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Sign Restrictions with a New-Keynesian Macro Model

Results From a "Quasi-Agnostic" Identification Procedure

Gregorio Impavido

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Sign Restrictions with a New-Keynesian Macro Model: Results From a "Quasi-Agnostic" Identification Procedure
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ABSTRACT: This paper proposes a "quasi-agnostic" sign restriction procedure to identify structural shocks in frequentist structural vector autoregression (SVAR) models. It argues that low acceptance rates, inherent to agnostic sign restriction procedures, are not necessarily an indication of model misspecification. They can be low because agnostic procedures fail to exploit the *ex ante* priors on the sign of responses of macro variables to structural shocks.

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* The author(s) would like to thank participants at an IMF seminar and the 2025 IRMC conference for useful comments. The usual caveat applies.

WORKING PAPERS

Sign Restrictions with a New-Keynesian Macro Model

Results from a “quasi-agnostic” identification procedure

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1 Introduction

In the early literature on structural vector autoregression (SVAR) models, policy and macroeconomic shocks were identified through parametric restrictions, predominantly zero restrictions, on the immediate responses of macroeconomic aggregates to these shocks. Contemporaneous zero restrictions continue to be justified often on the grounds that some variables are sluggish to adjust to new information or that new information is observed with a delay. For instance, a tightening of monetary policy could lead to a temporary decline in real economic activity, albeit with some delay. More recent studies have sought to relax these identification assumptions by employing sign restrictions. Unlike parametric restrictions, which necessitate specific coefficient values derived from prior knowledge of the structure of the economy, sign restrictions simply stipulate the direction of a shock's impact on macroeconomic aggregates but are agnostic about the specific structure of the economy. Hence, procedures used to identify shocks, are often referred to as "agnostic" identification procedures.

Prominent applications of sign restrictions to study monetary policy effectiveness include papers like Astveit et al. (2017), Canova and De Nicoló (2002), Elekdag and Han (2015), Faust (1998), and Uhlig (2005). Notably, Uhlig (ibid.) finds that contractionary monetary policy shocks do not exhibit a discernible effect on real GDP, suggesting that the neutrality of money is consistent with empirical data. Subsequent refinements to Uhlig's identification approach (Arias et al. 2019) and the use of identification based on external instruments (Gertler and Karadi 2015) have tended to reaffirm the conventional view that monetary policy exerts a short-term influence on GDP, as, for instance, predicted by models incorporating price rigidities à la (say) Calvo (1983).

This paper proposes a "quasi-agnostic" identification procedure to overcome the low acceptance rates typical of agnostic identification procedures. Agnostic identification procedures based on sign restrictions typically yield a low proportion of simulated structural shocks that satisfy the imposed sign restrictions (acceptance rates). For instance, Fisher and Huh (2020), find acceptance rates of less than 1 percent using their proposed algorithm. Low rates are also found in Arias et al. (2018). The algorithm proposed by Ouliaris and Pagan (2016) also yields very low acceptance rates when applied to the Cho and Moreno (2003) study.

The strategy proposed in this paper is akin to an iterative grid search that employs increasingly refined identification methods to identify the plausible set of structural parameters that satisfy the imposed sign restrictions. The strategy is designated as "quasi-agnostic", reflecting the fact that, at each iteration, it narrows down the likely interval of the plausible structural parameters using the information garnered from earlier iterations. Results suggest that this strategy can significantly enhance acceptance rates, revealing a larger set of economic structures consistent with the priors on the sign of responses of macro variables to structural shocks.

The rest of the paper is organized as follows. Section I lays out a three-variable recursive SVAR to estimate a conventional New-Keynesian small macro model. Section II critiques the rationale for employing a unique set of parametric restrictions, such as zero contemporaneous restrictions, and adopts the methodology proposed by Ouliaris and Pagan (2016) for imposing agnostic sign restrictions on the impulse response functions at various time horizons. Section III explores different alternative "quasi-agnostic" identification procedures, proposing that, even without comprehensive knowledge of the economic structure, higher acceptance rates than those commonly achieved through purely agnostic identification methods can be achieved. Section IV concludes and suggests areas for future research.

2 The baseline model

A SVAR for a small macro model with three variables is used as baseline model. The variables are the quarterly output gap, inflation, and average policy rate for the US economy between 1982Q1 and 2000Q1.

