

Model Comparison and Robustness: A Proposal for Policy Analysis after the Financial Crisis*

Volker Wieland
Goethe University Frankfurt, CEPR and CFS[†]

1st Version: November 28, 2010

This Version: March 21, 2011

Abstract

The state of macroeconomic modeling and the use of macroeconomic models in policy analysis has come under heavy criticism. Critics have accused macroeconomists in academia and policy institutions of relying too much on a particular class of macroeconomic models. This paper proposes a comparative approach to macroeconomic policy analysis that is open to competing modeling paradigms. It reviews recent work on building a macroeconomic model archive and platform that makes it much easier to conduct extensive model comparisons. The paper also points towards a range of competing modeling approaches that should be the focus of a systematic model comparison exercise in the future. An example of a recent model competition in terms of forecasting performance during U.S. recessions and recoveries is discussed. The paper concludes with a review of findings regarding the effectiveness of temporary fiscal stimulus measures from a range of models and studies.

Keywords: model uncertainty, policy robustness, monetary and fiscal policy, macroeconomic models, model comparison.

JEL-Codes: C53, D84, E31, E32, E37

* Wieland acknowledges funding support from European Community grant MONFISPOL under grant agreement SSH-CT-2009-225149. Excellent research assistance was provided by Elena Afanasyeva and Sebastian Schmidt. This paper was prepared for the 13th annual conference of the Cournot Center for Economic Studies organized by Robert Solow, Jean Louis Beffa and Jean-Phillipe Touffut on December 2-3, 2010 in Paris under the heading “What’s right with macroeconomics?” Helpful comments by Robert Boyer and conference participants were greatly appreciated. The usual disclaimer applies.

[†] Mailing address: Goethe University of Frankfurt, Gruenenburgplatz 1, Goethe Universitaet, House of Finance, 60323 Frankfurt am Main, Germany, E-mail: wieland@wiwi.uni-frankfurt.de.

1 Introduction

In the aftermath of the financial crisis the state of macroeconomic modeling and the use of macroeconomic models in policy analysis has come under heavy criticism. Media and other commentators have criticized macroeconomists for failing to predict the great recession of 2008-09 or at least failing to provide adequate warning of the risk of such a recession ahead of time. Practitioners have attributed this failure to academic and central bank researchers' love of a particular modeling paradigm. They blame so-called dynamic stochastic general equilibrium (DSGE) models for misdirecting the attention of policymakers. Indeed, even some well-known academics-cum-bloggers have published scathing commentaries on the current state of macroeconomic modeling. In March 2009, Willem Buiter wrote " ... *the typical graduate macroeconomics and monetary economics training received at Anglo-American universities during the past 30 years or so, may have set back by decades serious investigations of aggregate economic behavior and economic policy-relevant understanding.*" This view was echoed by Nobel Prize Winner Paul Krugman in the weekly *The Economist*, June 2010, " *Most work in macroeconomics in the past 30 years has been useless at best and harmful at worst.*"

Against this background, the present paper aims to develop a more constructive proposal for how to use macroeconomic modeling – whether state-of-the-art or 1970s vintage – in practical policy design. It is in the vein of the 1992 call for a pluralistic and rigorous economics by leading economists. The undersigned – among them Nobel prize winners Paul Samuelson and Franco Modigliani – were concerned with "*the threat to economic science posed by intellectual monopoly*" and pleaded for "*a new spirit of pluralism in economics, involving critical conversation and tolerant communication between different approaches*".¹ In this spirit, we propose a systematic comparative approach to macroeconomic modeling with the objective of identifying policy recommendations that are robust to model uncertainty.² This approach is open to a wide variety of modeling paradigms.

Scientific rigor demands a level-playing field on which models can compete. Rather than using rhetoric to dismiss competing approaches, emphasis should be put on empirical benchmarks that need to be satisfied by the models in order to stay in the race. For example, macroeconomic models used for monetary policy could be required to be estimated to fit the empirical dynamics of key time series such as output, inflation and nominal interest rates. Models should be able to provide answers to typical policymakers' questions such as what is the effect of an unanticipated increase (or decrease) in the central bank's operating target for the money market rate, or of an unanticipated temporary increase (or decrease) in government spending or transfers. Another typical concern is the degree of output, inflation and interest rate volatility and persistence predicted by the models under different policy rules. New modeling approaches may offer more sophisticated explanations of the sources of the great recession of 2008-09 and carry the promise of improved forecasting performance. This

¹ See the advertisement section of the American Economic Review - AEA Papers and Proceedings issue of May 1992.

² See Taylor and Wieland (2009) and Wieland et al. (2009) for an implementation of this model comparison approach.

promise should be put to a test rather than presumed. Estimated models could be compared along their relative real-time forecasting performance, in particular in periods of great change such as recessions and recoveries. An example of such a model competition is given by Wieland and Wolters (2011).

Macroeconomic data, however, are unlikely to provide sufficient testing grounds for selecting a single, preferred model for policy purposes. Instead, policy recommendations should be made robust to model uncertainty. In particular, the robustness of policy prescriptions can be improved by introducing them in multiple, competing models and comparing performance across models according to established target criteria. Policymakers continue to require models and are aware of the need for robustness. Most recently, ECB President Jean-Claude Trichet expressed these needs very clearly.

”We need macroeconomic and financial models to discipline and structure our judgemental analysis. How should such models evolve? The key lesson I would draw from our experience is the danger of relying on a single tool, methodology or paradigm. Policymakers need to have input from various theoretical perspectives and from a range of empirical approaches. Open debate and a diversity of views must be cultivated – admittedly not always an easy task in an institution such as a central bank. We do not need to throw out our DSGE and asset-pricing models: rather we need to develop complementary tools to improve the robustness of our overall framework”, he said.³

Macroeconomic model comparison projects have already helped produce some very influential insights for practical policy making. For example, Taylor (1993a) credits the comparison project organized by the Brookings Institution and summarized in Bryant et al. (1993) as the crucial testing ground for what later became known as the Taylor rule for monetary policy. More recently, the International Monetary Fund organized a large-scale model comparison exercise in order to evaluate the likely consequences of temporary fiscal stimulus measures (see Coenen et al. (2010)). However, such model comparisons have been infrequent and costly, because they require the input of many teams of researchers and multiple meetings to obtain a limited set of comparative findings.

To remedy this situation, Wieland et al. (2009) have implemented a new approach to model comparison that enables individual researchers to conduct such comparisons easily, frequently, at low cost and on a large scale. This methodology comes with a model archive that includes many well-known empirically estimated models of business cycle dynamics. These models can be used to evaluate the performance of macroeconomic stabilization policies. A computational platform that allows straightforward comparisons of models’ implications using MATLAB and DYNARE⁴ software is available online to download.⁵ Researchers can easily include new models in the database and compare the effects of novel extensions to established benchmarks.

³ See Jean-Claude Trichet, “Reflections on the nature of monetary policy non-standard measures and finance theory”, speech given on the occasion of the ECB Central Banking Conference Frankfurt, 18 November 2010.

⁴ See Juillard (1996).

⁵ See <http://www.macromodelbase.com>.

Our proposal is to use this comparative approach systematically in order to organize a pluralistic, yet rigorous and productive communication between competing modeling paradigms in macroeconomics. So far, the model database contains small, medium and large-scale macroeconomic models of different vintages and methodological traditions. In total, there are 38 models including many state-of-art New Keynesian DSGE models, but also earlier-vintage New-Keynesian models with rational expectations and nominal rigidities and some models that offer a more traditional Keynesian-style perspective on macroeconomic fluctuations with largely backward-looking dynamics. The model database and the computational platform for model comparison provide a level-playing field that is open to new entrants. Going forward, we propose to cover as many competing modeling paradigms as possible, to compare models' empirical implications in a systematic fashion, and to search for policy prescriptions that are robust along relevant dimensions of model uncertainty.

The remainder of the paper proceeds as follows. Section 2 shortly describes the comparison methodology, and gives an overview of the models available in the database. It also outlines a list of competing modeling paradigms that promise improvements of our understanding of macroeconomic dynamics. In future work, they should be compared to those approaches that have received most attention in recent years. Section 3 gives an example of a demanding test of comparative model performance, namely the real-time forecasting evaluation of a range of models relative to experts in the last five U.S. recessions conducted by Wieland and Wolters (2011). Section 4 then reviews findings from recent comparison studies regarding the impact of fiscal stimulus packages, and reports estimates of the impact of government transfers in selected models. Section 5 concludes.

2 Model comparison

The six older comparison projects reported in Bryant et al. (1988), Bryant et al. (1989), Klein (1991), Bryant et al. (1993), Taylor (1999), Hughes-Hallett and Wallis (2004) as well as the recent IMF exercise by Coenen et al. (2010) have all involved multiple teams of researchers, each team working only with one or a small subset of available models. The approach by Wieland et al. (2009) instead is meant to provide users easy access to the complete set of models considered in a comparison exercise. Furthermore, users should find it fairly straightforward to integrate their own models. To this end, Wieland et al. (2009), present a formal exposition of their comparative methodology. Taylor and Wieland (2011) have used the model database to compare three well-known models of the U.S. economy and analyze the robustness of simple monetary policy rules.

A general class of nonlinear dynamic stochastic macroeconomic models is augmented with a space of common comparable variables, parameters and shocks. Augmenting models in this manner is a necessary pre-condition for a systematic comparison of particular model characteristics. Given a space of common variables and parameters, one can define common policy rules as model input, and produce comparable objects as model output. These objects are also defined in terms of common

variables, parameters and shocks. Examples for such objects are impulse response functions, autocorrelation functions and unconditional distributions of key macroeconomic aggregates.

The space of common variables, parameters and policy rules comprises only a subset of each model's variables, parameters and equations. Most model-specific equations remain unchanged. Only the model-specific policy rules are replaced with common policy rules that express policy variables as functions of common variables and parameters. However, a new set of definitional equations needs to be added to each model. These definitional equations define the common variables in terms of model-specific variables. Once each model is augmented with the appropriate definitional equations and the common policy rules it is ready for comparative exercises. For a formal exposition of the procedure for integrating new models the reader is referred to Wieland et al. (2009). Several examples are carried out step by step in that paper. Furthermore, a detailed documentation of the augmented model files is also provided.

