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The Price Puzzle: Mixing the Temporary and Permanent Monetary Policy Shocks

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Monetary Policy Department

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by Ida Wolden Bache and Kai Leitemo

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The price puzzle: Mixing the temporary and permanent monetary policy shocks

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Abstract

We argue that the correct identification of monetary policy shocks in a vector autoregression requires that the identification scheme distinguishes between permanent and transitory monetary policy shocks. The permanent shocks reflect changes in the inflation target while the transitory shocks represent temporary deviations from the interest rate reaction function. Whereas both shocks may raise the nominal interest rate on impact, the inflation and output responses of the two shocks are different. We show, using a simple simulation experiment, that a failure to distinguish between the two types of shocks can result in a "price puzzle".

Keywords: Monetary policy shocks, VAR modeling, identification, price puzzle.

JEL codes: E47, E52, E61.

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1 Introduction

A large literature using VAR models to estimate the monetary transmission mechanism assumes that monetary policy shocks can be identified as the deviations of the instrument from an estimated policy rule. This type of identification is often plagued by a so-called "prize puzzle": the VAR models suggest that prices tend to increase after a contractionary monetary policy shock (see Sims (1992) and Eichenbaum (1992)). In this paper we argue that one possible explanation for the price puzzle is that the standard identification schemes ignore the presence of persistent shocks to the underlying inflation target. If such shocks are prevalent, an exogenous change in the nominal interest rate can either be due to changes to inflation expectations caused by changes to the inflation target or to temporary monetary policy shocks. The monetary policy shock identified by the recursive identification scheme then represents a mixture of the transitory shock and the shock to the inflation target.¹ If the latter is sufficiently important, the identified shock will produce a "price puzzle" because it is partly contaminated by the shock to the inflation target that produces a price "puzzle" that is no puzzle at all.

Several other explanations for the prize puzzle have been proposed in the literature. Sims (1992) called for the use of non-borrowed and borrowed reserves in the VAR model along with a commodity price index. Hanson (2004), investigating different commodity price indices, shows that this approach does not solve the price puzzle in pre-1979 data: there is still a significant increase in prices up to 18 months after a contractionary monetary policy shock. For the post-1982 period, there is no *significant* increase in prices, however, point estimates of the price level response tend to stabilize at a level that is higher than before the contractionary monetary policy shock. Barth and Ramey (2001) and Chowdhury et al. (2006) argue that the price puzzle is not really a puzzle, but reflects the increase in prices due to higher borrowing costs caused by the increase in the interest rate. Giordani (2004) suggests that the price puzzle is due to the VAR model not including a measure of potential output or the output gap. The price puzzle is hence a sign of model misspecification and is therefore distantly related to our explanation.

Section 2 presents a New Keynesian macro model which obeys the recursive contemporary restrictions often used to identify monetary policy in VAR models, but allows for both persistent (changes to the inflation target) and transitory (deviations from the reaction function) shocks to monetary policy. We derive the analytical solution to a simplified version of this model and show the effects of these shocks. In Section 3 we generate artificial data from the theoretical model,

¹See Smets and Wouters (2003), Ireland (2007), Melecky et al. (2008) and Bjørnland and Leitemo (2007) for studies that differentiate between the two monetary policy shocks.

estimate a VAR model on the artificial data and show how a "price puzzle" may appear when the standard recursive identification scheme. Section 4 concludes.

2 A simple theory model

We consider the New Keynesian model with implementation lags (of order j) in pricing and consumption decisions. The model is then given by

$$\begin{aligned}\pi_t &= \beta E_{t-j} \pi_{t+1} + \gamma E_{t-j} x_t + \varepsilon_t \\ x_t &= E_{t-j} x_{t+1} - \sigma^{-1} (E_{t-j} i_t - E_{t-j} \pi_{t+1} - \tilde{r}_t)\end{aligned}$$

where π is inflation, x is the output gap, i is the nominal interest rate, β is the discount factor and E_{t-j} is the expectations operator conditional on information in period $t-j$. We assume that the cost-push shock (ε_t) and the natural rate shock (\tilde{r}_t) follow AR(1) processes, i.e.,

$$\begin{aligned}\varepsilon_{t+1} &= \rho_\varepsilon \varepsilon_t + \hat{\varepsilon}_{t+1}, \\ \tilde{r}_{t+1} &= \rho_{\tilde{r}} \tilde{r}_t + \hat{r}_{t+1}.\end{aligned}$$