The model is defined as:

$$A_0 Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + B_0 \varepsilon_t \tag{1}$$

In this model, $Y = [o, \pi, r]'$ is the vector of the three endogenous variables: the output gap (o), inflation (π), and the policy rate (r); A_0 is a lower triangular matrix with ones over the diagonal capturing the contemporaneous interactions among the endogenous variables; A_1 and A_2 are full matrices of parameters for the lagged values of Y; B_0 is a diagonal matrix with the standard errors of the shocks on the diagonal;[1] $\varepsilon_t \sim N(0, I_3)$ is the vector of uncorrelated and orthogonalized shocks of unit variance.[2]

Given the contemporaneous correlation among shocks implied by the structure of A_0, there is an identification problem. There are 27 parameters to be estimated[3] and only 24 parameters can be estimated from the underlying VAR.

$$Y_t = V_1 Y_{t-1} + V_2 Y_{t-2} + e_t \tag{2}$$

where $V_p = A_0^{-1} A_p$ and $e_t = A_0^{-1} B_0 \varepsilon_t \sim N(0, \Sigma)$.[4] Hence, in order to identify the structural shocks $B_0 \varepsilon_t$ from the underlying VAR, three zero contemporaneous restrictions

[1] A SVAR with standard deviations along the diagonal of B_0 and ones along the diagonal of A_0 is called *normalized*. A SVAR with ones along the diagonal of B_0 and parameters to be estimated along the diagonal of A_0 is called *unnormalized*. The two representations are equivalent.

[2] The SVAR defined in equation (1) is consistent with a small New-Keynesian macro model with an aggregate demand (IS) structural equation, an aggregate supply equation in the spirit of Calvo (1983), and the Central Bank reaction function as discussed in Cho and Moreno (2003).

[3] There are 6 parameters in A_0, 9 in A_1, 9 in A_2, and 3 in B_0.

[4] The estimation of the underlying VAR defined in equation (2) yields 24 parameters: 9 in $\hat{V}_1$, 9 in $\hat{V}_2$, and only 6 in $\hat{\Sigma}$, which is symmetric. I.e., there are not enough moment conditions in the variance covariance matrix of the VAR disturbances to identify all the SVAR parameters.

are imposed in A_0, making the SVAR recursive and exactly identified.[5] I.e.:

$$A_0 = \begin{bmatrix} 1 & 0 & 0 \\ a_{21}^0 & 1 & 0 \\ a_{31}^0 & a_{32}^0 & 1 \end{bmatrix} \text{ and } B_0 = \begin{bmatrix} \sigma_o & 0 & 0 \\ 0 & \sigma_\pi & 0 \\ 0 & 0 & \sigma_r \end{bmatrix} \quad (3)$$

Traditional diagnostics are used to ensure model specification.

- **Lag selection**. Table 1 reports the final prediction error (FPE), Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (BIC), and the Hannan and Quinn information criterion (HQIC) lag-order selection statistics for a series of SVARs of order 1 through 7. A sequence of log-likelihood (LL), likelihood-ratio test statistics (LR), and their p-values for all the full SVAR models of order less than or equal to the highest lag order are also reported. The first likelihood-ratio test that rejects the null hypothesis that the additional parameters from adding a lag are jointly zero would suggest a SVAR of order 2. The other information criteria confirm this lag selection. A lag of order 2 is chosen to minimize the risk of overfitting.
- **Endogeneity**. Table 2 reports the Wald statistics for the Granger causality test for out three endogenous variables, their degrees of freedom, p-values. Results suggest that variables can be treated as endogenous in the sense that right hand side variables are jointly (even if not necessarily individually) important at predicting the left hand side variable in each structural equation.
- **Stability**. Figure 1 illustrates how all eigenvalues lie in the unit circle suggesting that the SVAR satisfies the stability condition.

The SVAR defined in equation (1), using the structural restrictions in A_0 defined in equation (3), can be estimated via FIML, or since it is exactly identified, simply via 2SLS using instrumental variables. This second option is used throughout this paper as it enables us to later cover more easily cases when the contemporaneous restrictions are different from zero.[6]

The IRFs derived from the SVAR model presented in equation (1), using the structural restrictions in A_0 defined in equation (3), are illustrated in Figure 2. The first column indicates that a one standard deviation demand shock exerts a contemporaneous impact on the

[5] Since $e_t = A_0^{-1} B_0 \varepsilon_t$, we need to impose 3 restriction on A_0 to complement the 6 moment conditions in Σ in order to be able to recover the SVAR parameters from the underlying VAR parameters. One way to do this is to take the Cholesky decomposition of the variance covariance matrix of the VAR disturbances $CC' = \hat{\Sigma}$. Then $C = \hat{A}_0^{-1} \hat{B}_0$ and, since the SVAR is exactly identified, $\hat{B}_0 = diag(C)$. It follows that $\hat{A}_0 = \left(C \left(diag\left(C \right) \right)^{-1} \right)^{-1}$.

