is whether a competitive market allocation of credit would lead to an amount of borrowing in the economy as a whole that deviates from a socially optimal allocation. The main finding is that if individuals at some stage in their life face a binding borrowing constraint due to collateral

requirements, this will distort the market allocation of credit in a way that there can be both over- and underborrowing in equilibrium compared to a socially optimal allocation. For macroprudential policies, the paper concludes that a financial transaction tax and capital controls would be unsuitable instruments to achieve a socially optimal allocation and are thus potentially harmful. How do arguments like this work in principle?

To contrast agent-based models with DSGE models, it is perhaps useful to briefly discuss how arguments are principally modeled. First, the aggregate behavior of consumption, credit and labor supply (demand) is derived from the solution to an intertemporal optimal decision problem of households with complete and consistent preferences over sequences of consumption and leisure. Borrowing is constrained by collateral requirements that may occasionally impede agents from borrowing as much as they would like. It is assumed that the economy will at each point in time be in equilibrium, meaning that prices and wages adjust to balance the supply of and the demand for goods and labor. This allocation is then compared to the allocation a planner would choose respecting the same collateral constraints. Unlike the agents, a planner would anticipate the aggregate economic effects of the binding collateral constraints and would value wealth differently than the agents. This creates a wedge between the market allocation and the planner solution. In an economy without production, the agents will always borrow more than the planner solution would imply. With production, the interaction between different markets can also lead to under-

borrowing. To identify which case is "typical," the parameters of the model are calibrated. This means that the parameters, e.g. the elasticity of labor supply and the share of labor in production, etc., are set to specific numerical values known from the empirical literature. In a next step, the particular policies are simulated for these particular parameter values. For this calibration, the authors find that typically, underborrowing would occur.

In a DSGE model, it is implicitly assumed that equilibrium is the appropriate concept to look at macroeconomic aggregates. The dynamics and the institutions that would bring about prices that balance supply and demand at each point in time remain unspecified. An unsatisfactory conceptual feature of this approach is that competitive equilibrium – while always described as a model of decentralized, competitive market exchange – at a model level is really quite undistinguishable from a planned economy. If exchange only occurs at equilibrium prices, a strong element of coordination of optimal plans is required; these plans have to be steadily adjusted to allow supply and demand to balance – as if a central clearing institution were solving an intricate fixed-point problem.

It is no accident that this ambiguity of the competitive equilibrium concept fueled an academic debate about socialist planning during the 1930s. Oskar Lange and Abba Lerner,[3] two leading figures in this debate, argued that a state-run economy could be as efficient as a planned economy if only the planner used the same type of price system as in a market economy.

The most famous opponent of Lange and Lerner, Friedrich Hayek, argued

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[3] Lange, O. and F. M. Taylor. 1938. On the Economic Theory of Socialism. University of Minnesota Press. Lerner, A. 1945. Economic Theory and Socialist Economy. In: Review of Economic Studies 2. 51–61.

that the debate misses an essential and deep feature of a market economy. In a famous paper published in 1945, Hayek wrote: "… what is the problem we wish to solve when we try to construct a rational economic order? If we possess all the relevant information, … the problem which remains is purely one of logic … This, however, is emphatically not the economic problem which society faces … The problem of a rational economic order is determined precisely by the fact that the knowledge of circumstances of which we must make use never exist in concentrated of integrated form, but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all separate individuals possess."[4]

What this citation from Hayek suggests is that a model of market exchange must be able to capture two fundamental facts: First, real trades and exchange occur bilaterally, and second, out of equilibrium, there is no common price vector for the economy which agents can take as a parameter for their own decisions. Only through production, consumption, exchange and observing the behavior of others can the system of prices emerging from bilateral exchange perhaps converge to something like a publicly known vector of equilibrium prices.

Ashraf, Gershman and Howitt took this idea as a starting point for their paper. While also concerned with financial markets and macroprudential issues, their model starts from a fundamentally different price formation process.

Instead of relying on a fictitious auctioneer to bring about equilibrium prices, this paper has built in a specific mechanism by which prices emerge: The basic idea derived from Howitt and Clower (2000)[5] is that a self-organizing network of business firms takes on the role of the Walrasian auctioneer. The mechanism of exchange is based on the fact that all trade occurs through a network of specialized business firms which adjust the prices for the products and inputs to a complex and competitive environment that they do not understand in its entirety. Consumers and business firms use simple, opportunistic rules of behavior and adapt to what is going on in their local environment. Since setting up and operating a business firm is costly, the entry and exit of firms causes the aggregate variables of the system to fluctuate over time. When no entry and exit occurs and prices are allowed to be flexibly adjusted in every period, the system has a theoretical steady-state equilibrium where almost all gains from trade are exhausted and the economy works at full capacity. When entry and exit occurs, the system shows an endogenous dynamics very much resembling an ordinary business cycle with some exceptional situations where the whole system spirals out of control and breaks down. This is a setup that allows not only the system in equilibrium but also its out-of-equilibrium behavior and properties to be studied.