2.1 A model database

In the following we give a brief overview of the model archive that is available with the comparison software. This database includes many well-known empirically-estimated macroeconomic models that may be used for quantitative analysis of monetary and fiscal stabilization policies. It contains estimated and calibrated models of the U.S. economy and the euro area. Furthermore there are a number of small open-economy models of countries such as Canada, Chile and Brazil. Finally, it also includes several multi-country models that cover industrialized economies. The models made available as of November 2010 are listed in **Table 1**.

Most models could be classified as New Keynesian models because they incorporate rational expectations, imperfect competition and wage or price rigidities. A subset of the models could be characterized as monetary business cycle models where all behavioral equations are derived in a completely consistent manner from the optimization problems of representative households and firms. Many authors use the term DSGE (dynamic stochastic general equilibrium) model to refer to this particular class of models. Thus, our data base offers interesting opportunities for comparing policy implications of this class of models to a broader set of empirically estimated, dynamic, stochastic, economy-wide macro models.

While most of the models assume that market participants form rational, forward-looking expectations, we have also included some models that assume little or no forward-looking behavior.⁶ Comparative analysis of these classes of models will be useful to evaluate recently voiced criticisms that the newer models are rendered invalid by the experience of the global financial crisis.

⁶ For example, the models of Rudebusch and Svensson (1999) and Orphanides (2003) are essentially structural VAR models with some restrictions on the coefficients. The ECB's Area-Wide Model is a medium-size structural model but with a relatively limited role for forward looking behavior compared to the other structural rational expectations models in the data base.

The models are grouped in five categories in **Table 1**. The first category includes small, calibrated versions of the basic New-Keynesian DSGE model. These models concentrate on explaining output, inflation and interest rate dynamics. Some of them are calibrated to U.S. data. The model taken from Clarida et al. (2002) is a two-country version of this type of model.

The second category covers estimated models of the U.S. economy. It includes small models of output, inflation and interest rate dynamics such as Fuhrer and Moore (1995) and Rudebusch and Svensson (1999). Other models are of medium scale such as Orphanides and Wieland (1998) or the well-known models of Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2007) that fully incorporate recent advances in terms of microeconomic foundations. The database includes the version of the Christiano-Eichenbaum-Evans model estimated by Altig, Christiano, Eichenbaum and Linde (2004) because this version contains other economic shocks in addition to the monetary policy shock studied by Christiano et al (2005).⁷ Furthermore, we have included an additional version of the Altig et al. (2004) model used in Taylor and Wieland (2011) that omits the cost-channel of monetary policy.⁸ The largest model of the U.S economy in the database is the Federal Reserve's FRB-US model of Reifschneider et al. (1999). We have included a linearized version of this model with rational expectations that was previously used in Levin et al. (2003), as well as two more recent versions from 2008, one with rational expectations and one with adaptive expectations based on a reduced form vector-autoregression (VAR). Federal Reserve economists Edge, Kiley and Laforte (2010) have developed a new two-sector DSGE model of the U.S. economy that is also included in our database, specifically a version of this model estimated in Wieland and Wolters (2011).

In addition, there are a number of smaller estimated models of the U.S. economy that offer new insights regarding the role of financial frictions in economic fluctuations. For example, Carabenciov et al. (2008) augment a simple backward-looking model with a measure of financial linkages and frictions. DeGraeve (2008) and Christensen and Dib (2008) introduce constraints on firms' financing following Bernanke et al. (1999) in a fully-fledged estimated DSGE model of the U.S. economy. These models provide an endogenous account of firms' external finance premium over the business cycle. Iacoviello (2005) includes the housing sector in a DSGE model. The model of Mankiw and Reis (2007) deviates from the assumption of rational expectations and allows for rational inattention. This mechanism introduces a role for outdated expectations (or informational frictions) in business cycle dynamics. All these extensions of the standard DSGE framework were accomplished before the financial crisis and could potentially be helpful in rendering DSGE models more useful in explaining developments during the crisis.

⁷ Because of complications in programming the informational timing assumptions regarding expectations in this model in DYNARE, two versions are included, one version for simulating the consequences of a monetary policy shock and the other version for simulating the consequences of the other economic shocks in the model.

⁸ This version was created in Taylor and Wieland (2011) to evaluate the effect of this assumption in comparing the Altig et al (2004) model with the model of Smets and Wouters (2007) that features no such cost channel.

Table 1: MODELS CURRENTLY AVAILABLE IN THE DATABASE
(NOVEMBER 2010)

=====

1. SMALL CALIBRATED MODELS

1.1	NK RW97	Rotemberg and Woodford (1997)
1.2	NK LWW03	Levin et al. (2003)
1.3	NK CGG99	Clarida et al. (1999)
1.4	NK CGG02	Clarida et al. (2002)
1.5	NK MCN99cr	McCallum and Nelson (1999), (Calvo-Rotemberg model)
1.6	NK IR04	Ireland (2004)
1.7	NK BGG99	Bernanke et al. (1999)
1.8	NK GM05	Gali and Monacelli (2005)

2. ESTIMATED US MODELS

2.1	US FM95	Fuhrer and Moore (1995)
2.2	US OW98	Orphanides and Wieland (1998) equivalent to MSR model in Levin et al. (2003)
2.3	US FRB03	Federal Reserve Board model linearized as in Levin et al. (2003)
2.4	US FRB08	2008 linearized version of Federal Reserve Board model.
2.5	US FRB08mx	2008 linearized version of FRB model (mixed expectations)
2.6	US SW07	Smets and Wouters (2007)
2.7	US ACELm	Altig et al. (2005), (monetary policy shock)
	US ACELt	Altig et al. (2005), (technology shocks)
	US ACELswm	no cost channel as in Taylor and Wieland (2009) (mon. pol. shock)
	US ACELswt	no cost channel as in Taylor and Wieland (2009) (tech. shocks)
2.8	US NFED08	based on Edge et al. (2007), version used for estimation in Wieland and Wolters (2010)
2.9	US RS99	Rudebusch and Svensson (1999)
2.10	US OR03	Orphanides (2003)
2.11	US PM08	IMF projection model US, Carabenciov et al. (2008)
2.12	US PM08fl	IMF projection model US (financial linkages), Carabenciov et al. (2008)
2.13	US DG08	DeGraeve (2008)
2.14	US CD08	Christensen and Dib (2008)
2.15	US IAC05	Iacoviello (2005)
2.16	US MR07	Mankiw and Reis (2007)

3. ESTIMATED EURO AREA MODELS

3.1	EA CW05ta	Coenen and Wieland (2005), (Taylor-staggered contracts)
3.2	EA CW05fm	Coenen and Wieland (2005), (Fuhrer-Moore-staggered contracts)
3.3	EA AWM05	ECB's area-wide model linearized as in Dieppe et al. (2005)
3.4	EA SW03	Smets and Wouters (2003)
3.5	EA SR07	Sveriges Riksbank euro area model of Adolfson et al. (2007)
3.6	EA QUEST3	QUEST III, model by DG-ECFIN EC, Ratto et al. (2009)

4. ESTIMATED/CALIBRATED MULTI-COUNTRY MODELS

4.1	G7 TAY93	Taylor (1993b) model of G7 economies
4.2	G3 CW03	Coenen and Wieland (2002) model of USA, Euro Area and Japan
4.3	EACZ GEM03	Laxton and Pesenti (2003) model calibrated to Euro Area and Czech republic
4.4	G2 SIGMA08	The Federal Reserve's SIGMA model from Erceg et al. (2008) calibrated to the U.S. economy and a symmetric twin.
4.5	EAUS NAWM08	Coenen et al. (2008), New Area Wide model of Euro Area and USA

5. ESTIMATED MODELS OF SMALL OPEN ECONOMIES

5.1	CL MS07	Medina and Soto (2007), model of the Chilean economy
5.2	CA ToTEM10	ToTEM model of Canada, based on Murchison and Rennison (2006), 2010 vintage
5.3	BRA SAMBA08	Gouvea et al. (2008), model of the Brazilian economy

The third category in **Table 1** covers estimated models of the euro area economy. Four of these models have been used in a recent study of robust monetary policy design for the euro area by Kuester and Wieland (2009): the medium-scale model of Smets and Wouters (2003), two small models by Coenen and Wieland (2005) that differ by the type of staggered contracts inducing inflation rigidity, and a linearized version of the Area-Wide Model that was used at the ECB for forecasting purposes. Recently, it has been replaced with a new DSGE model. In addition, we have included an estimated DSGE model of the euro area recently developed at the Sveriges Riksbank, Adolfson et al. (2007), and at the European Commission, Ratto et al. (2009). The latter model was developed with a particular focus on the analysis of euro area fiscal policy.

The fourth category includes estimated and calibrated models of two or more economies. Currently, the largest model in the database is the estimated model of the G7 economies of Taylor

(1993). The estimated model of Coenen and Wieland (2003) with rational expectations and price rigidities aims to explain inflation, output and interest rate dynamics and spill-over effects between the United States, the euro area and Japan. The model of Laxton and Pesenti (2003) is a two-country model with extensive microeconomic foundations calibrated to the economies of the euro area and the Czech republic. The Federal Reserve's SIGMA model is similarly rich in microeconomic foundations. The parameters in the two-country version of this model from Erceg et al (2008) are calibrated to the U.S. economy and a symmetric twin. Finally, we have a two-country calibrated version of the ECB's new area-wide DSGE model as presented by Coenen et al. (2008). This model also covers the U.S. economy.

The fifth category of models covers small open-economy DSGE models of Canada, Chile and Brazil. In addition to openness to trade and capital flows these models also consider particular economic features of the respective countries such as for example an important role of a natural resources sector in the economy.

