Are Policy Counterfactuals Based on Structural VARs Reliable?

Luca Benati
European Central Bank

2nd International Conference in Memory of Carlo Giannini
20 January 2010

The views expressed herein are personal, and do not necessarily reflect the position of the European Central Bank
This paper:

Issue: ‘Are SVAR-based policy counterfactuals reliable?’

Based on DSGE models, I explore to which extent SVAR-based counterfactuals can reliably capture the impact of changes in the Taylor rule on the properties of the economy.

Motivation:

SVAR-based policy counterfactuals are widely used:

- Primiceri (ReStat, 2005), Sims-Zha (AER, 2006), Gambetti, Pappa, Canova (JMCB, 2006) etc. etc. …

However:

- **reliability** has never been systematically checked conditional on a set of DGPs
- **only** piece of evidence—Benati and Surico (AER, 2009)—is negative …
Motivation (continued):

Benati and Surico (AER, 2009) provide a single example based on estimated DSGE models in which SVARs fail to uncover the truth about the DGP …

In particular, SVAR-based counterfactual dramatically fails to capture the impact of changes in the Taylor rule …

So, how serious is the problem?

Do Benati and Surico’s results crucially depend on their specific DGP, or do they point towards a general problem?

Let’s start by considering the key conceptual issue involved …
The problem in a nutshell

• Take a New Keynesian model
• Consider two sets of parameters for the Taylor rule:

\[
\begin{align*}
\text{Taylor}^1 &\Rightarrow [\rho^1, \psi^1_{\pi}, \psi^1_{y}] \\
\text{Taylor}^2 &\Rightarrow [\rho^2, \psi^2_{\pi}, \psi^2_{y}]
\end{align*}
\]

Together with other parameters, you have:

\[
\begin{align*}
\text{Taylor}^1 &\Rightarrow \text{DSGE}^1 \Rightarrow \text{SVAR}^1 \Rightarrow \text{MonetaryRule}^1 \\
\text{Taylor}^2 &\Rightarrow \text{DSGE}^2 \Rightarrow \text{SVAR}^2 \Rightarrow \text{MonetaryRule}^2
\end{align*}
\]

where MonetaryRule\(^i\), \(i = 1, 2\) is interest rate equation of the structural VAR representation of the DSGE model

Key issue is: ‘Switching MonetaryRule\(^1\) and MonetaryRule\(^2\) is not the same as switching Taylor\(^1\) and Taylor\(^2\),’

\(\Rightarrow\) difference is sometimes large …
Feed same set of shocks to New Keynesian 3-equation ‘toy’ model conditional on two alternative Taylor rules:

- Taylor\(^1\) \(\rightarrow [\rho_1, \psi_\pi^1, \psi_y^1]\) (call it ‘bad’ policy)
- Taylor\(^2\) \(\rightarrow [\rho_2, \psi_\pi^2, \psi_y^2]\) (call it ‘good’ policy)

A simple illustration:

Switching Taylor\(^1\) and Taylor\(^2\) within the DSGE model causes black lines to become blue, and vice versa …
Two alternative notions of policy counterfactual:

• Switching Taylor\(^1\) and Taylor\(^2\) within the DSGE model is the **authentic** policy counterfactual
• Switching MonetaryRule\(^1\) and MonetaryRule\(^2\) within the SVAR model is the **SVAR-based** policy counterfactual

**Question:** ‘**Can I replicate the authentic policy counterfactual by switching the monetary rules of the structural VAR representations of the DSGE models?**’

The **answer** is **NO**, and the difference between the outcome of the authentic policy counterfactual and the outcome of the SVAR-based counterfactual is sometimes large …

Let’s see in this case how large the error is in going from ‘bad’ to ‘good’ \(\Rightarrow\) imposing MonetaryRule\(^2\) in SVAR\(^1\)
If SVAR-based counterfactual worked, red lines would be identical to the blue lines ... but this is clearly not the case ...

• On the contrary, for inflation and output gap you hardly move from the ‘bad’ regime (red almost identical to black)
• SVAR-based counterfactual fails to capture truth

⇒ Let’s see results based on numerical methods ...
Theoretical properties of SVAR-based policy counterfactuals

- Model: standard New Keynesian model with backward and forward-looking components

\[ y_t = \gamma y_{t+1|t} + (1 - \gamma) y_{t-1} - \sigma^{-1}(R_t - \pi_{t+1|t}) + \epsilon_{y,t} \]

\[ \pi_t = \frac{\beta}{1 + \alpha \beta} \pi_{t+1|t} + \frac{\alpha}{1 + \alpha \beta} \pi_{t-1} + \kappa y_t + \epsilon_{\pi,t} \]

\[ R_t = \rho R_{t-1} + (1 - \rho) [\phi_{\pi} \pi_t + \phi_y y_t] + \epsilon_{R,t} \]

- Country: United States
- Sample period: post-1960 period
- Bayesian estimates: standard (Random-Walk Metropolis)

These ‘benchmark’ estimates imply certain theoretical properties for the economy

⇒ trivially recovered from VAR implied by DSGE model …
I will show results from the following exercise:

- Let Taylor$^B \equiv [\rho^B, \psi_{\pi}^B, \psi_y^B]$ be the estimated benchmark Taylor rule.
- Let Taylor$^A \equiv [\rho^A, \psi_{\pi}^A, \psi_y^A]$ be an alternative Taylor rule, with different values of the key coefficients.

