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# Learning and time-varying macroeconomic volatility

Fabio Milani *

*Department of Economics, 3151 Social Science Plaza, University of California, Irvine, CA 92697-5100, United States*

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ABSTRACT

This paper presents a DSGE model in which agents' learning about the economy can endogenously generate time-varying macroeconomic volatility. Economic agents use simple models to form expectations and need to learn the relevant parameters. Their gain coefficient is endogenous and is adjusted according to past forecast errors.

The model is estimated using likelihood-based Bayesian methods. The endogenous gain is jointly estimated with the structural parameters of the system.

The estimation results show that private agents appear to have often switched to constant-gain learning, with a high constant gain, during most of the 1970s and until the early 1980s, while reverting to a decreasing gain later on. As a result, the model can generate a pattern of volatility, which is increasing in the 1970s and falling in the second half of the sample, with a decline that can roughly match the magnitude of the so-called "Great Moderation" in the 1984–2007 period. The paper also documents how a failure to incorporate learning into the estimation may lead econometricians to spuriously find time-varying volatility in the exogenous shocks, even when these have constant variance by construction.



## 1. Introduction

### *1.1. TV macroeconomic volatility*

Several studies have documented large changes in the volatility of macroeconomic fluctuations in the US over the post-war period. Kim and Nelson (1999), McConnell and Pérez-Quiròs (2000), Blanchard and Simon (2001), and Stock and Watson (2002), among several others, have identified a large decline of output growth volatility in the years post-1984 and before the 2007 financial crisis, compared to the previous two decades (the large shift in volatility is commonly referred to as "The Great Moderation"). The reduction in volatility is apparent if one looks at simple measures as the variances of output growth and inflation in the 1950–1980 versus the 1980–2007 samples. Slightly more sophisticated approaches yield a similar message: Fig. 1, for example, shows the conditional standard deviations from GARCH models for inflation and output gap over time. The conditional standard deviations for both series increase in the 1970s and substantially decline after the early 1980s.

* Tel.: +1 949 824 4519; fax: +1 949 824 2182.
*E-mail address:* fmilani@uci.edu
*URL:* http://www.socsci.uci.edu/~fmilani

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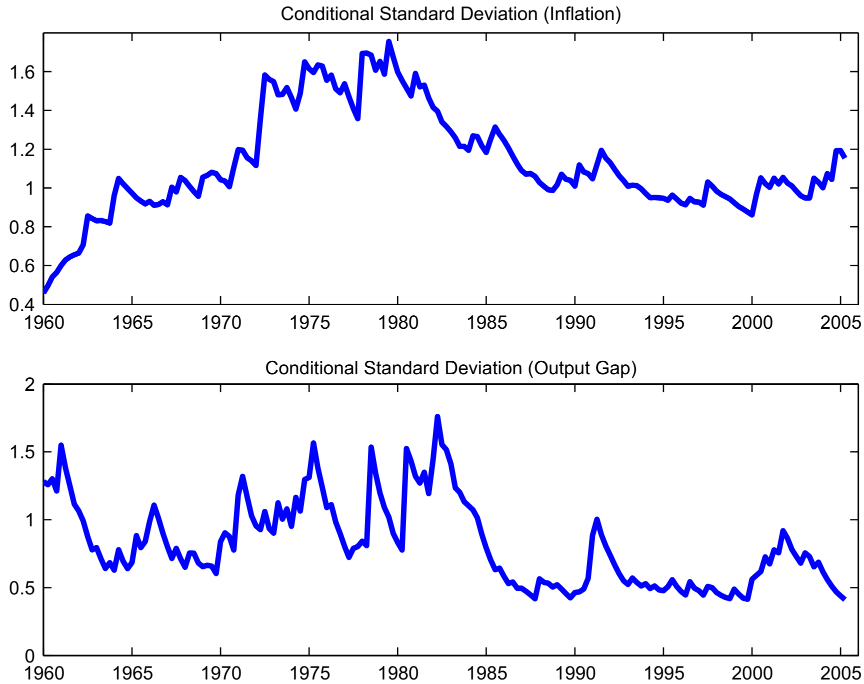


**Fig. 1.** Conditional standard deviation series for inflation and output gap. *Notes*: to compute the conditional standard deviation series, I have estimated AR(1) models for inflation and output gap series (the latter calculated using the deviation of real GDP from the CBO's potential GDP series), allowing for a GARCH(1,1) specification for the residuals.

Correctly modeling changes in volatility has been shown to be important for understanding macroeconomic fluctuations. Sims and Zha (2006) find that incorporating regime changes in the volatilities of disturbances in a Bayesian VAR overturns the evidence of large regime switches in US monetary policy. Primiceri (2005), instead, estimates a VAR in which he allows for a continuously changing variance–covariance matrix: he similarly concludes that the role played by the falling volatility of exogenous shocks seems more important than monetary policy changes in explaining the recent behavior of US inflation and unemployment.

With few exceptions, however, estimated DSGE models still habitually assume that the shocks have maintained constant variance throughout the whole sample (e.g., Smets and Wouters, 2003, 2007; Lubik and Schorfheide, 2004; An and Schorfheide, 2007). The papers by Justiniano and Primiceri (2008) and Fernandez-Villaverde and Rubio-Ramirez (2007) were the first to relax this assumption. Both papers incorporate stochastic volatility in optimizing DSGE models. They find that the volatilities of the shocks have significantly changed over time and that accounting for those variations is important to improve the models' fit to the data.

The existence of time-varying volatility in the economy, therefore, can be now considered an empirical regularity. But what drives the changes in the volatility of macroeconomic fluctuations?

In Justiniano and Primiceri (2008) and Fernandez-Villaverde and Rubio-Ramirez (2007), the changes in volatility are modeled as *exogenous*. But if these are an important feature of the economy as they appear to be, it becomes crucial to try to understand their potential causes.

### *1.2. Paper's contribution*

This paper takes a step in this direction by presenting a model in which stochastic volatility arises endogenously in the economy. I present a stylized New-Keynesian DSGE model in which agents' learning about the economy has implications for macroeconomic volatility. Economic agents use simple models to form expectations and need to learn the relevant model parameters over time.[1] Their learning speed is endogenous and depends on previous forecast errors. When the forecast errors are large, agents become concerned that the economy may be experiencing a structural break and, therefore, they start assigning a larger weight to new information. When the forecast errors are, instead, relatively modest, economic agents remain confident about their model and turn less responsive to new information. The endogenous time-varying learning speed has implications for the volatility of the macroeconomic variables that agents are trying to learn about. In this way, agents' learning with an endogenous gain can generate stochastic volatility in the economy.

[1] See Evans and Honkapohja (2001) for a treatment of several models with adaptive learning.