In sum, the current breadth of model coverage allows for a variety of interesting comparison exercises, for example, comparisons between earlier vintage and more recent Keynesian style models of business cycle dynamics for a given country, cross-country comparisons between the United States, the euro area and some small open economies, or comparisons between standard New-Keynesian DSGE models and such DSGE models that also include certain financial or informational frictions.

2.2 A proposal for extending the coverage of competing modeling paradigms

In the aftermath of the financial crisis the DSGE modeling approach has come under heavy criticism. Many critics have argued that models of this type that were in use prior to the crisis did not incorporate realistic treatments of banking and therefore failed to account for the macroeconomic risks resulting from a fragile financial sector. Other critics have suggested that the crucial flaw of the DSGE approach is of a more fundamental nature. Many of them question the central assumption of homogenous, rational expectations. They point out that in practice economic agents are imperfectly informed, they are engaged in a learning process and they often disagree about likely future developments. Others go further and call into doubt the basic microeconomic assumption of rational optimizing behavior by households and firms.

Policy makers are keen to have modeling frameworks at their disposal that address these criticisms. Their interest in the matter is well exemplified by ECB President Trichet who requests the following steps: "*we need to better integrate the crucial role played by the financial system into our macroeconomic models, ... we may need to consider a richer characterisation of expectation formation, ... We need to deal better with heterogeneity across agents and the interaction among those*

heterogeneous agents, (and) we need to entertain alternative motivations for economic choices”.⁹ In the following, we highlight some recent studies that explore these different directions.

Risks of the financial sector.

Proponents of the DSGE approach have been hard at work to provide more explicit modeling of financial intermediation and risks by extending the standard DSGE framework. Such models should at least include a financial sector where banks are exposed to risk and the functioning of the banking sector affects the real economy. Recent contributions along these lines include Goodfriend and McCallum (2007), Gertler et al. (2007), De Fiore et al. (2009), DeWalque et al. (2009), Christiano et al. (2010), Gerali et al. (2010), Angeloni and Faia (2010), Meh and Moran (2010), Nolan and Thoenissen (2009), Dib (2010), Gertler and Karadi (2009) and Gertler and Kiyotaki (2009).

All these contributions examine the interaction of financial risk, business cycle dynamics and monetary policy. They differ in how banking and financial intermediation are modeled, and in the focus of the particular policy application. Some of them investigate the implications of banking and financial intermediation on business cycle fluctuations in a fully-fledged DSGE model. From the perspective of modelers, an important question to be investigated in the future is whether such extensions offer a satisfactory explanation of the financial crisis. One would hope that such an explanation would not only reveal the sources that caused the crisis in form of particular economic shocks, but also propagation mechanisms that would help modelers to predict the development of such a crisis in the future.

Learning and diverse beliefs.

Households and firms in complex modern DSGE models are assumed to have access to forecasts that are equivalent to the expectation calculated under complete knowledge about the structural features of the model economy. Furthermore, households and firms typically are assumed to share homogeneous expectations regarding future developments of key macroeconomic variables. Expectations play a crucial role in determining the dynamics of these models and the policy recommendations derived from the models. Expectations, of course, also appear to play a very important role in actual real-world markets and economies. Thus, the debate among modelers should not be about the importance of expectations in macroeconomics. Rather it should be about the sensitivity of the business cycle and policy implications derived under the homogeneous rational expectations assumption to alternative specifications of market participants' beliefs.

A number of different approaches for modeling less-than-fully rational expectations and belief diversity have been proposed in the economic literature. A first step away from rational expectation is adaptive learning. It implies that market participants re-estimate simple reduced-form models of the variables to be forecasted and update the parameter estimates of these forecasting models once they

⁹ See Jean-Claude Trichet, "Reflections on the nature of monetary policy non-standard measures and finance theory", speech given on the occasion of the ECB Central Banking Conference Frankfurt, 18 November 2010.

obtain new data. An example of such a learning process is recursive least squares. Adaptive learning has been discussed in macroeconomics already for more than two decades.¹⁰ However, the expectations obtained from adaptive learning are typically homogeneous across market participants in these models. Some examples of recent investigations of the implications of adaptive learning for macroeconomic dynamics, monetary and fiscal policy are Orphanides and Williams (2006), Slobodyan and Wouters (2008) and Wieland (2009). Even so, medium- to large-scale DSGE models used at central banks and other policy institutions are typically simulated under rational expectations.

It would be of interest to conduct a systematic comparison of DSGE models with rational expectations versus DSGE models with adaptive learning in order to evaluate whether adaptive learning can play an important role in interpreting the period leading up to the global financial crisis or the reaction of market participants during the crisis. Furthermore, if adaptive learning better characterizes real-world market participants' process of expectations formation, models with adaptive learning might also perform better in forecasting exercises.

Expectation heterogeneity, however, has so far been largely ignored in structural macroeconomic models used for policy analysis. While empirical studies have documented a substantial degree of heterogeneity of professional forecasts (cf. Kurz et al. (2003), Kurz et al. (2005), Giordani and Söderlind (2003), Capistran and Timmermann (2009) and Wieland and Wolters (2011)), theoretical research has emphasized that expectational heterogeneity itself can be an important propagation mechanism for economic fluctuations and a driving force for asset price dynamics. Theories of heterogeneous expectations and endogenous fluctuations have been advanced, for example, by Kurz (1994a, 1994b, 1996, 1997a, 1997b, 2008), Brock and Hommes (1998), Kurz et al. (2005), Chiarella et al. (2007), Branch and McGough (2011), Branch and Evans (2011) and De Grauwe (2011).

Since belief diversity can cause economic volatility, macroeconomic policy analysis cannot ignore the diversity of expectations among households, firms and policy makers themselves. While in homogenous models such volatility would be attributed to other shock processes, models with heterogeneous expectations offer a possibility to disentangle which fraction of economic volatility can be attributed to heterogeneous expectations and which fraction is explained by other economic shocks. Some of the above-mentioned studies explore the impact of diverse beliefs in small New Keynesian models. It would be of great interest to introduce such models into the macroeconomic model database and conduct a systematic comparison of models with homogenous and heterogeneous beliefs. Possibly, variations in the diversity of beliefs that is the degree of optimism and pessimism among market participants may have played an important role in the asset price boom before the crisis, and its subsequent collapse. If these variations in diversity act as a propagation mechanism and were themselves to some extent predictable, then models with diverse beliefs might stand a chance to deliver better forecasting performance before such recessions than standard DSGE models.

¹⁰ A well-known textbook that provides a comprehensive framework for adaptive learning in Evans and Honjapohja (2001).

Deviations from strictly optimizing behavior.

In the last two decades several significant strands of literature have developed that investigate fundamental deviations from strictly optimizing behavior by economic agents and consider alternative motivations for economic choices and decisions. Behavioral economics brings lessons from psychology to bear on the analysis of economic decision making. Contributions to this strand of the literature have argued that empirical failures of the classical paradigm of fully rational behavior may be resolved by introducing particular psychological motivations for economic behavior (see Diamond and Vartiainen (2007) and Akerlof and Shiller (2010)). With regard to policy analysis with structural macroeconomic models, an important question is what behavioral macroeconomic models are best suited to be considered as competitors of standard DSGE models, or the new DSGE models with detailed banking sector and financial frictions. Sometimes, behavioral approaches are mentioned as support for more traditional Keynesian-style models with backward-looking dynamics. However, the richness of the behavioral economics approach would suggest that a new line of structural macroeconomic models should emerge from this literature.

Another large literature is known under the term agent-based modeling and crosses the borders between engineering, physics and economics. For a recent survey of agent-based models in economics see Tesfatsion and Judd (2006). Agent-based modeling is the computational study of economic processes modeled as dynamic systems of interacting agents. Here "agent" refers broadly to a bundle of data and behavioral methods representing an entity constituting part of a computationally constructed world. Instead of the fully optimizing rational decision-makers in standard DSGE models, these agents can range from active data-gathering decision makers with sophisticated learning capabilities to passive world features with no cognitive function. Researchers have built computational "laboratories" with thousands or even millions of such agents. These laboratories have been used to investigate whether agent-based modeling can replicate certain empirical regularities in financial, goods and labor markets and other areas of economics. Another aim is to test certain government regulations and policies in terms of the simulation outcomes they would generate in such models. A recent contribution that describes a model of the euro area economy is Deissenberg et al. (2008). With regard to policy analysis with structural macroeconomic models, an important question is how agent-based models can be used to deliver answers to the type of questions policy makers typically ask of DSGE models. For example, what are the models' predictions for growth and inflation over the coming year? What would be the effect of an increase in the central bank's interest rate or of an unexpected increase in fiscal transfers such as a tax rebate? A comparison of agent-based and DSGE models with regard to such questions should be tremendously useful for practical macroeconomic policy analysis.

3 A recent model comparison: Forecasting U.S. recessions

In general, macroeconomic models used for policy analysis in a particular economy ought to be empirically estimated or calibrated to fit macroeconomic time series of that economy. A particularly demanding test, however, would be an evaluation of the real-time forecasting performance of such models. Recently, Wieland and Wolters (2011) have conducted such a forecasting exercise with six different models of the U.S. economy. They have investigated the accuracy and heterogeneity of output growth and inflation forecasts during the current and the four preceding NBER-dated U.S. recessions. Model forecasts are compared to professional forecasts from the Federal Reserve's Greenbook and the Survey of Professional Forecasters (SPF).¹¹ Importantly, the model parameters and model forecasts are derived from historical data vintages so as to ensure comparability to historical forecasts by professionals. The comparison is conducted for successive quarter-by-quarter forecasts up to four quarters into the future. Arguably, the periods around recessions and recoveries pose the greatest challenge for economic forecasters.