This is something that the agent based model is able to deliver and that general equilibrium models have consistently failed at. When Franklin Fisher published a research monograph in the series of the econometric society in 1983 on the topic "Disequilibrium

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[4] Friedrich Hayek. 1945. *The Use of Knowledge in Society. In: American Economic Review. 519–530.*

[5] Howitt, P. and R. Clower. 2000. *The Emergence of Economic Organisation. In: Journal of Economic Behavior and Organisation 41(1).*

Foundations of Equilibrium Economics,"[6] he had to report that research had not made much progress on these issues during the past 40 years. It seems that the same could be said today. So here is an area where the agent-based models really allow the frontier to be pushed a bit further because it permits for studying an economic system at a macroscopic level in and out of equilibrium.

In their paper, Ashraf, Gershman and Howitt build on a model with this price formation process by a self-organized network of business firms to study a stylized model of banking and to examine how banking and finance impact on the mechanism of exchange and the entry and exit of firms. They find some conflicts between micro- and macroprudential goals in regulation as well as familiar boom-bust cycles in which financial institutions exacerbate both booms and busts.

In combining the model with data, the agent-based model proceeds in a fairly similar way to the DSGE model presented by Benignio. The parameters – a much larger set in the case of the agent-based model – are calibrated and the model is simulated using this calibration. This leads to a particular system behavior for individual runs and on average across many runs, and it suggests certain properties of the system.

Thus, while at a certain level both approaches are fairly abstract and stylized, the agent-based model has a price formation process which – while based also on theoretical reasoning only – is much more in line with the fundamental facts of market exchange. But is this

important? Could it not be the case that an abstract analysis of equilibrium captures the salient qualitative properties of the economy as well as a model that has an explicit built-in price formation process? Only research will eventually be able to answer this question. The fact that agent-based models provide a tool that allows for a meaningful investigation not only of applications but of questions about the theoretical foundation of economic theory is certainly one of the attractive aspects of these models.[7]

Are Agent-Based Models More Realistic Models of the Macro-economy?

On the first day of the workshop, three additional programmatic presentations by agent-based modelers all advocated agent-based models on the grounds that they allow for a higher degree of realism in modeling economic systems. At first sight, this claim raises some deeper issues about the ultimate purpose of modeling.

One might argue to the contrary that the goal of modeling is not more realism, but higher abstraction to be able to qualitatively understand whatever phenomenon happens to be in the focus of analysis. Of course, once we have achieved a deeper qualitative understanding of a phenomenon, we would like to reach a level of quantitative understanding, perhaps even a prediction, that makes use of the insights gained. So, as J. Doyne Farmer put it nicely during the discussion, every modeling exercise comprises a scien-

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[6] Fisher, F. M. 1983. Disequilibrium Foundations of Equilibrium Economics. Econometric Society Monographs 6. Cambridge University Press.

[7] My use of Benignio and Ashraf, Gershman and Howitt to discuss the issue of equilibrium price formation does not do justice to the excellent discussions of both papers by Paul Pichler (Benignio) and Piergiorgio Alessandri (Ashraf, Gershman, Howitt), who more specifically took issue with the details of both models.

tific aspect as well as an engineering aspect. Obviously, both aspects should matter in economics. Now, do agent-based models contribute more to the scientific or to the engineering aspect of economics? The presentations did not provide a fully clear answer, but the effort to construct more realistic models seems to be leaning more toward the engineering aspect.

Herbert Dawid, University of Bielefeld, gave a general presentation of the EURACE@unibi model, an agent-based simulation platform that can be used for policy evaluation at a European level. The model can reproduce stylized facts about macroeconomic data and other empirical facts like the size distribution of firms. In a policy simulation, different simulation batches are run for different policy interventions, and then the evolution of key economic variables is analyzed. Such simulations provide insights into policy questions like "what are the effects of labor market integration in the EU" and "what migration patterns between old and new EU member states might one expect as a result of these policies."

J. Doyne Farmer, Santa Fe Institute, gave an extensive overview of agent-based models, their past achievements and some of the general open issues. For Farmer, the key question is whether we are able to model the complexity of the real world. He believes that for many issues we face in economics, agent-based models will eventually turn out to be much more suitable than models based on conventional economic theory. Farmer believes that only agent-based models will eventually do this job well enough to be useful in an engineering sense, citing weather prediction as his frequently used role model.

Finally, *Domenico Delli Gatti, University of Milan,* presented a macro

model with fairly standard basic building blocks – households, firms, banks, government and a central bank. In its model of behavior and in its abstinence from equilibrium thinking, it is, however, clearly and importantly different from a standard economic macro model.