The model is closed by a rule for the interest rate,

$$i_t = \rho_i i_{t-1} + (1 - \rho_i) (E_t \pi_{t+1} + \theta_\pi [E_t \pi_{t+1} - \pi_t^*]) + m_t,$$

which is a forward-looking "inflation targeting" rule with interest-rate smoothing (see Clarida et al. (2000) and Bernanke and Gertler (2001)). The processes for the inflation target and the transitory monetary policy shock are, respectively,

$$\begin{aligned}\pi_{t+1}^* &= \rho_\pi \pi_t^* + \hat{\pi}_{t+1}, \text{ and} \\ m_{t+1} &= \rho_m m_t + \hat{m}_{t+1}.\end{aligned}$$

2.1 The analytical solution

In order to elicit the impulse responses to the monetary policy shocks we solve a version of the model analytically. Since the intermediate-length impulse responses to the model do not depend on the implementation lags or the smoothing parameter in the Taylor rule, we set $j = 1$ and $\rho_i = 0$

in order to make the problem tractable.

The equilibrium solution takes the form

$$\begin{aligned}\pi_{t+1} &= \phi_\varepsilon \varepsilon_t + \phi_r r_t + \phi_\pi \pi_t^* + \phi_m m_t + \hat{\varepsilon}_{t+1}, \\ x_{t+1} &= v_\varepsilon \varepsilon_t + v_r r_t + v_\pi \pi_t^* + v_m m_t + \sigma^{-1} \hat{r}_{t+1}.\end{aligned}$$

The values of the coefficients can be determined by the minimal state variable solution method and are given by

$$\begin{aligned}\phi_\varepsilon &= \frac{(1 - \rho_\varepsilon)}{A_\varepsilon} > 0, \quad v_\varepsilon = \frac{-\sigma^{-1} \theta_\pi}{A_\varepsilon} < 0, \quad \phi_r = \frac{\gamma \sigma^{-1}}{A_r} > 0, \quad v_r = \frac{(1 - \beta \rho_r) \sigma^{-1}}{A_r} > 0, \\ \phi_\pi &= \frac{\gamma \sigma^{-1} \theta_\pi}{A_\pi \rho_\pi} > 0, \quad v_\pi = \frac{(1 - \beta \rho_\pi) \sigma^{-1} \theta_\pi}{A_\pi \rho_\pi} > 0, \quad \phi_m = \frac{-\gamma \sigma^{-1}}{\rho_m (1 - \beta \rho_m) (1 - \rho_m) + \gamma \sigma^{-1} \theta_\pi} < 0, \\ v_m &= \frac{-(1 - \beta \rho_m) \sigma^{-1}}{\rho_m (1 - \beta \rho_m) (1 - \rho_m) + \gamma \sigma^{-1} \theta_\pi} < 0,\end{aligned}$$

where $A_n \equiv (1 - \beta \rho_n) (1 - \rho_n) + \gamma \sigma^{-1} \theta_\pi$ and $n \in \{\varepsilon, r, \pi\}$. The equilibrium condition for the interest rate takes the form

$$i_t = \eta_\varepsilon \varepsilon_t + \eta_r r_t + \eta_\pi \pi_t^* + \eta_m m_t,$$

where

$$\begin{aligned}\eta_\varepsilon &= \frac{(\rho_\varepsilon + \theta_\pi) (1 - \rho_\varepsilon)}{A_\varepsilon} > 0, \\ \eta_r &= \frac{(\rho_r + \theta_\pi) \gamma \sigma^{-1}}{A_r} > 0, \\ \eta_\pi &= \frac{\theta_\pi (\rho_\pi \gamma \sigma^{-1} - (1 - \beta \rho_\pi) (1 - \rho_\pi))}{A_\pi}, \\ \eta_m &= \frac{(1 - \rho_m) (1 - \beta \rho_m) - \rho_m \gamma \sigma^{-1}}{A_m}.\end{aligned}$$