Among the six macroeconomic models considered by Wieland and Wolters (2011) (WW in the following) are three small-scale New-Keynesian models that differ in terms of structural assumptions, a non-structural Bayesian VAR model, and two medium-scale New-Keynesian DSGE models of the type currently used by leading central banks. Two of the small-scale models are variants of the New-Keynesian models 1.1 and 1.2 in Table 1 estimated with U.S. data. They were estimated by Del Negro and Schorfheide (2004) and Wieland and Wolters (2011) respectively and are denoted by the acronyms *NK-DS* and *NK-WW*. The third small-scale model is a variant of model 2.1. in Table 1 and due to Fuhrer (1997). It is denoted by *NK-Fu* while the VAR is referred to with *BVAR-WW*. The three small-scale New-Keynesian models and the Bayesian VAR are estimated to fit three macroeconomic time series: real GDP growth, inflation measured by the GDP deflator and the federal funds rate.

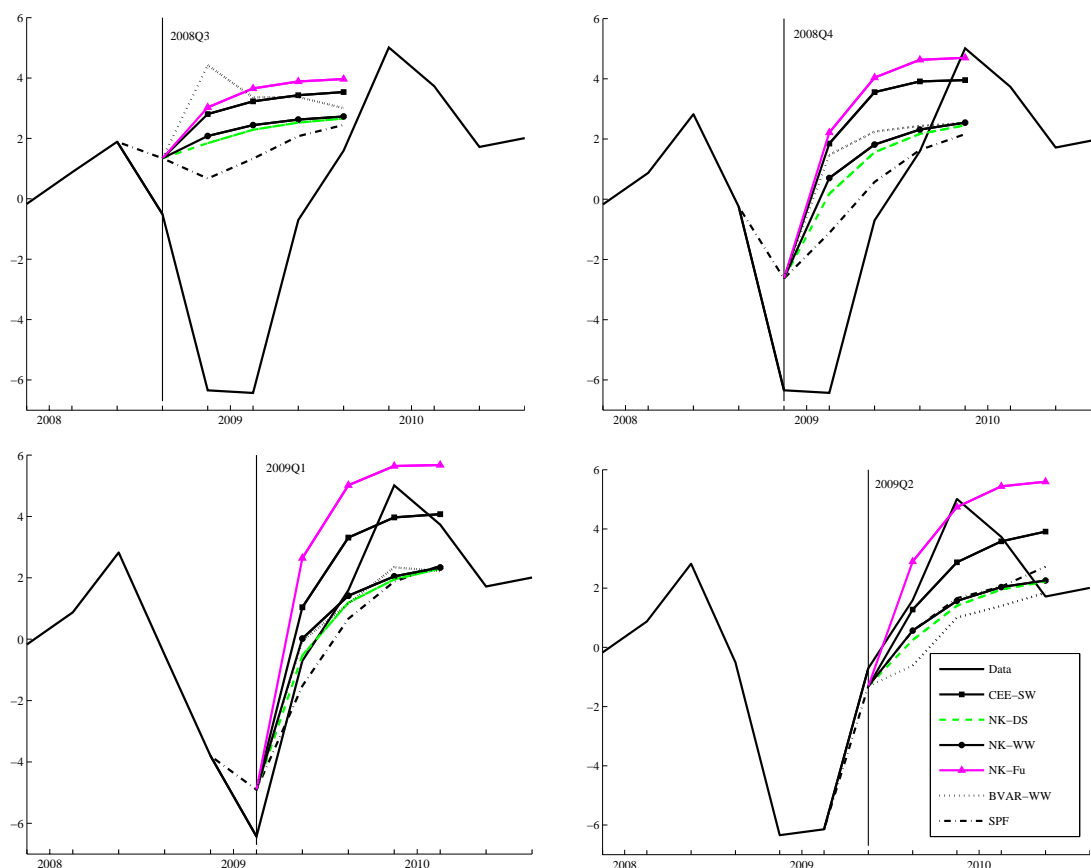
The first medium-scale model is the well-known DSGE model estimated by Smets and Wouters (2007) (model 2.6. in Table 1), which itself is a version of the DSGE model developed in Christiano et al. (2005). It is referred to as *CEE-SW* model in the forecasting exercise. This model is estimated with 7 variables which include consumption, investment, wages and hours worked. The largest model in the forecasting exercise is a version of the Federal Reserve's new DSGE model estimated by Edge et al. (2010) (model 2.8. in Table 1). It is denoted by *FRB-EDO* in the forecast evaluation. This model accounts for the breakdown in durables versus non-durables and services consumption, residential versus business investment, and the related deflators. It is estimated on 11 macroeconomic data series.

¹¹ The SPF is conducted quarterly and contains responses by 30 to 50 professional forecasters. It was initiated in 1968 by the American Statistical Association and the NBER and is administered by the FRB Philadelphia since 1990. The Greenbook is not a survey. It contains a single forecast produced by the staff of the Board of Governors of the Federal Reserve System in Washington DC and becomes publicly available with a five-year lag.

3.1 Forecasting the 2008-09 recession: Models versus experts

To render model-based forecasts comparable to historical SPF and Greenbook forecasts, Wieland and Wolters (WW) have put them on a similar footing in terms of the data vintage used for parameter estimation and initial conditions. Thus, WW have created a large real-time data set that contains all the historical quarterly vintages of the 11 time series used in the largest model. Every quarter we re-estimate all the model parameters on the basis of the data vintage that was available at that exact point in time. Using this parameterization we then compute an estimate of the current state of the economy—the so-called *nowcast*—and forecasts for one to four quarters into the future. Then, we assess forecast precision relative to the revised data that became available during the subsequent quarters for the dates to which the forecasts apply.

Figure 1: Real output growth forecasts during the 2007-2009 recession



Notes: The mean SPF nowcast forms the starting point for model-based forecasts regarding future quarters.

The model-based forecasts only use quarterly data vintages where the most recent data entries concern the quarter preceding the quarter in which the forecast is made. In practice, however, there are many data series that are available on a monthly, weekly or daily frequency that can be used to improve current-quarter estimates of GDP. Examples are industrial production, sales, unemployment,

money, opinion surveys, interest rates and other financial prices. This data can be used to improve nowcasts and the Federal Reserve staff and many professional forecasters certainly make use of it. Methods for using higher frequency data systematically in combination with quarterly structural macroeconomic models in conjunctural analysis are available (see Giannone et al. (2009)). To illustrate the impact of the timeliness of the nowcast on model-based forecasts, WW compare model forecasts during the 2008-2009 recession initiated with both types of nowcasts.

The four panels in **Figure 1** show the individual model forecasts that are initialized with the mean SPF nowcast. Each panel displays model forecasts relative to the mean SPF forecast (dash-dotted line) and the actual data (solid line) that has become available so far. The top left panel shows forecasts made in the third quarter of 2008. The top right panel then shows forecasts from the fourth quarter of 2008 and the lower two panels from the first two quarters of 2009.

As indicated by the top left panel, professional forecasters – on average – failed to foresee the downturn as late as in the third quarter of 2008. The mean SPF forecast indicates a slowdown in the fourth quarter followed by a return to higher growth in the first quarter of 2009. The model-based forecasts we generate based on the data vintage of 2008:Q3 would not have performed any better. Following the Lehman debacle professional forecasters drastically revised their assessments of the current situation downwards, and continued to do so in the first quarter of 2009.

Table 2: RMSEs of Output Growth Forecasts Initialized with Expert Nowcasts

Sample / Horizon	NK-DS	NK-WW	CEE-SW	FRB-EDO	NK-Fu	BVAR-WW	Mean	GB	SPF
1980:1 - 1981:3									
0	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	–
1	8.14	8.13	6.33	6.06	7.18	6.69	5.83	6.65	–
2	6.34	6.36	4.80	5.60	6.48	6.48	4.83	5.54	–
3	5.50	5.74	5.20	5.37	6.49	7.74	5.20	6.11	–
4	5.56	5.75	4.23	4.24	4.12	5.50	4.05	5.32	–
1981:4 - 1983:4									
0	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.14
1	4.28	4.50	3.74	3.27	3.80	3.23	3.54	3.58	3.88
2	3.99	4.05	4.22	4.09	3.98	4.09	3.86	3.93	4.11
3	4.14	4.23	4.05	4.52	4.64	4.87	4.25	3.91	4.41
4	4.08	4.11	4.07	4.67	4.73	4.89	4.28	3.84	4.02
1990:1 - 1992:1									
0	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.12
1	2.64	2.87	3.22	1.70	3.11	2.00	2.47	2.09	1.45
2	2.95	3.04	3.80	1.92	3.68	2.28	2.82	2.34	2.06
3	3.08	3.13	3.78	2.42	3.67	2.55	2.94	2.31	2.54
4	2.71	2.76	3.65	2.16	3.48	2.29	2.69	2.18	2.37
2000:4 - 2002:4									
0	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.22
1	2.17	2.15	2.31	2.84	2.06	2.48	2.23	2.20	2.30
2	2.09	2.10	2.11	2.61	2.35	1.98	2.11	2.34	2.21
3	2.74	2.72	2.68	2.98	2.51	2.66	2.65	2.76	2.65
4	2.25	2.26	2.08	2.40	2.24	2.30	2.19	2.18	2.13
2007:4 - 2009:3									
0	1.94	1.94	1.94	–	1.94	1.94	1.94	–	1.94
1	3.74	3.90	4.24	–	4.54	4.85	4.21	–	3.30
2	4.52	4.62	4.94	–	5.48	5.10	4.89	–	4.11
3	5.05	5.11	5.39	–	5.83	5.27	5.32	–	4.80
4	5.50	5.52	5.86	–	6.07	5.57	5.70	–	5.39

Interestingly, from 2009:Q2 onwards the model-based forecasts perform quite well in predicting the recovery of the U.S. economy. From that point onwards, several of the models deliver predictions that are very similar to the mean SPF forecast and match up with the subsequent data releases surprisingly well. The 2009:Q1 forecast for the second and third quarter of 2009 that is implied by the *CEE-SW* and *NK-WW* models already looks surprisingly accurate relative to the data releases that have become available so far.