It seemed that the discussants of these papers, who were all from mainstream macroeconomics, were not persuaded that there was much to be gained by adding agent-based models to their modeling toolbox.

Michael Reiter, Institute for Advances Studies, Vienna, in his discussion of Herbert Dawid's presentation pointed out that the attempt to include heterogeneity, local interactions, incomplete markets and bounded rationality can all be handled within the framework of mainstream economics. The really unresolved open question in Reiter's view was how the dynamics of expectations can be modeled beyond mechanical learning rules. In his view, agent-based models have nothing to contribute to push the frontier here, since they use rather myopic and mechanical expectations mechanisms. The particular assumptions made in agent-based models seemed to him to be as stylized as the assumptions in the DSGE literature, and he found no criterion according to which he could judge the importance of assumptions about including particular frictions and deviations from rationality rather than others.

In a similar vein, *Karl Walentin, Sveriges Riksbank,* observed in his discussion of Domenico Delli Gattis paper that all the building blocks and interactions in this particular agent-based macro model are very much like those of any DSGE model, with the exception that agents follow different rules of behavior. He found no compelling arguments based on a priori reasoning

or empirical facts for the particular way in which the behavior is chosen, and found it remarkable that the rules of behavior neither change nor that there is any learning dynamics concerning the behavioral rules in place. He observed that too often, if agent-based modelers choose the DSGE model as an object of critique, they attack a straw man, and that the differences in the ability to model heterogeneity, incomplete markets and frictions between the two model classes are too often exaggerated.

J. Doyne Farmer, too, was confronted by his discussant Mike Wickens, University of York, with the question of on what grounds the merits of an agent-based model would ultimately be judged. Based on J. Doyne Farmer's distinction between engineering and science, he took a clear stance that ultimately economic models must be useful in the engineering sense. According to Farmer, precisely this may be the merit of a more detailed model which is built – in his words – with the help of a lot of "plumbing" and sometimes lacks of mathematical elegance. Farmer conceded, however, that agent-based models have yet to prove that they can do a good job as engineering tools. He personally seemed convinced that they would be eventually be able to do so, provided enough research resources in this direction are mobilized.

Surprisingly, the debate, despite the clearly voiced refusal by the mainstream economists to be persuaded by their competitors, was not really hard-hitting, and in the end the audience was left with the skillful and interesting presentation of two views of modeling the economy without much of a controversial discussion.

The reluctance to engage in an open battle of arguments beyond the contribution by the assigned discussant went both ways. For instance, when, *Frank Smets, ECB,* presented a standard DSGE model in which unemployment arises as a result of market power in the labor market on the second workshop day, he was confronted with a sweeping critique by his discussant, Axel Leijonhufvud, UCLA, in which the discussant concluded that the techniques and concepts applied in Smet's paper were "hopelessly inadequate" as a strategy to come to a deeper understanding of unemployment as well as the financial crisis and its aftermath. This critique, presented in a carefully crafted argument, was left standing in the room without much defense from the speaker, not to mention controversial debate in the audience.

The question of what advantages and disadvantages a more detailed model would have remained unresolved. If we had a model that would be able to reproduce any stylized fact about the economy, would this be a good model? Would it help our understanding of how the economy works? Is criticizing DSGE models really criticizing a straw man, or are there deeper issues that will not be settled with a bit of broader and deeper scholarship of the modern mainstream macro literature? All these questions, obvious and interesting as they might seem for such a workshop, remained essentially on the table.

Modeling Learning and Expectations

Expectations, and the correct modeling of expectations, seem to be one of the big conundrums of both agent-based and mainstream models. The workshop therefore gave some room to papers that come down straight to the matter of expectations and expectation dynamics.

The difficulty in coming to terms with modeling the expectations of economic agents lies in the problem of taking human reasoning correctly into account. While in the macroeconomic literature of the 1960s and 1970s, it was often assumed that expectations are merely adaptive reactions to macroeconomic aggregates, this form of expectation modeling was already then regarded as unsatisfactory because it implied that it was possible to "fool all of the people all of the time." In the subsequent rational expectations literature, this form of expectation formation was given up, and the concept of equilibrium thinking was pursued to its ultimate consequences. In a model where the agents know the model structure and know that prices will adjust to balance supply and demand, the only consistent way of reasoning takes this mechanism into account and forms expectations consistent with the model.

While this description of expectation formation by human subjects seems so obviously false that it does not even deserve further elaboration or debate, it is nevertheless hard to give up this way of reasoning once one has accepted the otherwise standard framework of general equilibrium thinking. Rational expectations are intimately connected to the conceptual framework of general equilibrium analysis in which trade always occurs at a publicly known vector of equilibrium prices. In this highly centralized mechanism of exchange, a rational expectations model almost conceptually enforces itself upon the modeler. If, on the other hand, the world is truly decentralized, as in Hayek's vision of the economic role of the price system or in Howitt and Clower's agent-based model of exchange, all expectations have to be adaptive because the true model of the

economy is unknowable. The whole debate about expectations and expectations dynamics, while seemingly a scholastic debate among insiders, therefore has a deeply conceptual dimension.