We have

$$\text{Taylor}^B \Rightarrow \text{DSGE}^B \Rightarrow \text{SVAR}^B \Rightarrow \text{MonetaryRule}^B$$
$$\text{Taylor}^A \Rightarrow \text{DSGE}^A \Rightarrow \text{SVAR}^A \Rightarrow \text{MonetaryRule}^A$$

which implies two sets of theoretical standard deviations for the series

$$\text{SVAR}^B \Rightarrow \text{STDs}^B$$
$$\text{SVAR}^A \Rightarrow \text{STDs}^A$$
By definition, Substituting Taylor$^A$ with Taylor$^B$ implies that STDs$^A$ becomes STDs$^B$.

**Question:** ‘What if I try to do that via the SVARs, by imposing MonetaryRule$^B$ into SVAR$^A$?’

Let STDs$^C$ (C for counterfactual) be the theoretical standard deviations of the series produced by such SVAR-based policy counterfactual.

If it worked fine, we would have, for each variable

$$\text{STDs}^C = \text{STDs}^B$$

So that for each possible alternative Taylor rule (Taylor$^A$), their ratio would be uniformly one …

⇒ but that’s not the case
The ratio $\text{STDs}^C / \text{STDs}^B$ for grids of values for $\rho^A$ and $\psi^A$: 

Only close to 1 if Taylor$^A$ is close to Taylor$^B$ … 

⇒ In general, SVAR-based counterfactual fails …
Same results based on two alternative DSGE models:

(i) Lubik and Schorfheide (AER, 2004)
(ii) Andres, Lopes-Salido, and Nelson (St. Louis FED WP, 2008), which I estimate for post-WWII United States

Problem also pertains macroeconomic relationships …

⇒ SVAR-based counterfactuals distort macro relationships, as captured by VAR-implied cross-spectral statistics between the series …

Next, key question: ‘Where does the problem originate from?’
‘Where does the problem originate from?’

I show it is due to the cross-equations restrictions imposed by rational expectations on the solution of macroeconomic models with forward-looking components …

So it is exactly the problem discussed by Sargent in his critique of VAR methods, and it has to do with the Lucas critique …

Seriousness of the problem, however, has never been checked conditional on a set of models …

Formally, let the SVAR representations of the DSGE model conditional on 2 alternative values of the policy parameters, $\theta_1$ and $\theta_2$, be:

\[
\begin{align*}
\tilde{B}_0(\theta_1) Y_t & = \tilde{B}_1(\theta_1) Y_{t-1} + \ldots + \tilde{B}_p(\theta_1) Y_{t-p} + \epsilon_t \\
\tilde{B}_0(\theta_2) Y_t & = \tilde{B}_1(\theta_2) Y_{t-1} + \ldots + \tilde{B}_p(\theta_2) Y_{t-p} + \epsilon_t
\end{align*}
\]
The SVAR-based counterfactual associated with imposing the SVAR’s structural monetary rule for regime 2 onto the SVAR for regime 1 produces the following structure:

\[
\begin{bmatrix}
\tilde{B}_0^R(\theta_2) \\
\tilde{B}_0^\sim R(\theta_1)
\end{bmatrix} Y_t = \begin{bmatrix}
\tilde{B}_1^R(\theta_2) \\
\tilde{B}_1^\sim R(\theta_1)
\end{bmatrix} Y_{t-1} + \ldots + \begin{bmatrix}
\tilde{B}_p^R(\theta_2) \\
\tilde{B}_p^\sim R(\theta_1)
\end{bmatrix} Y_{t-p} + \epsilon_t
\]

The problem is clear:

- **SVAR-based counterfactual only changes \( \theta \) in the interest rate equation**
- **it leaves \( \theta \) unchanged in the other equations**

Therefore, in general, results from SVAR-based counterfactual are different from results of DSGE-based counterfactual …

Paper shows mathematically that problem disappears only in one extreme case: when model solution is vector white noise …
‘How relevant is the problem in practice?’