3.2 The relative accuracy of model-based and expert forecasts

For the purpose of a systematic evaluation of forecast accuracy WW compute the root mean squared errors (RMSE) of the nowcast and forecasts from one- to four-quarters-ahead for each model during the five recessions. The typical recession sample covers the period from 4 quarters prior to the trough determined by the NBER Business Cycle Dating Committee to 4 quarters after the trough.¹² The Greenbook nowcast is used as initial condition for the model-based forecasts, except in the latest recession where the mean SPF nowcast is used. Models are re-estimated every quarter and forecasts are computed for horizons of one to four quarters into the future. **Table 2** reports the associated root mean squared errors of output growth and inflation forecasts for the different recession episodes. It compares the accuracy of the individual model forecasts to the mean model forecast that is the average of the six models, the mean SPF forecast and the Greenbook forecast.

Model forecasts perform quite differently. There is no single model that dominates the others in all recessions. The *CEE-SW* model performs best in the 1980-1981 recession. It even beats the Greenbook forecast in this recession, though the Greenbook forecast is unusually far off the mark in this period compared to later ones. The *NK-DS* and *CEE-SW* models perform best among the model forecasts in the 1981-1982 recession, while the Greenbook forecast performs best overall in this case. In the 1990-1992 period the *FRB-EDO* model and the Bayesian VAR deliver the best predictions among the models. For the short horizon the mean SPF forecast is best, but the Greenbook dominates the other forecasts over three to four quarters. In the period around the 2001 recession, the *NK-Fu* model and the *CEE-SW* model dominate the others over a horizon of three to four quarters. In the 2008-2009 period, so far, the *NK-DS* and *NK-WW* models appear to perform best among the models. Of course, as shown in Figure 1, it is only during the recovery phase that the models appear to have some predictive power. The same is largely true, however, for the four preceding recessions.

Interestingly, the mean model forecast outperforms the Greenbook forecast in the 1980 and 2001 recessions. The mean model forecast also compares well to the mean SPF forecast in the 1981-82 and 2001 recessions. The Greenbook forecasts still perform best in the 1981-82 and 1990-91 recessions, while the mean SPF forecast appears to be the most accurate in the ongoing recession, for which no Greenbook data and forecasts are publicly available.

¹² Exceptions are the 1980 and 2008/9 recessions. In the first case, we start only 2 quarters prior to the trough because of data availability. In the second case, the trough is not yet determined. We start in 2007Q4 (peak) and end in 2009Q3.

The forecast comparison gives no cause for much shoulder-slapping among modelers nor among professional forecasters. Both tend to miss the onset of recessions. This is not only true in the 2008-09 recession, but also in the four preceding ones. Thus, there is no reason for expert forecasters, who tend to rely more often on traditional Keynesian-style models with backward-looking dynamics, to point fingers at DSGE modelers for supposedly having too much influence on central banks. Experts and models exhibit some predictive power during the recovery phase. They predict a return to mean and the speed of return predicted seems to be reasonably accurate once the recovery has actually started. Some encouragement for modeling efforts, however, can be drawn from the finding that mean model forecasts perform quite well at horizons of three to four quarters and sometimes dominate Greenbook or mean SPF forecasts.

Given these findings it does not seem to be appropriate to utterly dismiss state-of-the-art New Keynesian DSGE models in favor of those Keynesian-style models that only use theory older than 30 years as suggested by the Buiter and Krugman commentaries cited in the introduction of this paper. However, it would seem urgent to investigate whether any of the innovations discussed in section 2.2., such as more thorough modeling of the financial sector, the inclusion of learning and diverse beliefs, or behavioral and agent-based modeling can deliver upon the promise of improved forecasting power.

4 Investigating policy robustness

Model competitions in terms of empirical fit or predictive power will certainly help narrow down the field of models relevant for policy analysis. However, the preceding forecasting exercise suggests that such competitions are not likely to deliver a unique preferred model for policy purposes. As recognized by policy makers such as ECB President Trichet, who was quoted accordingly in the introduction, multiple models need to be used as tools for making policy recommendations robust to model uncertainty. There exist recent examples. Several model comparison studies were conducted to investigate the likely consequences of temporary fiscal stimulus.

Importantly, in January 2009, Christina Romer, then Chair of the U.S. President's Council of Economic Advisers, and Jared Bernstein, Chief Economist of the Office of the Vice-President, used macroeconomic models in a report on the likely impact of a large-scale stimulus package proposed by the Obama Administration. Soon after, U.S. Congress approved 787 billion dollars of additional spending, transfers and tax reductions with the 2009 *American Recovery and Reinvestment Act* (ARRA). The ARRA extended over five years, with much of the additional spending occurring in the first two years. Many other economies around the world also announced fiscal stimulus measures. In Europe, the EU initiated the *European Economic Recovery Plan* (EERP) while national governments announced their own fiscal stimuli. Among them, the German government launched two "*Konjunkturpakete*" in a row. The European stimulus packages were to be concentrated on 2009 and 2010 only.

4.1 Recent comparative evaluations of fiscal stimulus

The literature on fiscal stimulus has expanded very quickly. Here, we only focus on a few contributions that used multiple structural macroeconomic models to evaluate the likely impact of such measures with an eye towards robustness to model uncertainty. Romer and Bernstein (2009), for example, provide numerical estimates of the impact of an increase in government spending and government transfers, respectively, on GDP and employment by averaging over models of the Federal Reserve and private sector business consultancies. They estimate that an increase in government purchases of 1 percent of GDP would induce an increase in real GDP of 1.6 percent.¹³ Thus, one or more of the models they use exhibit a text-book Keynesian multiplier effect.

The text-book multiplier follows from the national accounts' spending identity when combined with the Keynesian consumption function. An increase in government spending boosts aggregate spending and thereby aggregate output and after-tax household income. Consumption is assumed to increase with current after-tax income. Consequently, a debt-financed increase in government spending boosts total spending (and therefore total GDP) more than one for one. Details of the individual model simulations behind this average effect are not made available with the Romer-Bernstein study, however the authors clarify that interest rates were assumed to remain constant for five years in the model simulations. On this basis, they project that a package similar in magnitude to the eventual ARRA legislation would boost U.S. GDP by 3.6 percent.

Shortly after the ARRA had passed the House and Senate Cogan et al. (2009) (eventually published as Cogan et al. (2010)) evaluated its likely impact on U.S. GDP using empirically-estimated New-Keynesian models, such as the models of Taylor (1993b) and Smets and Wouters (2007), that is model 4.1 *G7-TAY93* and 2.6 *US-SW07* in Table 1. In these models, government purchases multipliers are typically smaller than one. They exhibit significant crowding-out of private consumption and private investment following an increase in government purchases. Consumption declines because forward-looking households expect increased government debt to be paid off at a later stage with higher taxes. This negative wealth effect induces additional saving and reduced consumption earlier on. Private investment declines because increased government debt puts upward pressure on interest rates. The expectation of higher future interest rates and lower wealth in the future, in turn reduces private investment already in the near term. As a consequence, estimates of the GDP effects of ARRA legislation obtained with the model of Smets and Wouters (2007) are only one-sixth as large as the estimates of Romer and Bernstein (2009).

While the original Smets-Wouters model only contains forward-looking "permanent-income" consumers, Cogan et al. (2010) also estimate a variant of this model that includes households whose consumption is determined by their current after-tax income as prescribed by the Keynesian

¹³ See Romer and Bernstein (2009), Appendix 1, page 12. This paper was written during the transition period in early January before Christina Romer was sworn in as Chair of the Council of Economic Advisers.

consumption function. The empirically estimated share of these "rule-of-thumb" households is 26.5 percent. At this scale, the presence of rule-of-thumb consumers has only a small impact on the multiplier on the ARRA government purchases. It remains well below one in this model. In addition, Cogan et al. (2010) investigated the interaction of monetary and fiscal policy when monetary policy is constrained at the zero-interest-rate-floor. If the central bank's desired policy rate is negative and thus below the actual rate of zero, it will not respond to an increase in GDP by raising the policy rate as in normal times. Consequently, the crowding-out effect of an increase in government purchases would be lessened. Cogan et al. (2010) consider simulations with one and two years of constant interest rates, as well as simulations where the time spent at the zero lower bound is endogenous and projected from the trough of the recession in the first quarter of 2009 onwards. Though the GDP impact of ARRA purchases increases it remains far below the Romer-Bernstein estimate of 3.6 percent by the end of 2010.

The euro area stimulus measures were summarized and evaluated in Cwik and Wieland (2011)¹⁴ using five different structural models of the euro area economy due to Fagan et al. (2005), Smets and Wouters (2003), Ratto et al. (2009), Laxton and Pesenti (2003) and Taylor (1993b), respectively models 3.3 *EA-AWM05*, 3.4 *EA-SW03*, 3.6 *EA-QUEST3*, 4.3 *EACZ-GEM03* and 4.1 *G7 TAY93* from Table 1. The ECB's Area-Wide model described in Fagan et al. (2005) largely ignores forward-looking motives for private decision-making and provides a traditional Keynesian perspective. The other four models are of the New-Keynesian variety with forward-looking households and firms. Smets and Wouters (2003) is a euro area version of the medium-size DSGE model of Christiano et al. (2005). The *EA-QUEST3* model is an estimated DSGE model developed for fiscal policy analysis at the European Commission by Ratto et al. (2009). This model also accounts for rule-of-thumb consumers. Their share is estimated at 35 percent, not too far from the estimate obtained with U.S. data by Cogan et al. (2010). The *EACZ-GEM03* model is a calibrated two-country DSGE model of the euro area and Czech Republic developed by IMF researchers. Together with Taylor's multi-country model it can account for the possible diversion of fiscal stimulus towards import demand.

Cwik and Wieland (2011) confirm the differential assessment of traditional Keynesian and New-Keynesian models concerning the size of the government purchases multiplier that was emphasized by Cogan et al. (2010) relative to Romer and Bernstein (2009). In their baseline scenario, the New-Keynesian models of the euro area provide no support for a traditional Keynesian multiplier effect of government purchases. Crowding-out of consumption, investment and net exports dominates. The ECB's area-wide model, however, supports a strong impact of government spending on GDP that is substantially greater than one for one. However, the boom is followed by a bust. Thus, the cumulative effect of government on private spending eventually also turns negative in that model. More importantly, models with backward-looking dynamics may not be as well-suited for the analysis

¹⁴ See also the earlier working paper version, Cwik and Wieland (2009).

of major policy measures as the New-Keynesian models that account for the interaction of policy announcements and private sector expectations.