To determine the signs of η_π and η_m , the coefficients on the shocks to inflation target and the transitory shock in the reaction function, we consider the case where $\rho_\pi \rightarrow 1$ and $\rho_m = 0$, i.e., the shock to the inflation target is permanent (approaches a random walk) and the transitory shock is white noise. Under these assumptions, we have that

$$\begin{aligned}\eta_\pi|_{\rho_\pi \rightarrow 1} &= 1 > 0, \\ \eta_m|_{\rho_m \rightarrow 0} &= \frac{1}{1 + \gamma \sigma^{-1} \theta_\pi} > 0.\end{aligned}$$

The model predicts that realizations of the monetary policy shocks that move the interest rate

in the same direction, will produce opposite effects on inflation and output. An increase in the nominal interest rate caused by an increase in the inflation target will cause inflation and output to increase, whereas a contractionary temporary shock will lower inflation and output.

This result illustrates that aggregating the two shocks is indeed problematic since the shocks have different quantitative and qualitative properties. An identification scheme that do not distinguish between the two shocks will identify a shock that is a mix of the two underlying shocks, potentially producing "puzzling" results.

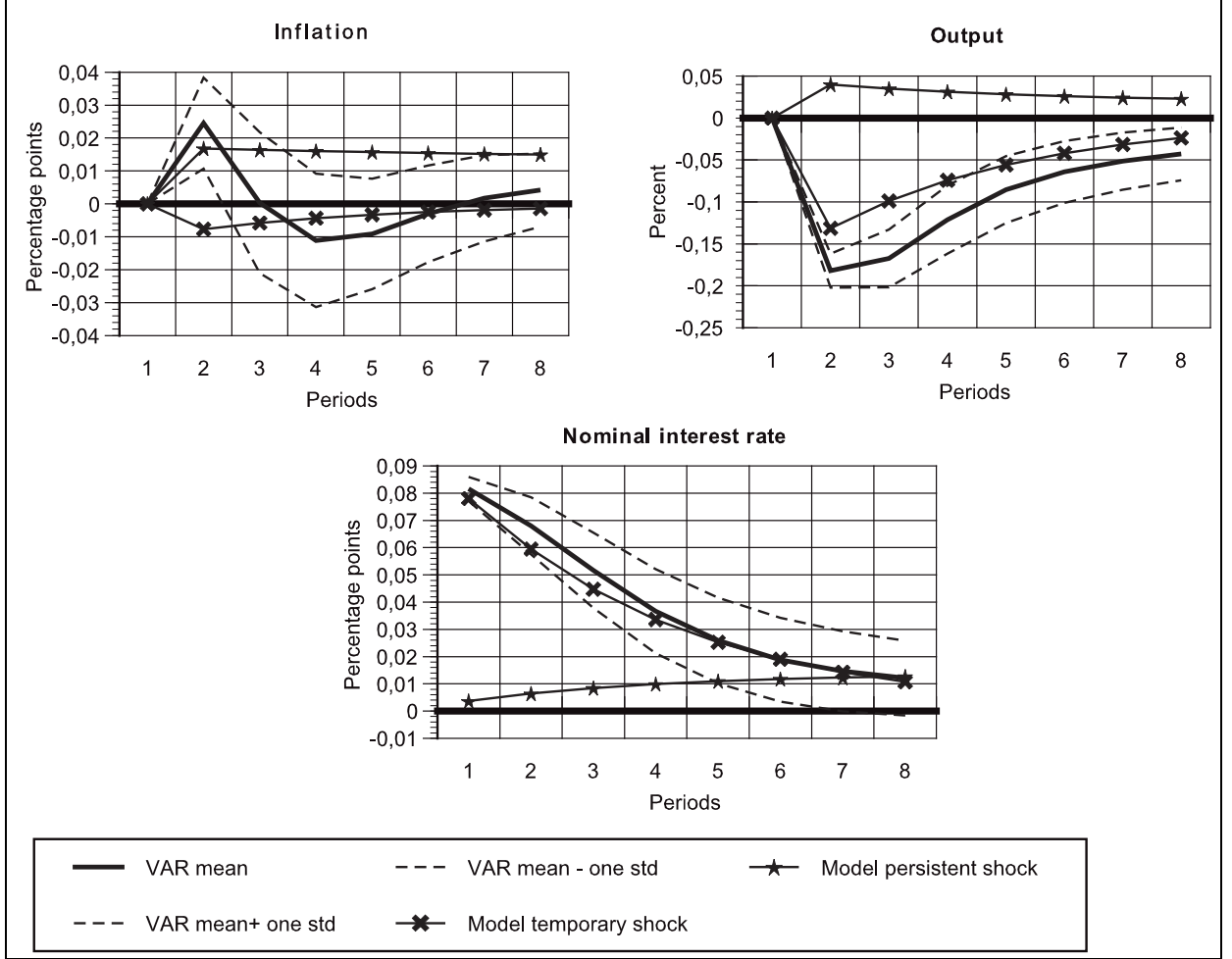
3 A simulation experiment

To illustrate our point we conduct a simple simulation experiment. We generate artificial datasets for inflation, the output gap and the nominal interest rate from the theory model, estimate a VAR on the artificial data and compute the impulse responses to a monetary policy shock using a standard recursive identification scheme. Specifically, we identify the monetary policy shock by placing the interest rate last in a recursive ordering of the variables and use a Choleski decomposition of the estimated variance-covariance matrix of the residuals to recover the impact matrix of the shocks. This identification scheme implies that the nominal interest rate can respond to contemporaneous shocks to inflation and the output gap, while the output gap can respond to contemporaneous shocks in inflation alone. Inflation is assumed not to respond to contemporaneous shocks neither to the interest rate nor to the output gap. Importantly, this identification scheme is consistent with the underlying theoretical model. We set the parameters in the IS- and Phillips curves² to $\gamma = 0.015, \beta = 0.99, \sigma = 