[6] With non-zero contemporaneous restrictions one can always redefine the endogenous variables to make the SVAR recursive but the A_0 stemming from the Cholesky decomposition of the variance-covariance matrix of the shocks of the underlying VAR would be associated to these modified endogenous variables and an additional step is needed to derive the structural matrix of the original non-redefined variables.

output gap equal in magnitude to the shock, and with a persistence of about ten periods. This shock also results in a modest positive contemporaneous effect on inflation and a small immediate increase in the policy rate, which subsequently rises over time in response to an expanding output gap. In the second column, a one standard deviation supply shock has a zero contemporaneous impact on the output gap, dictated by the zero contemporaneous restriction in A_0. However, this impact increases to about ten basis points in about eight periods. This shock also elicits a positive contemporaneous response in inflation, indicating that rising production costs are rapidly transferred to consumer prices, alongside a contemporaneous increase in the policy rate that reaches about thirty basis points within eight periods before inflationary pressures abate. Lastly, in the third column, a one standard deviation monetary shock has a zero contemporaneous impact on the output gap and on inflation, again dictated by the zero contemporaneous restriction in A_0. The output gap response accelerates to about eighteen basis points in few periods, while the response of inflation is positive, yielding a "price puzzle".

The observation that a positive monetary shock leads to a positive inflation response raises concerns about potential misspecification of the model. To address these type of puzzles, typical of recursive systems, the literature suggests various corrective approaches, including (i) incorporating additional endogenous variables to better reflect the underlying economic structure, (ii) redefining existing endogenous variables to capture different relationships or effects, (iii) employing non-recursive, less strict, identification procedures, and (iv) introducing latent variables that can account for unobservable factors influencing the relationships within the model.

Approach (i), the addition of new endogenous variables, is a viable strategy to address the price puzzle, as it can be informed by theoretical or intuitive considerations. For instance, incorporating a monetary aggregate into the model can help resolve the price puzzle by accounting for the implicit money demand, which is currently absent. I.e., it is believed that there is an implicit money supply represented by the interest rule in the model but not a money demand; and its absence allows prices to increase when the interest rate increases. Additionally, there could be a hidden exchange rate puzzle that is not evident in the current version of the model because the exchange rate is missing as additional endogenous variable. I.e., the monetary shock would depreciate the currency (rather than appreciating it, as it is normally the case) and this causes prices to increase through the exchange rate passthrough. Or additionally still, the monetary shock would cause inflation expectations to increase because (say) of low credibility of the Central Bank and, through this channel, increase current prices. However, adding more endogenous variables increases exponentially the number of parameters to be estimated. It also increases the number of shocks and hence, it requires identifying additional restrictions,[7] and additional puzzles may arise.

Approach (iv), introducing latent variables, is conceptually similar to approach (i): it increases the number of shocks relative to the observed variables and it can help resolve observed puzzles. It also comes with similar drawbacks. In addition, when it is believed that

[7]The number of additional identifying restrictions required increases by $\left(\frac{d(d-1)}{2} + nd\right)$ where n is the number of original endogenous variables and d is the number of endogenous added to the system.

latent variables are present, estimation typically involves casting the model in its state space representation and estimating impulse response functions via MLE using the Kalman filter; all beyond the scope of this paper.

In the next section, we follow approaches (ii) and (iii) to solve the price puzzle and to relax the recursive assumption for the structure of the economy.

3 Imposing agnostic sign restrictions

The recursive assumption stemming from the zero contemporaneous restrictions and the specific ordering of the endogenous variables used in Y need to be justified. Without additional information on the structure of the economy and on how shocks propagate in the economy, it is not possible to answer these two fundamental questions. There could be an infinite number of combinations of restrictions that are compatible with our priors regarding the responses of macro variables to structural shocks. How to find these combinations of restrictions is the objective of the literature on sign restrictions. In particular, Ouliaris and Pagan (2016) propose an identification procedure based on sign restrictions of generated coefficients (SRC) according to which the zero contemporaneous restrictions in A_0 are imposed using random coefficients of the form $a_{ij} = \frac{\theta}{1-abs(\theta)}$ with $\theta \sim U(-1,1)$.