Overall, the euro area stimulus package was much smaller than the U.S. package in magnitude, but it was to be more concentrated on 2009 and 2010. The findings in Cwik and Wieland (2011) suggest that such a shorter and sharper increase in government spending induces less crowding-out than the ARRA package that includes significant additional spending from 2011 onwards. Cwik and Wieland (2011) also discuss some factors that may have played a role in the recession of 2008-2009: namely implementation lags, the zero-interest-rate floor and the share of rule-of-thumb consumers. Time lags arise because of the steps needed to move from a timely announcement to actual implementation of government spending plans. Such implementation lags lead to more crowding out and may even cause an initial contraction. If interest rates are anticipated to remain constant due to zero-bound effects for two years, that is the complete period of fiscal stimulus, Cwik and Wieland document a small crowding-in effect in some of the DSGE models. For the multiplier to be greater than one, however, it is important that the two-year constant rate window is already anticipated as of the first quarter of 2009.

A number of studies have used other structural macroeconomic models to assess the impact of different fiscal policy tools. Typically they focus on a single model. An interesting extension of the EU-Quest model by Roeger and in't Veld (2009) includes a third type of households that are credit-constrained. Their benchmark calibration apparently has 40 percent liquidity-constrained households and another 20 percent credit constrained households, which would be too high relative to the survey evidence available regarding the share of such households during the financial crisis. The IMF's new preferred model for fiscal policy analysis, the so-called GIMF model, has been used by Freedman et al. (2010) to analyze the consequences of different fiscal measures. An innovative element of this model is that it features overlapping generations of households with finite horizons. As shown by Taylor (2010b) the effects of longer-lasting or permanent fiscal stimuli in the GIMF are very close to the effects reported by Cogan et al. (2010) for New-Keynesian DSGE models. A short-term government spending shock in GIMF has a multiplier of unity under normal circumstances. Unfortunately, the GIMF model is calibrated and not estimated with state-of-the-art methods to fit US or euro area data. It would be very useful to see how it fares in estimation relative to the estimated models we have used.

Recently, a very commendable model comparison study was executed by 17 researchers from the IMF, OECD, ECB, Federal Reserve and European Commission in Coenen et al. (2010). It covers seven structural models used at policy institutions including GIMF, the modified version of EU-Quest with additional constrained households, the Fed's SIGMA and FRB-US models, the OECD Fiscal Model, the Bank of Canada-GEM model and the ECB's New Area-Wide Model. They mostly find somewhat higher short-run government purchases multipliers than Cogan et al. (2010) and Cwik and

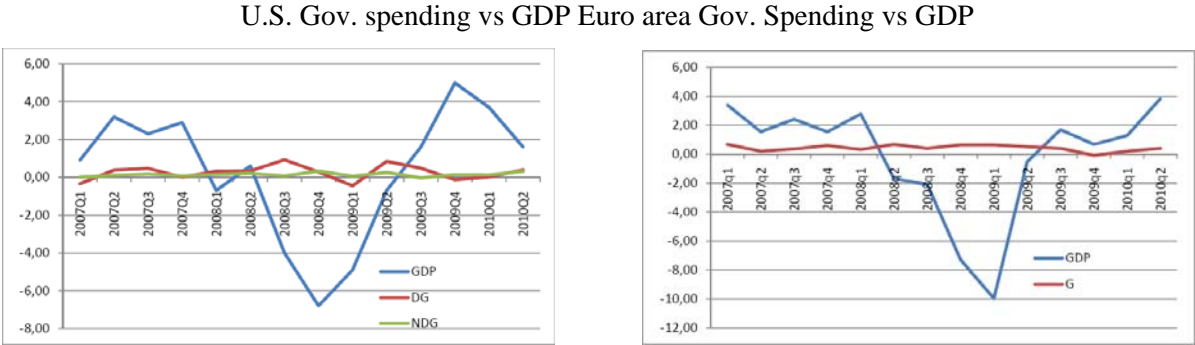
Wieland (2011) and attribute this difference to the assumptions regarding rule-of-thumb households. Indeed, three of these models include shares of 40 or 50 percent of rule-of-thumb households.

Further comparison of our findings with those by Coenen et al. (2010) would be very useful. Unfortunately, Coenen et al. (2010) employ a traditional model comparison approach whereby separate teams of researchers conduct a specific set of experiments, each team in their own model, and report outcomes. It would be very useful if the policy institutions that are represented by these researcher teams would choose to create a platform for model comparison as in Wieland et al. (2009) or add their models to this new model data base. Such a platform would render their model simulations also directly replicable and transparent to researchers outside these teams and institutions. Replicability is a basic scientific standard that ensures that correct comparisons can be made and policy recommendations can be properly scrutinized. Several of these institutions have already made earlier models publicly available for such purposes and the publication of the Coenen et al. (2010) study would provide a perfect occasion to proceed accordingly.

4.2 Government purchases versus government transfers

The preceding review of the literature focused primarily on the likely size of the government purchases multiplier. Recently, however, doubts have surfaced whether the 2009 ARRA legislation in the United States did achieve the announced increase in government consumption and infrastructure investment - that is the announced multiplicand. Using new data from the Bureau of Economic Analysis and considering developments at both the federal and the state and local level, Cogan and Taylor (2010) find that the government purchases multiplicand through the 2nd quarter of 2010 has been only 2 percent of the total spending announced by the American Recovery and Reinvestment Act. This increase in purchases has occurred mainly at the federal level, while state and local governments apparently used the substantial grants they received under the ARRA to reduce borrowing and increase transfer payments rather than purchases.

Figure 2: Government spending contributions to GDP growth: 2007-2010



Notes: GDP: GDP growth, NDG: non-defense spending contribution to GDP growth, DG: defense spending contribution, G: government spending contribution to growth. Sources: BEA and ECB. Vintage: September 2010.

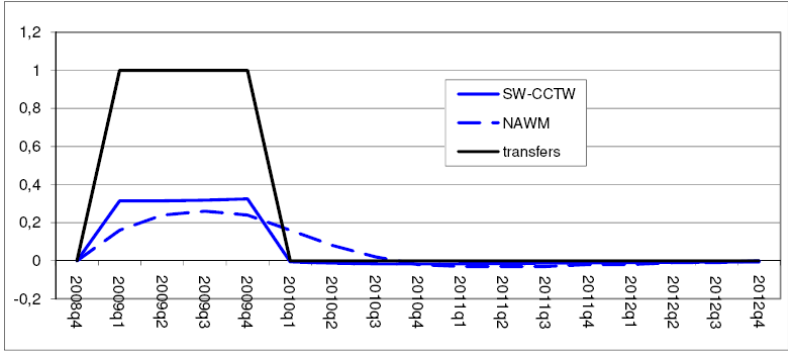
The Cogan and Taylor (2010) finding would seem to explain why the contribution of government spending to GDP growth in the national accounts has remained rather flat. As shown in the left panel of Figure 2 non-defense spending (green line) varied little over the recession and recovery from 2008 to 2010. There is no strong upward spike in its contribution to GDP growth visible in 2009 or 2010. Interestingly, the contribution of government spending to GDP growth in the euro area also remained fairly flat throughout the recession and recovery as is apparent from the right panel of Figure 2 (red line). It seems difficult to make a case for a crucial role of government spending in stimulating growth based on the inspection of this chart. It would be very useful if the European Commission and national euro area governments would similarly publish information on the actual spending pattern regarding the announced measures. This information is crucial for appropriate ex-post evaluations of their effectiveness.

In light of these findings, assessments of the impact of the government stimulus packages in 2009 in the U.S. and euro area should perhaps focus more on the likely effect of government transfers on GDP growth. Romer and Bernstein (2009) estimated based on their models that additional permanent government transfers and tax cuts planned by the U.S. administration would increase GDP by 2010 by one for one.¹⁵ Of course, given that the overall amount of the ARRA was limited the announced changes in transfers and taxes were primarily temporary in nature. The effect of such temporary measures depends crucially on importance of different motives for consumer behavior. Traditional Keynesian-style models may predict a positive impact of temporary transfers on GDP because consumption is modeled as a function of current after-tax income. Forward-looking, permanent-income consumers would instead see through the temporary increase and expect little or no boost to permanent income, because future tax increases may be needed to pay off the government debt incurred. Thus, their consumption would not change at all. For this reason, the DSGE models of Smets and Wouters (2003) and Smets and Wouters (2007) as well as the new DSGE model of Fed researchers Edge et al. (2010) predict no effect on GDP from a temporary increase in government transfers or temporary tax cuts or tax rebates.

As discussed earlier, some of the empirically-estimated New-Keynesian DSGE models allow for the presence of rule-of-thumb consumers. In Cogan et al. (2010) the estimated share is 26.5 percent and similar to other estimates available in the literature. In order to illustrate the impact of government transfers and tax cuts we simulate an increase in government transfers in that model of 1 percent of GDP for the duration of one year (solid black line in Figure 3). As shown in Figure 3 GDP (solid blue line) then increases by about 30 basis points for a year. In this simulation, interest rates are set according to Taylor's rule. We have also considered interest-rate accommodation for one or two years due to zero bound effects. However, the resulting increase in the GDP effect of transfers is rather small.

¹⁵ See the appendix 1: multipliers for different types of spending.

Figure 3: The GDP impact of temporary increase in government transfers of 1 % of GDP



Notes: SW-CCTW: DSGE model with rule-of-thumb households estimated in Cogan et al. (2010) with U.S. data. NAWM: calibrated two-country version of ECB’s New-Area-Wide model due to Coenen et al. (2008). Temporary increase of transfers in the U.S. economy.

