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Estimating general equilibrium models with stochastic volatility and changing parameters

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ABSTRACT

This paper explores the importance of specification in estimated general equilibrium models with changing monetary policy parameters and stochastic volatility. Simulated data is used to estimate models with incorrectly specified exogenous shocks (time-varying vs. constant variance) and models misspecifying the way Taylor rule parameters change over time (constant vs. drifting vs. regime-switching). The model correctly identifies some changes in monetary policy parameters, even when misspecified. The inclusion of stochastic volatility greatly improves model fit even when the data is generated using constant variance exogenous shocks; this relationship is stronger in data generated from models with changing policy parameters.

1. Introduction

Dynamic stochastic general equilibrium (DSGE) models have become an integral part of macroeconomic research and the estimation of these models has been used to research many economic questions. An often overlooked concern is the impact that misspecification may have when estimating DSGE models. This is particularly relevant when studying changing macroeconomic volatility, which often focuses on changes in monetary policy reaction functions and changes in the volatility of exogenous shocks. Misspecification in these models is a major concern since there are a variety of ways of modeling changing monetary policy and it is impossible to truly know which specification is correct. Therefore, it is important to ask the question, what impact does misspecification of changes in monetary policy have when estimating DSGE models?

To answer this question, I estimate a DSGE model with drifting monetary policy parameters and stochastic volatility, which allows the standard deviation of exogenous shocks to change over time, under a variety of misspecifications. The model is estimated using both actual United States macroeconomic data and simulated data generated from models with homoscedastic shocks and a variety of monetary policy specifications. Monetary policy parameters in these models are allowed to drift over time, change discretely, or remain constant through time. The simulated data is use to test whether the model can determine the importance of stochastic volatility, even if the model is misspecified. Additionally, this paper shows how best to determine the importance of stochastic volatility by analyzing both model fit and studying the filtered underlying states of misspecified models. This can help researchers interpret results when there are concerns about misspecification, which is often a major worry with DSGE estimation.

Determining the importance of stochastic volatility and changing monetary policy is critical since they have been singled out as key causes of the Great Moderation, a period of reduced macroeconomic volatility starting in the 1980s. The true cause of the moderation is unclear since some research supports “good luck,” where a reduction in the variance of the economys underlying shocks caused lower macroeconomic volatility (e.g. McConnell and Perez-Quiros, 2000; Sims and Zha, 2006; Liu et al., 2011; Fernández-Villaverde et al., 2015a), while other research supports “good policy,” which points to improved monetary policy as the root cause of the moderation (e.g. Clarida et al., 2000).[1] Being able to disentangle whether “good luck” or “good policy” caused macroeconomic volatility to change is critical since they are starkly different causes. One explanation suggests that there is nothing that can be done, while the other suggests that strong monetary policy is needed to maintain low volatility. If it is in fact good monetary policy that caused the Great Moderation, then more research should be done regarding optimal monetary policy.

One reason why empirical studies differ in their finding is the tools used in the analysis. Benati and Surico (2009) show that using a vector autoregression (VAR) to studying time-varying volatility can lead to incorrect conclusions since a VAR can give inaccurate results about what causes changes in economic volatility. A VAR is likely to attribute changes in observed volatility to changes in the variance of structural shocks, even if this was caused by a change in monetary policy. Due to these findings, recent research often uses DSGE models which place more structure on the estimation. This structure increases the chances

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[1] For other explanations see Dynan et al. (2006), Fuentes-Albero (2014), and Morley and Singh (2016).

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that a correctly specified DSGE model will accurately identify the causes of time-varying volatility. Since this is a major area of research in macroeconomics, it is vital that researchers know whether DSGE models are good tools for identifying these causes.

While the structure of DSGE models can help improve identification, these models are not without faults. The researcher must fully model not just the structure of the economy, but the structure of the exogenous shocks and any changing parameters. In particular, the researcher must decide whether to model changes as happening smoothly over time with parameter drifting models or with discrete changes using regime-switching models. This decision is not straightforward since monetary policy may change discretely when there is a new chair or may change slowly over time as monetary theory evolves. Since estimation of large regime-switching DSGE models is often impractical, it is important to know how well models with stochastic volatility and parameter drifting perform when misspecified. A question to consider is: could misspecification of changing monetary policy lead to misinterpretations about changes in the standard deviation of exogenous shocks? For example, a discrete reduction in the central banks reaction to inflation is likely to lead to a sudden increase in volatility in the economy. If the policy reaction is modeled as evolving slowly over time, some of this change in volatility may incorrectly be attributed to changes in the standard deviation of exogenous shocks. This may cause the researcher to observe an increase in stochastic volatility, even if there is no change in the standard deviation of the underlying exogenous shocks.