The SRC procedure is implemented as follows:

- We take the SVAR defined in equation (1), using an unrestricted structural matrix $A_0 = \begin{bmatrix} 1 & a_{12}^0 & a_{13}^0 \\ a_{21}^0 & 1 & a_{23}^0 \\ a_{31}^0 & a_{32}^0 & 1 \end{bmatrix}$.
- Next, we then simulate 1,200 combinations of parameters a_{12}^0, a_{13}^0, and a_{23}^0 using the SRC procedure.
- For each combination of parameters, we estimate B_0 and the remaining parameters in A_0 using 2SLS, and we use OLS to estimate the parameters of A_1 and A_2.
- Next, the signs of the contemporaneous $IRF_{h=0} = \hat{A}_0^{-1}\hat{B}_0$[8] are then compared with our priors on the signs of the responses of macro variables to positive structural shocks reported in Table 3, and IRFs inconsistent with priors are discarded.
- Ultimately, the acceptance rate is computed as the number of combinations consistent with priors over total draws.

[8]The solution for the underlying VAR defined in equation (2) is given by the moving average $Y_t = \sum_{j=0}^{\infty} D_j e_{t-j}$ where $D_0 = I_3$ and D_j is the j^{th} horizon impulse response of Y_{t+j} to a unit change of e_t. The solution for the SVAR defined in equation (1) is given by the moving average $Y_t = \sum_{j=0}^{\infty} C_j \varepsilon_{t-j}$ where C_j is the j^{th} horizon impulse response of Y_{t+j} to a unit change in ε_t. Now, since $e_t = A_0^{-1}B_0\varepsilon_t$, it must be the case that $C_0 = A_0^{-1}B_0$.

The IRFs derived from this procedure are illustrated in Figure 3, where sign restrictions are imposed at horizon zero: i.e., only on contemporaneous responses. Several points can be noted:

- The price puzzle is now resolved. A one standard deviation demand shock has a positive impact on inflation between zero and twenty basis points and a positive impact on interest rate thirty and seventy basis points. A one standard deviation supply shock has a positive impact on inflation between twenty and seventy basis points and a positive impact on the interest rate between zero and twenty-five basis points. A one standard deviation monetary shock has negative impact on the output gap between zero and thirty basis points and now a negative impact on inflation between zero and seventy basis points.
- The low acceptance rate suggests in principle that the model specification can be further improved. While this is generally always the case, it will be argued in the next section that the acceptance rate is also dependent on the method adopted to impose sign restrictions, leaving the question of the relative contribution of these two factors (potential misspecification and choice of identification procedure) to such low acceptance rates unanswered.
- Sign restrictions solve the structural identification problem but are not helpful in solving the model identification problem (Fry and Pagan 2011). Each IRF reported in Figure 3 is generated by a unique set of structural parameters and the lack of a unique model raises the question of which one to use. Summary statistics like median, percentiles, or average values of the IRFs fail to acknowledge the model identification problem. In the absence of prior knowledge on how to reject implausible IRFs, the range of models can be narrowed by imposing sign restrictions on more than just contemporaneous impulse responses.
- Ultimately, sign restrictions alone permit variation in the magnitude of the standard deviation of the structural shocks across different models. This does not matter for the shape of the IRFs, which does not depend on the standard deviation of the shock. However, it matters for contemporaneous responses. In our analysis, this variability is reported by the panels along the diagonal of Figure 3. It is always possible to normalize the IRFs to solve this issue.

4 From agnostic to "quasi-agnostic" sign restrictions

A completely agnostic identification procedure, such as the SRC procedure, does not take into account the priors about the signs of responses to structural shocks, resulting in lower than desired acceptance rates. Indeed, the definition of a plausible range of structural parameters is dependent not only on the endogenous variables involved, but also on the identification procedure used. In particular, the SRC procedure is characterized by a high standard deviation of possible structural parameters, leading to many values falling outside the plausible range consistent with the priors about the sign of macro responses and thus, leading to a low acceptance rate.

A "quasi-agnostic" identification procedure is proposed that exploits the priors on the sign of the responses to structural shocks and thereby increases acceptance rates. The proposed approach to refine the range of plausible structural parameters resembles a grid search across progressively refined identification procedures. These procedures are designated as "quasi-agnostic", reflecting their adaptive nature, wherein subsequent methodologies are adapted based on the insights garnered from the results of earlier procedures regarding the likely interval of plausible structural parameters.