For comparison, we have also included a simulation of the same temporary increase in government transfers in the calibrated two-country version of the ECB’s New-Area-Wide model due to Coenen et al. (2008). An estimated single-economy euro area version of this model has recently replaced the AWM model in ECB policy analysis. This estimated model was also used in the Coenen et al. (2010) study. In the calibrated two-country model the share of rule-of-thumb agents is set a 25 percent. Transfers, however, are assumed unevenly distributed, in per-capita terms, over the two types of households. The rule-of-thumb households are favored at a ratio of 3 to 1. As indicated by the dashed line in Figure 3 the impact on GDP of a one-percent increase in transfers is similar though slightly smaller than the estimate obtained with the model of Cogan et al. (2010).

In sum, this preliminary comparison suggests that the effects of the temporary increase in government transfers and tax cuts implied by the ARRA may be quite a bit smaller than expected by Romer and Bernstein. The models we considered so far suggest an effect between zero and 30 basis points on GDP per one percent of GDP increase in transfers. A possible concern is that the share of rule-of-thumb households has increased in the course of the financial crisis. The argument goes as follows. A standard justification for hard-wiring rule-of-thumb households in macro models is to capture borrowing constraints. Households who desire to borrow but are credit constrained would increase consumption along with increases in current disposable income. The number of such households might then have increased during the financial crisis, because banks were more reluctant to extend credit. Alternatively, it is also possible that the share of consumers that want to borrow declined during the recession. In particular, households who expect a lasting reduction in life-time income, because of less promising job opportunities, asset losses, sustained unemployment, or higher taxes may decide to save more. In this manner some of those households that were borrowing-constrained before, may now want to save rather than spend any additional income they might receive from the government.

The tax rebate in spring 2008 by the Bush administration and similar tax rebates or credits by the Obama administration in the context of the ARRA in spring 2009 have been the focus of a recent survey by Claudia Sahm and Slemrod (2010) that may shed some light on the direction of this effect. They write that 25 percent of households reported that the one-time economic stimulus payment in 2008 led them mostly to increase their spending. In 2009, it was 13 percent of households that report to have mostly spent the extra pay from the lower withholding. This finding, taken together with the above model-based analysis, may help explain the behavior of aggregate consumption and income. As pointed out by Taylor (2009) and Taylor (2010a), the rebate payments are directly apparent as upward spikes in aggregate disposable income in May-June 2008 and 2009, while aggregate consumption growth in those periods is relatively smooth and flat.

5 Conclusions

In this paper, we have presented a proposal for a comparative approach to macroeconomic policy analysis that is open to competing modeling paradigms. We have reviewed recent work on building a macroeconomic model archive and platform that makes it much easier to conduct extensive model comparisons. In addition, we have pointed towards a range of competing modeling approaches that should be the focus of a systematic model comparison exercise in the future. To illustrate the use of empirical benchmarks in a model competition, we have reviewed findings from a recent model comparison in terms of forecasting performance during U.S. recessions and recoveries. Model comparison can be a very valuable tool for robustifying policy recommendations. To illustrate what is meant by policy robustness, we have reviewed recent findings regarding the effectiveness of temporary fiscal stimulus measures from a range of models and studies.

References

- Adolfson, M., Andersson, M. K., Linde, J., Villani, M., and Vredin, A. (2005). Modern forecasting models in action: Improving macroeconomic analyses at central banks. Sveriges Riksbank Working Paper No. 190.
- Adolfson, M., Lasen, S., Lind, J., and Villani, M. (2007). Bayesian estimation of an open economy DSGE model with incomplete pass-through. *Journal of International Economics*, 72:481–511
- Akerlof, G. and Shiller, R. J., editors (2010). *Animal Spirits: How Human Psychology Drives the Economy, and Why It Matters for Global Capitalism*. Princeton University Press.
- Altig, D. E., Christiano, L. J., Eichenbaum, M., and Lind, J. (2005). Firm-specific capital, nominal rigidities and the business cycle. CEPR Discussion Papers 4858.
- Angeloni, I. and Faia, E. (2010). Capital regulation and monetary policy with fragile banks. Working Paper.
- Bernanke, B., Gertler, M., and Gilchrist, S. (1999). The financial accelerator in a quantitative business cycles framework. In Taylor, J. B. and Woodford, M., editors, *Handbook of Macroeconomics Volume 1C*. Amsterdam: Elsevier Science, North-Holland.
- Branch, W. A. and Evans, G. W. (2011). Monetary policy with heterogeneous expectations. *Economic Theory*, forthcoming.
- Branch, W. A. and McGough, B. (2011). Business cycle amplification with heterogeneous expectations. *Economic Theory*, forthcoming.
- Brock, W. and Hommes, C. (1998). Heterogeneous beliefs and routes to chaos in a simple asset pricing model. *Journal of Economic Dynamics and Control*, 22:1235–1274.
- Bryant, R., Currie, D., Frenkel, J., Masson, P., and Portes, R., editors (1989). *Macroeconomic Policies in an Interdependent World*. Washington, D.C.: The Brookings Institution.
- Bryant, R., Henderson, D. W., Holtham, G., Hooper, P., and Symansky, S. A., editors (1988). *Empirical Macroeconomics for Interdependent Economies*. Washington, D.C.: The Brookings Institution.
- Bryant, R., Hooper, P., and Mann, C., editors (1993). *Evaluating Policy Regimes: New Research in Empirical Macroeconomics*. Washington, D.C.: The Brookings Institution.
- Capistran, C. and Timmermann, A. (2009). Disagreement and biases in inflation expectations. *Journal of Money, Credit, and Banking*, 41:365–396.
- Carabenciov, I., Ermolaev, I., Freedman, C., Juillard, M., Kamenik, O., Korshunov, D., and Laxton, D. (2008). A small quarterly projection model of the US economy. IMF Working Paper 08/278.
- Chiarella, C., Dieci, R., and He, X.-Z. (2007). Heterogeneous expectations and speculative behavior in a dynamic multi-asset framework. *Journal of Economic Behavior and Organization*, 62:408–427.

- Christensen, I. and Dib, A. (2008). The financial accelerator in an estimated new keynesian model. *Review of Economic Dynamics*, 11:155–178.
- Christiano, L., Motto, R., and Rostagno, M. (2010). Financial factors in economic fluctuations. ECB Working Paper 1192.
- Christiano, L. J., Eichenbaum, M., and Evans, C. L. (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy*, 113(1):1–45.
- Clarida, R., Gal, J., and Gertler, M. (1999). The science of monetary policy: A new keynesian perspective. *Journal of Economic Literature*, 37(4):1661–1707.
- Clarida, R., Gal, J., and Gertler, M. (2002). A simple framework for international monetary policy analysis. *Journal of Monetary Economics*, 49:879–904.
- Claudia Sahm, M. S. and Slemrod, J. (2010). Check in the mail or more in the paycheck: Does the effectiveness of fiscal stimulus depend on how it is delivered? NBER Working Paper 16246.
- Coenen, G., Erceg, C. J., Freedman, C., Furceri, D., Kumhof, M., Lalonde, R., Laxton, D., Lind, J., Mourougane, A., Muir, D., Mursula, S., de Resende, C., Roberts, J., Roeger, W., Snudden, S., Trabandt, M., and in't Veld, J. (2010). Effects of fiscal stimulus in structural models. IMF Working Papers.
- Coenen, G., McAdam, P., and Straub, R. (2008). Tax reform and labour-market performance in The euro area: A simulation-based analysis using the new area-wide model. *Journal of Economic Dynamics & Control*, 32(8):2543–2583.
- Coenen, G. and Wieland, V. (2002). Inflation dynamics and international linkages: A model of the united states, the euro area and japan. ECB Working Paper Series 181.
- Coenen, G. and Wieland, V. (2005). A small estimated euro area model with rational expectations and nominal rigidities. *European Economic Review*, 49:1081–1104.
- Cogan, J. F., Cwik, T., Taylor, J. B., and Wieland, V. (2009). New keynesian versus old keynesian government spending multipliers. NBER Working Paper Series No. 14782.
- Cogan, J. F., Cwik, T., Taylor, J. B., and Wieland, V. (2010). New keynesian versus old keynesian government spending multipliers. *Journal of Economic Dynamics and Control*, 34:281–295.
- Cogan, J. F. and Taylor, J. B. (2010). What the government purchases multiplier actually multiplied in the 2009 stimulus package. NBER Working Paper 16505.
- Cwik, T. and Wieland, V. (2009). Keynesian government spending multipliers and spillovers in the euro area. CEPR Discussion Paper 7389.
- Cwik, T. and Wieland, V. (2011). Keynesian government spending multipliers and spillovers in the euro area. *Economic Policy* (forthcoming).
- De Fiore, F., Teles, P., and Tristani, O. (2009). Monetary policy and the financing of firms. ECB Working Paper 1123.
- De Grauwe, P. (2011). Animal spirits and monetary policy. *Economic Theory*, forthcoming.