2, \rho_\varepsilon = \rho_{\tilde{r}} = 0.65, \sigma_{\tilde{\varepsilon}} = 0.16$ and $\sigma_{\tilde{r}} = 0.30$. which do not seem a priori unreasonable. The parameters in the reaction function are $\theta_\pi = 0.75$ and $\rho_i = 0.78$. Finally, we set $\rho_\pi = 0.99, \rho_m = 0.01, \sigma_{\hat{\pi}} = 0.017$ and $\sigma_{\hat{m}} = 0.081$ for the processes governing the monetary policy shocks. The standard deviations of the two monetary policy shocks correspond to the estimated posterior mode in Smets and Wouters (2003).

We simulate 1000 datasets consisting of 180 observations from the theory model and estimate a VAR in inflation, the output gap and the nominal interest rate with two lags. The impulse responses from the model are shown in Figure 1. We see from the figure that the VAR model produces a price puzzle in the sense that inflation increases in the first few periods after the shock and then falls. The failure to properly identify the transitory monetary policy shock does not affect the ability of the VAR to identify the effect of the temporary monetary policy shock on the output

²Although the Phillips curve is specified as fully forward looking, we obtain similar results if the model is 'hybrid' and is moderately backward-looking. Cogley and Sbordone (2006) argue, however, that once accounting for changes in the inflation target, the Phillips curve is best described as being fully forward-looking.

Figure 1
Impulse response functions.



The figure shows the impulse responses from the identified monetary policy shock in the VAR model (with one standard deviation bands) and the temporary and persistent monetary policy shocks from the theoretical model.

gap and the interest rate in any significant way. Hence, our explanation for the price puzzle does not imply any other puzzles.

4 Conclusion

We suggest that the presence of a "price puzzle" in VAR models of the monetary transmission mechanism could be due to a failure to differentiate between temporary deviations from the interest rule and persistent changes in the underlying inflation target. An important goal for future research is to present a identification scheme that takes into account the very different propagation mechanisms of the two shocks. A possible solution is to take advantage of the different response of the term structure of interest rates to the two shocks.

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