In order to understand the intuition behind "quasi-agnostic" procedures, consider a simple supply and demand model without (for the sake of exposition) lagged endogenous variables:

$$\begin{aligned} Q_t &= \alpha p_t + e_s \\ Q_t &= \beta p_t + e_d \end{aligned} \tag{4}$$

where the first equation is the supply equation and the second equation is the demand equation. The associated SVAR would be given by:

$$\begin{aligned} A_0 Y_t &= B_0 \varepsilon_t \\ \begin{bmatrix} 1 & a_{12}^0 \\ 1 & a_{22}^0 \end{bmatrix} \begin{bmatrix} Q_t \\ p_t \end{bmatrix} &= \begin{bmatrix} \sigma_s & 0 \\ 0 & \sigma_d \end{bmatrix} \begin{bmatrix} \epsilon_s \\ \epsilon_d \end{bmatrix} \end{aligned} \tag{5}$$

The priors regarding the sign of the impulse responses would be given by:

$$P = \begin{bmatrix} + & + \\ + & - \end{bmatrix} \tag{6}$$

with a positive demand shock (ϵ_d) increasing both quantities and prices in the first column and a positive supply (productivity) shock (ϵ_s) increasing quantities and decreasing prices in the second column.

Contemporaneous impulse responses would be given by:

$$IRF_{h=0} = \hat{A}_0^{-1}\hat{B}_0 = \begin{bmatrix} \frac{\hat{a}_{22}^0 \hat{\sigma}_s}{(\hat{a}_{22}^0 - \hat{a}_{12}^0)} & \frac{-\hat{a}_{12}^0 \hat{\sigma}_d}{(\hat{a}_{22}^0 - \hat{a}_{12}^0)} \\ \frac{-\hat{\sigma}_s}{(\hat{a}_{22}^0 - \hat{a}_{12}^0)} & \frac{\hat{\sigma}_d}{(\hat{a}_{22}^0 - \hat{a}_{12}^0)} \end{bmatrix} \tag{7}$$

In order for $IRF_{h=0}$ to be consistent with the priors on the signs of responses to structural shocks reported by the P matrix defined in equation (6), three restrictions need to be imposed on the possible structural parameters: (i) the determinant of the structural matrix needs to be negative ($\hat{a}^0_{22} - \hat{a}^0_{12} < 0$), so that the response of prices to a demand shock be positive and the response of prices to a productivity shock be negative; (ii) $\hat{a}^0_{12} > 0$, so that the response of quantities to a productivity shock be positive; and (iii) $\hat{a}^0_{22} < 0$, so that the response of quantities to a demand shock be positive.[9] The progressive application of these three restrictions is represented by the yellow area in Figure 4. This means that searching for $\hat{a}^0_{12} \in (-\infty, +\infty)$ as the SRC procedure would do, would yield many values falling outside the plausible range, unnecessarily lowering acceptance rates.[10]

With more endogenous variables, it becomes more difficult to find *ex ante* all the necessary restrictions and other methods are needed. One possible strategy is to exploit *ex post* information and progressively trim identification procedures to focus on most plausible sets of parameters. This strategy is illustrated with the use of Figure 5. For each parameter a^0_{12}, a^0_{13}, and a^0_{23}, Figure 5 reports the median of the distribution (represented by the line in the box), the first and third quartiles (represented by the top and bottom of the box), the first and last quintiles (represented by the whiskers), eventual outliers, and the acceptance rate stemming from 1200 simulations using alternative sign restriction procedures applied to sign restrict the IRFs at horizon zero, one, and two. The first line reports data when the fully agnostic SRC procedure is used. Several things can be noted: (i) all successful parameters are positive; the mean of a^0_{12} is the smallest followed by the means of a^0_{23} and a^0_{13}; (ii) the standard deviation of a^0_{12} is very small suggesting that all successful parameters are concentrated around the mean; (iii) the standard deviation of a^0_{13} and a^0_{23} are larger and their distributions skewed, suggesting that successful parameters are dispersed around the mean and potentially be very large.

With this information at hand, it seems natural to modify the procedure to limit the random draws of plausible structural parameters to the $(0, +\infty)$ interval. This is done in the second line of Figure 5 where the absolute values of the SRC procedure are taken. This new procedure, labeled here as abs(SRC), yields higher acceptance rates at all time horizons. It also reveals new (larger) plausible parameters for a^0_{13} which, however, tend to disappear when IRFs are restricted at higher time horizons.