Only way to answer would be to know the true data generation process …

In what follows I will provide tentative evidence on likely practical relevance of the problem, based on estimated DSGE models for Great Inflation and most recent period

- **Countries**: United States, United Kingdom
- **Models**: (i) standard New Keynesian backward- and forward-looking, and (ii) Andres, Lopes-Salido, and Nelson (*JEDC*, 2009)
- **Estimation**: Bayesian ➔ Random-Walk Metropolis
- I allow for one-dimensional indeterminacy, but no sunspot shocks
  ➔ with sunspot shocks, identification problem under indeterminacy …
Then, based on estimated models for two periods, I perform policy counterfactuals

- both DSGE-based and SVAR-based
- for both periods

Let’s see the results …
I: U.S., New Keynesian backward- and forward-looking model
II: U.K., New Keynesian backward- and forward-looking model
III: U.S., Andres et al. (JEDC, 2009) model

Great Inflation

SVAR-based counterfactual

DSGE-based counterfactual

Post-Volcker stabilisation
Key points to stress: I

Results are already sufficiently **bad without sunspots** …
If I **allow** for **sunspots**, everything becomes **worse**, because

- there’s an **identification** problem under indeterminacy ($N$ VAR residuals, $N+1$ shocks)
  - ‘identified’ shocks under indeterminacy are **not true structural shocks**
- the **DSGE**-based counterfactual ‘**kills off**’ the sunspots, the **SVAR**-based one cannot …
  - results are necessarily distorted
Key points to stress: II

SVAR-based counterfactuals suffer from key logical problem

- reliability crucially depends on unknown structural characteristics of data generation process
  ➔ extent of forward- as opposed to backward-looking behaviour, etc.

- you can’t just assume it

- only way to check for reliability within specific context is to estimate a (DSGE) structural model …

- but that’s exactly what the SVAR methodology wanted to avoid in the first place!!
Summing up

SVAR-based counterfactuals perform well only conditional on extreme model features ➔ model solution is vector white noise

Under normal circumstances SVAR-based counterfactuals always suffer from an approximation error which can be quite substantial …

Results from SVAR-based counterfactuals should be taken with caution, precisely because they may suffer from a substantial imprecision …

SVAR-based counterfactuals suffer from crucial logical problem: only way to check for reliability within specific context is to estimate structural model …
Still to be done:

What Sims would say:

• ‘All of this pertains to the case of a one-time, unanticipated, permanent change in policy …’
• ‘If policy can change, rational agents will attach probabilities to various regimes’
• ‘This will nullify the impact of switches across regimes’

⇒ Sims’ rebuttal of the Lucas critique

So let’s see … There are two competing ‘technologies’, as far as fitting macro post-WWII data is concerned:

• the random-walk VAR cum reflecting barriers of Cogley and Sargent (*NBER Macro Annuals*, 2001; *RED*, 2005)
• the Markov-switching VAR of Sims and Zha (*AER*, 2006)
They have fundamentally different implications for the issue at hand …

- in the random-walk VAR of Cogley-Sargent, all shifts are permanent
  - the results you’ve seen up until now apply directly
  - SVAR-based policy counterfactuals do have fundamental problems …

- In the Sims-Zha Markov-switching environment, everything depends on the transition matrix …

Assume monetary rule switches between 2 regimes, and consider the following transition matrices:

\[
T_1 = \begin{bmatrix} 0.5 & 0.5 \\ 0.5 & 0.5 \end{bmatrix} \quad T_2 = \begin{bmatrix} 1-\epsilon & \epsilon \\ 0 & 1 \end{bmatrix}
\]
$T_1 = \begin{bmatrix} 0.5 & 0.5 \\ 0.5 & 0.5 \end{bmatrix} \quad T_2 = \begin{bmatrix} 1-\epsilon & \epsilon \\ 0 & 1 \end{bmatrix}$

$T_1$ and $T_2$ encode two extreme, polar cases ...

- Under $T_1$, the expectation of the future is independent of the current state of the economy ...
  - impact of change in policy is minimised, because it only affects period $t$, whereas it has no impact on expectations ...
  - this is an extreme example of what Sims has in mind ...

- $T_2$, with $\epsilon$ in a neighbourhood of zero, is very close to notion of unanticipated and permanent change in regime
  - impact of change in policy is maximised
  - this is essentially the case I have analysed up until now

Question: ‘Which of 2 cases is closer to reality?’ Let’s see ...
I: Results from estimated Markov-switching DSGE models

Bianchi (2009) estimates 2-state Markov-switching DSGE model. This is estimated probability of the Hawk regime:

![Graph showing the probability of the Hawk regime over time.]

It is obviously quite far away from $T_1$: indeed, diagonal elements of transition matrix are 0.92 and 0.92 …

So, first thing I’ll do next is estimate Markov-switching DSGE model conceptually in line with Bianchi (2009), and, based on estimated model, check whether SVAR-based counterfactuals capture the impact of a switch in the Taylor rule …
II: Implications for long-term interest rates

A necessary implication of $T_1$, is that long-term interest rates should be approximately constant

- if reality is $T_1$, only impact of regime switch is on current period
- this will have almost no impact on interest rates at the 20-30 year maturity

If I find a lot of movement in long-term rates, this implies that, no matter what other features of reality are, we are pretty far away from $T_1$ …

Indeed …
**Bottom line:**

Two technologies for fitting macro series:

- **Cogley-Sargent**: SVAR-based policy counterfactuals have problems
- **Sims-Zha**: SVAR-based counterfactuals do not have problems if and only if we are close to $T_1$ …
  ➔ … but this does not seem to be empirically the case …