To study this question, I use simulate data to better understand the importance of misspecification when using models with changing parameters and stochastic volatility. To perform this analysis, I first simulate data from a New Keynesian model with regime switches in the Taylor coefficients and constant variance shocks. I use a simple model along the lines of Lubik and Schorfheide (2004), and I use their results to calibrate the model. This model is simulated with regime-switching, drifting parameter, and constant parameter specifications of the monetary policy rule. All of the simulated models have constant variance shocks. I then use the simulated data to estimate the parameters of a model featuring parameter drift in the monetary policy coefficients and either stochastic volatility or homoscedastic shocks. This means that the policy rule can be properly specified, misspecified in the way that parameters change (discrete changes vs. slow changes), or misspecified about whether or not parameters change. Additionally, the model is estimated using actual U.S. macroeconomic data, which can help determine if these concerns are relevant when studying actual data. The models are estimated using a particle filter and Bayesian techniques. The estimation results are used to compare model fit and analyze the underlying states. If the misspecifications are not important, the inclusion of stochastic volatility should not improve the fit and the underlying states should show no change in the stochastic volatility terms over time when using simulated data.

The results of the study show that the inclusion of stochastic volatility can dramatically improve model fit, even when the underlying generated data does not have stochastic volatility. This effect is stronger in models with changing monetary policy, especially when the changing policy parameters are misspecified. This is driven by two factors. First, changes in the monetary policy rule will directly impact the volatility of the interest rate, while also having indirect effects on output and inflation through monetary transmission mechanisms. The model is going to attribute part of the change in volatility caused by drifting monetary policy to a rise or fall in stochastic volatility. Second, when the model is misspecified, any change that the model cannot account for will show up as an additional random shock to the model. The inclusion of stochastic volatility incorporates more shocks into the model, which can then improve model fit by explaining these errors that arise due to misspecification. This effect is naturally offset by a penalty that the Bayesian estimation procedure naturally places a penalty on additional coefficients through the priors. Based on the size of the improvements in model fit, the improved fit of the data overwhelms the penalty the priors impose and is so large that researchers would determine that stochastic volatility is a necessary part of the model.

The finding that adding stochastic volatility to DSGE models can improve model fit even when the underlying true, simulated data has constant variance shocks is troubling. This is concerning since the inclusion of stochastic volatility does, in fact, improve model fit when studying actual U.S. data. Since the true data generating process of the real data is unknown, this may be resulting from misspecification or the real data actually having stochastic volatility. Stochastic volatility may arise due to truly exogenous “luck” or it can arise because demographic changes, sector composition changes, or globalization can change the volatility of supply and demand shocks. For example, as a population ages they may be less likely to change jobs or have large swings in consumption demands, so the size of supply and demand shocks may be smaller with this demographic change. The importance of stochastic volatility is shown by Fernández-Villaverde et al. (2015a), where stochastic volatility is singled out as the key driver of the Great Moderation. Looking beyond the Great Moderation, Bloom (2009) and Fernández-Villaverde et al. (2015b) show that increased uncertainty, which is modeled using stochastic volatility, can have large impacts on the economy. Therefore, it is vital that researchers be able to empirically identify the importance of stochastic volatility in DSGE models.

Studying model fit is not the only way to determine the relevance of stochastic volatility in DSGE models. The underlying states that are generated from the particle filter can also be analyzed. These states show how stochastic volatility and monetary policy terms change over time. This analysis is quite accurate, even when there is misspecification. These accurately show when the reaction of monetary policy to inflation changes and if there are changes in the standard deviation of the exogenous shocks. Since model comparison based on model fit can be influenced by misspecification, studying the underlying states is a helpful exercise when studying DSGE models.

While this paper focuses on the importance of changing monetary policy parameters and stochastic volatility, the results have broader relevance. Since the true nature of the economy is not known, DSGE models are likely to be misspecified. If an economist is worried about whether or not a model is correctly specified then studying the model fit should be done with caution. To better understand the importance of certain model features over time, the researcher should focus on the underlying states of the model instead of the model fit.

The rest of the paper is organized as follows. Section 2 presents the models used to generate the data and to estimate the generated data. Section 3 explains how the data was generated and discusses some of the features of the generated and actual data. Section 4 presents the estimation methodology and describes how the likelihood is approximated. Section 5 presents and analyzes the estimation results. Section 6 provides some concluding remarks.

2. Models

In order to study the interaction of parameter drifting and stochastic volatility a model must be specified. Since this paper studies misspecification, including regime switching, a small-scale model must be used. The model selected as the basis for the study is a simple, log-linearized New-Keynesian model. The New-Keynesian model is widely used in the literature and is one of the fundamental models of monetary policy analysis. A log-linearized version of the model is used so that the only non-linearities of the model will arise from changes in the monetary policy rule and the stochastic volatility. In the analysis, there are four variations of the basic model: a model with regime switching in the policy parameters, a model with parameter drift and stochastic volatility, a model with parameter drift and constant variance shocks, and a model with constant parameters and constant