The exercise is re-conducted using random draws from a normal distribution with zero mean and a standard deviation of one. Results reported in line three of Figure 5 are broadly comparable to the SRC method simply because in the SRC method, the ratio of two uniform distributions approximates a normal distribution. A final round of this grid search strategy is conducted by calibrating the random draws by exploit the difference in the means and standard deviation of the three parameters observed in earlier rounds. Results are reported in the last line of Figure 5. Clearly, the acceptance rate tends to increase the more parameters are drawn around the means of plausible parameters. The IRFs derived from our SVAR model when restrictions are applied at horizon two following this last procedure are illustrated in

[9] Clearly, the last two restrictions make the first restriction redundant.

[10] It is also worth noting that the assumption of a recursive economy structure is inconsistent with the priors reported by the P matrix defined in equation (7) as prices and quantities react simultaneously.

Figure 6.

5 Conclusions

The structural parameters of a small macro model for the US using output gap, inflation, and policy rate are estimated using an exactly identified recursive SVAR. Results indicate that identified shocks exert a durable influence on the output gap and interest rates, while their effect on inflation are generally less persistent.

The recursive nature of the model cannot be justified with available knowledge of the structure of the economy and furthermore, it produces a "price puzzle" in the form of a positive response of inflation to a positive monetary shock. Hence, parametric short-term restrictions are relaxed, and agnostic sign restrictions are imposed on impulse response functions at different time horizons using the SRC algorithm proposed by Ouliaris and Pagan (2016). The "price puzzle" is resolved and results suggest that there are many plausible structures of the economy consistent with the priors on the sign of responses of macro variables to structural shocks. However, the procedure yields very low acceptance rates suggesting either model misspecification, or identification procedure limitations.

To overcome possible identification procedure limitations, this study proposes a strategy aimed at identifying a greater number of plausible economic structures. The proposed strategy is akin to a grid search across progressively refined identification procedures. These procedures are designated as "quasi-agnostic", reflecting their adaptive nature, wherein subsequent methodologies are informed by the *ex-post* insights garnered from the results of earlier procedures regarding the likely interval of plausible structural parameters. Results suggest that this strategy can significantly enhance acceptance rates, revealing a larger set of economic structures consistent with the priors on the sign of responses of macro variables to structural shocks.

For a bivariate SVAR, it is possible to find a closed form solution to impose restrictions *ex ante* on structural parameters that are consistent *ex post* with the priors on the sign of responses of macro variables to structural shocks. For higher dimensions SVAR, the use of only *ex post* information in restricting the set of plausible structural parameters does not guarantee that all possible structural parameters consistent with the priors on the signs of macro responses have been identified. In other words, results still leave open the question of the relative importance of possible model misspecification and identification procedure in determining the acceptance rate. Future research should identify *ex ante* restrictions on structural parameters for higher dimension SVARs.

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Appendix: Tables and Figures

Table 1: Lag Selection

Horizon	LL	LR	Pval	FPE	AIC	HQAIC	SBIC
0	-378.58			10.899	10.902	10.941	10.999
1	-177.03	403.09	0.000	0.044	5.401	5.554	5.786
2	-148.47	57.12	*0.000	*0.025	*4.842	*5.110	*5.517
3	-141.31	14.31	0.112	0.027	4.895	5.277	5.858
4	-134.00	14.63	0.102	0.029	4.943	5.440	6.196
5	-128.23	11.55	0.240	0.032	5.035	5.647	6.577
6	-124.40	7.65	0.569	0.037	5.183	5.910	7.014
7	-118.89	11.02	0.275	0.042	5.283	6.125	7.403

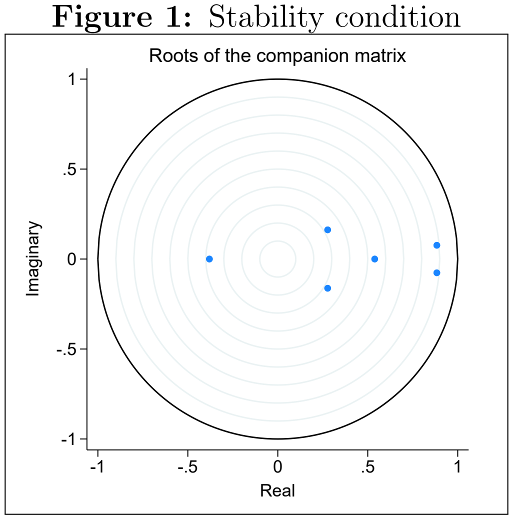
Source: Authors' calculations.