- DeWalque, G., Pierrard, O., and Rouabah, A. (2009). Financial (in)stability, supervision and liquidity injections: A dynamic general equilibrium approach. *Economic Journal*, page forthcoming.
- DeGraeve, F. (2008). The external finance premium and the macroeconomy: US post-WWII evidence. *Journal of Economic Dynamics and Control*, 32:3415–3440.
- Deissenberg, C., Dawid, H., and van der Hoog, S. (2008). Eurace: A massively parallel agent-based model of the European economy. *Applied Mathematics and Computation*, 204:541–552.
- Del Negro, M. and Schorfheide, F. (2004). Priors from general equilibrium models for VARs. *International Economic Review*, 45(2):643–673.
- Diamond, P. and Vartiainen, H., editors (2007). *Behavioral economics and its applications*. Princeton University Press.
- Dib, A. (2010). Banks, credit market frictions, and business cycles. Bank of Canada.
- Dieppe, A., Kuester, K., and McAdam, P. (2005). Optimal monetary policy rules for the euro area: An analysis using the area wide model. *Journal of Common Market Studies*, 43(3):507–5372.
- Edge, R.M., Kiley, M. T., and Laforte, J.-P. (2007). Documentation of the Research and Statistics Division’s estimated DSGE model of the U.S. economy: 2006 version. Finance and Economics Discussion Series 07-53, Board of Governors of the Federal Reserve System.
- Edge, R. M., Kiley, M. T., and Laforte, J.-P. (2010). A comparison of forecast performance between Federal Reserve staff forecasts, simple reduced form models, and a DSGE model. *Journal of Applied Econometrics*, forthcoming.
- Erceg, C. J., Guerrieri, L., and Gust, C. (2008). Trade adjustment and the composition of trade. *Journal of Economic Dynamics & Control*, 32:2622–2650.
- Evans, G. and Honjapohja, S. (2001). *Learning and Expectations in Macroeconomics*. Princeton University Press.
- Fagan, G., Henry, J., and Mestre, R. (2005). An area-wide model for the euro area. *Economic Modelling*, 22:39–59.
- Freedman, C., Kumhof, M., Laxton, D., Muir, D., and Mursula, S. (2010). Global effects of fiscal stimulus during the crisis. *Journal of Monetary Economics*, 57:506–526.
- Fuhrer, J. C. (1997). Inflation/output variance trade-offs and optimal monetary policy. *Journal of Money, Credit and Banking*, 29(2):214–234.
- Fuhrer, J. C. and Moore, G. (1995). Inflation persistence. *The Quarterly Journal of Economics*, 110(1):127–159.
- Gerali, A., Neri, S., Sessa, L., and Signoretti, F. (2010). Credit and banking in a DSGE model of the euro area. *Journal of Money, Credit and Banking*, 42(6):supplement.
- Gertler, M., Gilchrist, S., and Natalucci, F. (2007). External constraints on monetary policy and the financial accelerator. *Journal of Money, Credit and Banking*, 39(2-3).
- Gertler, M. and Karadi, P. (2009). A model of unconventional monetary policy. mimeo.

- Gertler, M. and Kiyotaki, N. (2009). Financial intermediation and credit policy in business cycle analysis. (in preparation for the Handbook of Monetary Economics).
- Giannone, D., Monti, F., and Reichlin, L. (2009). Incorporating conjunctural analysis in structural models. In Wieland, V., editor, *The science and practice of monetary policy today*, pages 41–57. Springer Science.
- Giordani, P. and Söderlind, P. (2003). Inflation forecast uncertainty. *European Economic Review*, 47:1037–1059.
- Goodfriend, M. and McCallum, B. T. (2007). Banking and interest rates in monetary policy analysis: A quantitative exploration. *Journal of Monetary Economics*, 54(5):1480–1507.
- Gouvea, S., Minella, A., Santos, R., and Souza-Sobrinho, N. (2008). Samba: Stochastic analytical model with a bayesian approach. Manuscript.
- Hughes-Hallett, A. and Wallis, K. F., editors (2004). *EMU Macroeconomic Model Comparison exercise for the Euroconference 7-8 June 2002*. Economic Modelling 21(5).
- Iacoviello, M. (2005). House prices, borrowing constraints, and monetary policy in the business cycle. *The American Economic Review*, 95(3):739–764.
- Juillard, M. (1996). Dynare: A program for the resolution and simulation of dynamic models with forward variables through the use of a relaxation algorithm. CEPREMAP working paper, 9602.
- Klein, L., editor (1991). *Comparative Performance of U.S. Econometric Models*. Oxford, Eng.: Oxford University Press.
- Kurz, M. (1994a). On rational belief equilibria. *Economic Theory*, 4:859–876.
- Kurz, M. (1994b). On the structure and diversity of rational beliefs. *Economic Theory*, 4:877–900.
- Kurz, M. (1996). Rational beliefs and endogenous uncertainty: an introduction. *Economic Theory*, 8:383–397.
- Kurz, M. (1997a). Endogenous economic fluctuations and rational beliefs: A general perspective. In Kurz, M., editor, *Endogenous Economic Fluctuations: Studies in the Theory of Rational Beliefs*. Springer Series in Economic Theory, No. 6, Springer Verlag.
- Kurz, M., editor (1997b). *Endogenous Economic Fluctuations: Studies in the Theory of Rational Beliefs*. Springer Series in Economic Theory, No. 6, Springer Verlag.
- Kurz, M. (2009). Rational diverse beliefs and market volatility. In Hens, T. and Schenk-Hoppe, K., editors, *Handbook of financial markets: dynamics and evolution*. North Holland.
- Kurz, M., Jin, H., and Motolese, M. (2003). *Knowledge, Information and Expectations in Modern Macroeconomics: Essays In Honor of Edmund S. Phelps*, chapter 10: Endogenous Fluctuations and the Role of Monetary Policy, pages 188 –227. Princeton University Press: Princeton, N.J.
- Kurz, M., Jin, H., and Motolese, M. (2005). The role of expectations in economic fluctuations and the efficacy of monetary policy. *Journal of Economic Dynamics & Control*, 29:2017–2065.

- Laxton, D. and Pesenti, P. (2003). Monetary rule for small, open, emerging economies. *Journal of Monetary Economics*, 50:1109–1146.
- Levin, A., Wieland, V., and Williams, J. C. (2003). The performance of forecast-based monetary policy rules under model uncertainty. *The American Economic Review*, 93(3):622–645.
- Mankiw, N. G. and Reis, R. (2007). Sticky information in general equilibrium. *Journal of the European Economic Association*, 5(2-3):603–613.
- McCallum, B. and Nelson, E. (1999). Performance of operational policy rules in an estimated semi-classical structural model. In Taylor, J. B., editor, *Monetary Policy Rules*. Chicago: University of Chicago Press.
- Medina, J. P. and Soto, C. (2007). The Chilean business cycles through the lens of a stochastic general equilibrium model. Central Bank of Chile Working Papers 457.
- Meh, C. A. and Moran, K. (2010). The role of bank capital in the propagation of shocks. *Journal of Economic Dynamics and Control*, 34(3):555–576.
- Murchison, S. and Rennison, A. (2006). ToTEM: The Bank of Canada’s new quarterly projection model. Bank of Canada Technical Report No. 97.
- Nolan, C. and Thoenissen, C. (2009). Financial shocks and the US business cycle. *Journal of Monetary Economics*, 56:596–604.
- Orphanides, A. (2003). The quest for prosperity without inflation. *Journal of Monetary Economics*, 50:633–663.
- Orphanides, A. and Wieland, V. (1998). Price stability and monetary policy effectiveness when nominal interest rates are bounded at zero. Finance and Economics Discussion Series 98-35, Board of Governors of the Federal Reserve System.
- Orphanides, A. and Williams, J. C. (2006). *Journal of the European Economic Association*, 4:366–375.
- Ratto, M., Roeger, W., and in ’t Veld, J. (2009). QUEST III: An estimated open-economy DSGE model of the euro area with fiscal and monetary policy. *Economic Modelling*, 26(1):222–233.
- Reifschneider, D., Tetlow, R., and Williams, J. C. (1999). Aggregate disturbances, monetary policy and the macroeconomy: The frb/us perspective. *Federal Reserve Bulletin*, 85(1):1–19.
- Roeger, W. and in ’t Veld, J. (2009). Fiscal policy with credit constrained households. Working Paper.
- Romer, C. and Bernstein, J. (January 8, 2009). The job impact of the American Recovery and Reinvestment Plan.
- Rotemberg, J. J. and Woodford, M. (1997). An optimization-based econometric framework for the evaluation of monetary policy. *NBER Macroeconomics Annual*, 12:297–346.
- Rudebusch, G. D. and Svensson, L. E. O. (1999). Policy rules for inflation targeting. In Taylor, J. B., editor, *Monetary Policy Rules*. Chicago: University of Chicago Press.
- Slobodyan, S. and Wouters, R. (2008). Estimating a medium-scale DSGE model with expectations based on small forecasting models. mimeo.

- Smets, F. and Wouters, R. (2003). An estimated dynamic stochastic general equilibrium model of the euro area. *Journal of the European Economic Association*, 1 (5):1123–1175.
- Smets, F. and Wouters, R. (2007). Shocks and frictions in US business cycles: A Bayesian DSGE approach. *The American Economic Review*, 97(3):586–606.
- Taylor, J. B. (1993a). Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy*, 39:195–214.
- Taylor, J. B. (1993b). *Macroeconomic Policy in a World Economy*. W.W. Norton, New York. Online Edition available on: <http://www.stanford.edu/johntayl/MacroPolicyWorld.htm>.
- Taylor, J. B. (1999). *Monetary Policy Rules*. The University of Chicago Press.
- Taylor, J. B. (2009). The lack of an empirical rationale for a revival of discretionary fiscal policy. *American Economic Review, Papers and Proceedings*, 99(2).
- Taylor, J. (2010a). Getting back on track: Policy lessons from the financial crisis. *Federal Reserve Bank of St. Louis Review*, 92:165–176.
- Taylor, J. B. (2010b). Comment on "global effects of fiscal stimulus during the crisis". *Journal of Monetary Economics*, 57:527–530.
- Taylor, J. B. and Wieland, V. (2011). Surprising comparative properties of monetary models: Results from a new data base forthcoming in, *The Review of Economics and Statistics*.
- Tesfatsion, L. and Judd, K. L., editors (2006). *Handbook of Computational Economics, Volume 2: Agent-Based Computational Economics*. North Holland.
- Wieland, V. (2009). Learning, endogenous indexation and disinflation in the new-keynesian model. In Walsh, C. and Schmidt-Hebbel, K., editors, *Monetary Policy under Uncertainty and Learning*. Central Bank of Chile.
- Wieland, V., Cwik, T., Müller, G. J., Schmidt, S., and Wolters, M. (2009). A new comparative approach to macroeconomic modeling and policy analysis. Manuscript, Center for Financial Studies, Frankfurt.
- Wieland, V. and Wolters, M. (2011). The diversity of forecasts from macroeconomic models of the U.S. economy, forthcoming in, *Economic Theory*.