Liam Graham's paper "Learning, Information and Heterogeneity" takes up these issues by proposing three departures from a standard macro model. It suggests that equilibrium analysis does not necessarily require rational expectations. Agents are heterogeneous, have limited information and have to learn the structure of the economy. In these assumptions of imperfect information and the inability to form model-consistent (rational) expectations, Graham's models share features of some of the agent-based models. While imperfect information is important for the behavior of the aggregate economy, the inability to form rational expectations has only a minor impact on the properties of economic aggregates. Still, the economy converges to equilibrium. Discussant Markus Knell found this relative minor impact of learning behavior on the aggregate economy surprising and raised the question how far this result could have to do with other structural features of the model.

The question of model-consistent expectations kept popping up during the discussion of Paul De Grauwe's paper "Booms and Busts in Economic Activity: A Behavioral Explanation." De Grauwe presented a model where agents can switch between two behavioral rules in an otherwise standard DSGE monetary macro model: Either they can form expectations according to some fundamental analysis of the economy, or they can follow a trend. Depending on the share of agents behaving according to some particular rule, it becomes more costly for an

agent to stick with this particular rule, and he might eventually decide to switch. This creates boom-and-bust behavior with sharp asymmetries because during the boom the two groups form expectations that go into opposite directions while in busts all expectations point into the negative downward direction. While this model had many more interesting features and some problems, which were addressed by the discussant, Stefano Neri, it mainly led to a discussion of whether the agents who stick to the behavioral rules are rational. It was criticized in the general discussion that if the agents knew the structure of the model, both fundamentalists and trend followers would take this into account and form their expectations model-consistently and thus differently. Is this just sophistic splitting of hairs, or is there more to the discussion? One could argue that if the model really had such a simple structure and the macro economy and monetary policy could be described by the system of three equations as in the paper, then indeed the question why agents do not form model-consistent expectations has some legitimacy. Only in a truly complex environment does the assumption that expectations follow some adaptive process gain plausibility.

Bringing the Models to the Data: Problems and Unresolved Issues

A recurring debate during the workshop centered on how the models are validated empirically. This seems to be an unresolved issue more generally and is apparently not taken seriously enough in both approaches. From an empirical side, both camps seem to be satisfied if the model can somehow reproduce some stylized facts seen in the data. Both models "calibrate" parameters and then use simulations.

But does this capture the empirical challenges?

Let us start with equilibrium models first. Bringing an equilibrium model to field data always works with the auxiliary assumption that we observe data that are generated by equilibrium of the underlying economy. However, this auxiliary assumption cannot be verified independently using the field data. In this case, we look at the macroeconomy through a concept we cannot independently verify from the data we have. In such a setting, the whole exercise of calibration is also less convincing, as the analogy to the sciences suggests. If we calibrate a thermometer, we define 0 degrees Celsius as the freezing point of water and 100 degrees Celsius as the boiling point. The scale in between is determined by the theory of how mercury expands when temperatures rise. This theory is, however, independently verified using experimental data from the lab. Thus calibration only makes sense once we know that we have a reliable model of the problems we want to analyze. Equilibrium models do not pass this test.

But the same is true for the calibration of an agent-based model. To make calibration empirically useful, we would have to know that the agent model we use for the analysis is the right lens through which we look at the economy. But we need an independent source of data to gain some confidence that this is the case.

Thus, from an empirical point of view, both models seem to share a fundamental conceptual difficulty that impedes the empirical validation of the models with field data. The independent sources by which the tools and models we use to look at the world are verified in the sciences are experiments. The empirical validation of equilibrium models of markets is based

on research that has not progressed far yet,[8] nor are there many results in the agent-based literature, either. While these empirical issues were not discussed much at the workshop, they seem to be a field where both approaches show — at least structurally — similar gaps.

Conclusions

Economic modelers are currently experiencing competition from other modeling approaches. The competitors have by now achieved enough interesting results that an experiment like this workshop that brought together DSGE modelers and agent-based modelers in one program worked very well. The debate could have been a bit fiercer and hard-hitting, though. While economists need to work harder on their conceptual foundations, agent-based modelers in all their justified critique of standard economic models and their assumptions seem to underestimate the intricacies of concepts like equilibrium and expectations formation. It looks as if both approaches could learn from each other. A few more research workshops and a serious debate about some of the deeper conceptual issues may well be useful to realize the gains from this exchange.

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[8] See, for instance, Bossaerts for a discussion of equilibrium asset pricing: Bossaerts, P. 2002. The Paradox of Asset Pricing. Princeton University Press.