Table 2: Granger causality

Equation	Variable	W	d.f.	Pval
	π	1.010	2	0.604
o	r	4.625	2	0.099
	all	8.148	2	0.086
	π	3.630	2	0.163
π	r	4.084	2	0.130
	all	11.360	2	0.023
	π	4.066	2	0.131
r	r	6.399	2	0.041
	all	8.088	2	0.088

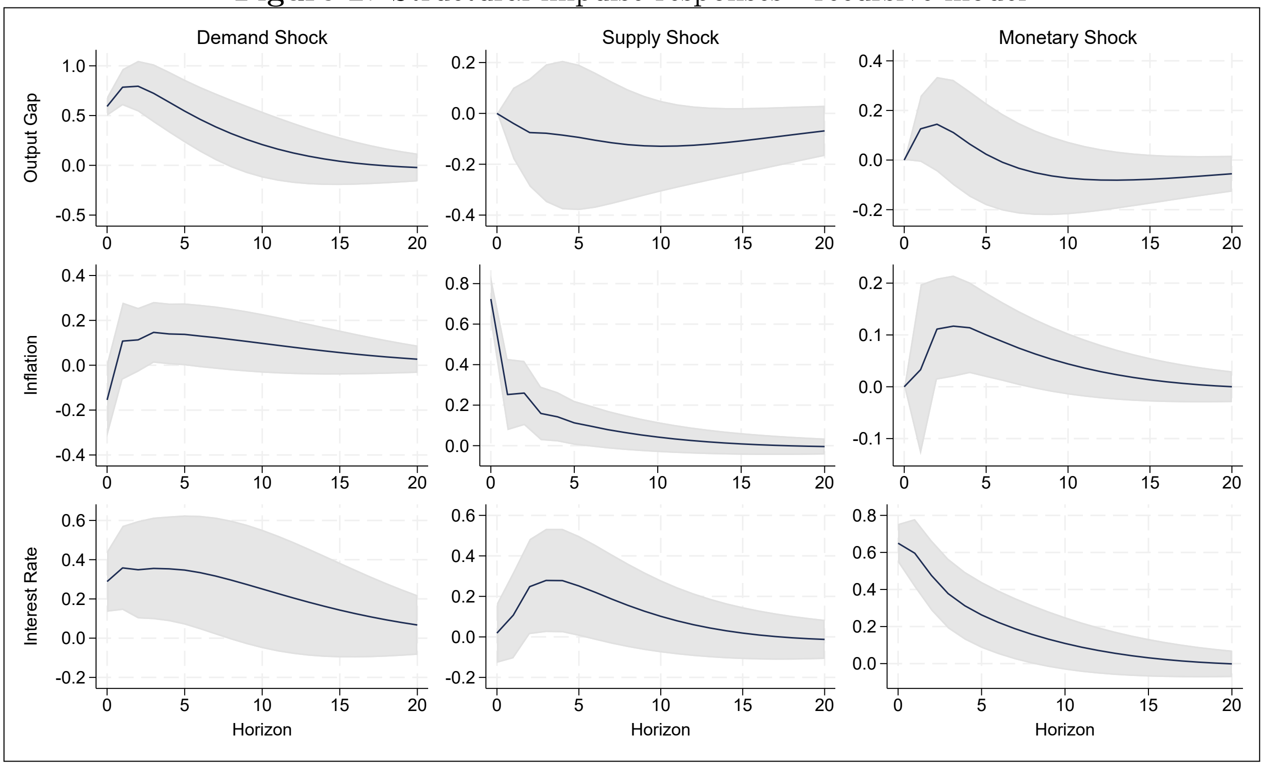
Source: Authors' calculations.

Figure 1: Stability condition



Source: Authors' calculations.

Figure 2: Structural impulse responses - recursive model

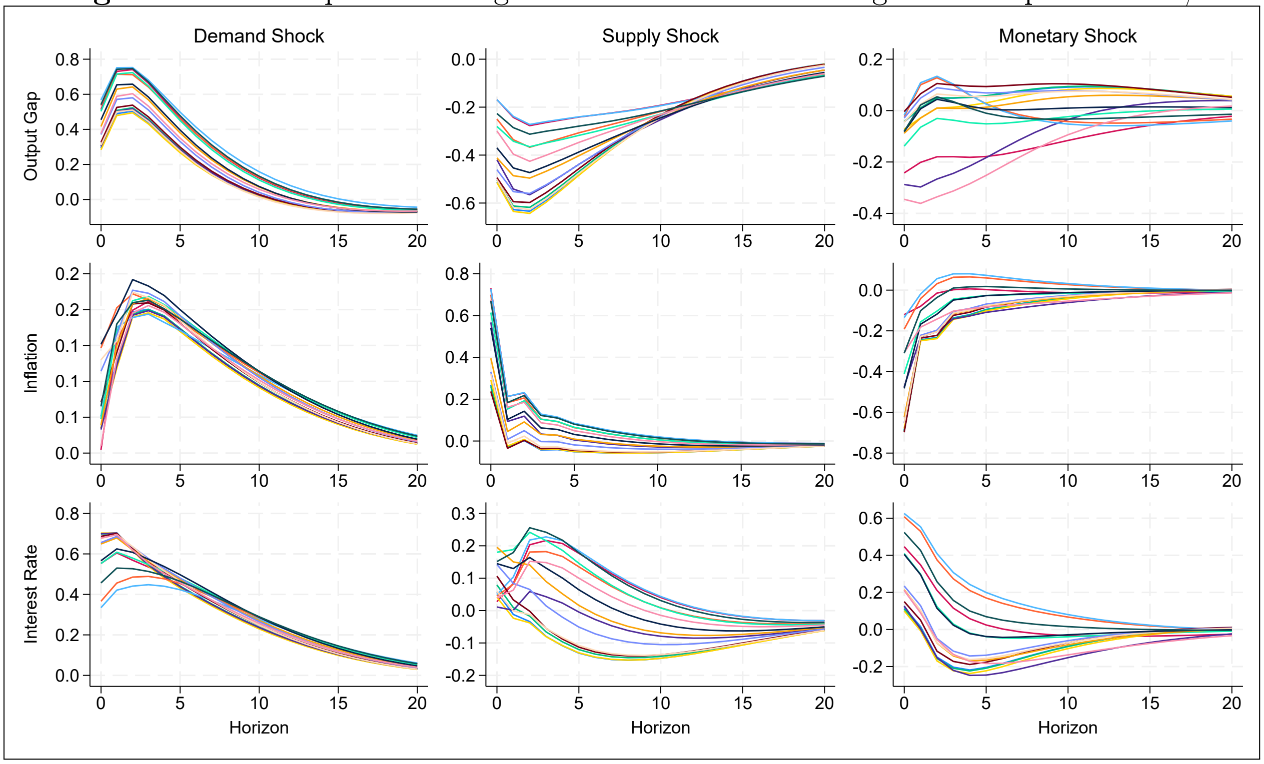


Source: Authors' calculations.

Table 3: Sign restrictions for positive structural shocks

	Demand Shock	**Supply Shock**	**Monetary Shock**
o	$+$	$-$	$-$
π	$+$	$+$	$-$
r	$+$	$+$	$+$

Figure 3: Contemporaneous sign restrictions on IRFs using the SRC procedure 1/



Source: Authors' calculations.

/1 Acceptance rate of 1.25 percent, 1,200 simulations, and sign restrictions imposed at horizon 0.

Figure 4: Ex ante restrictions on structural parameters

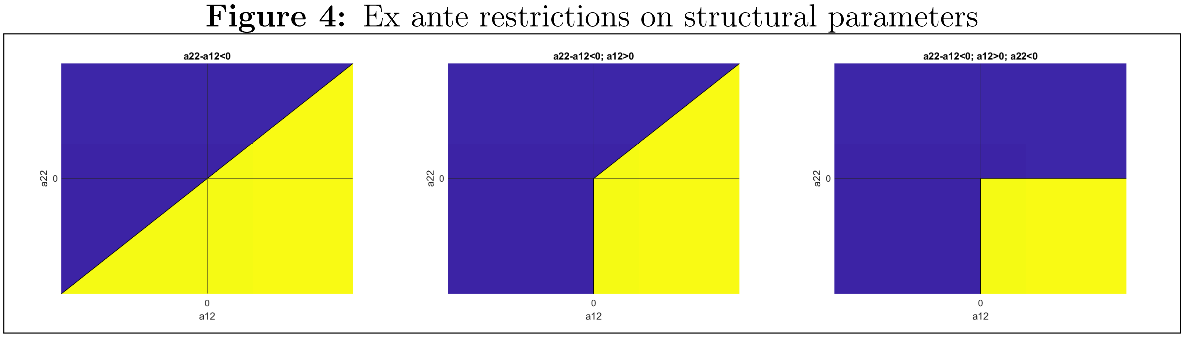
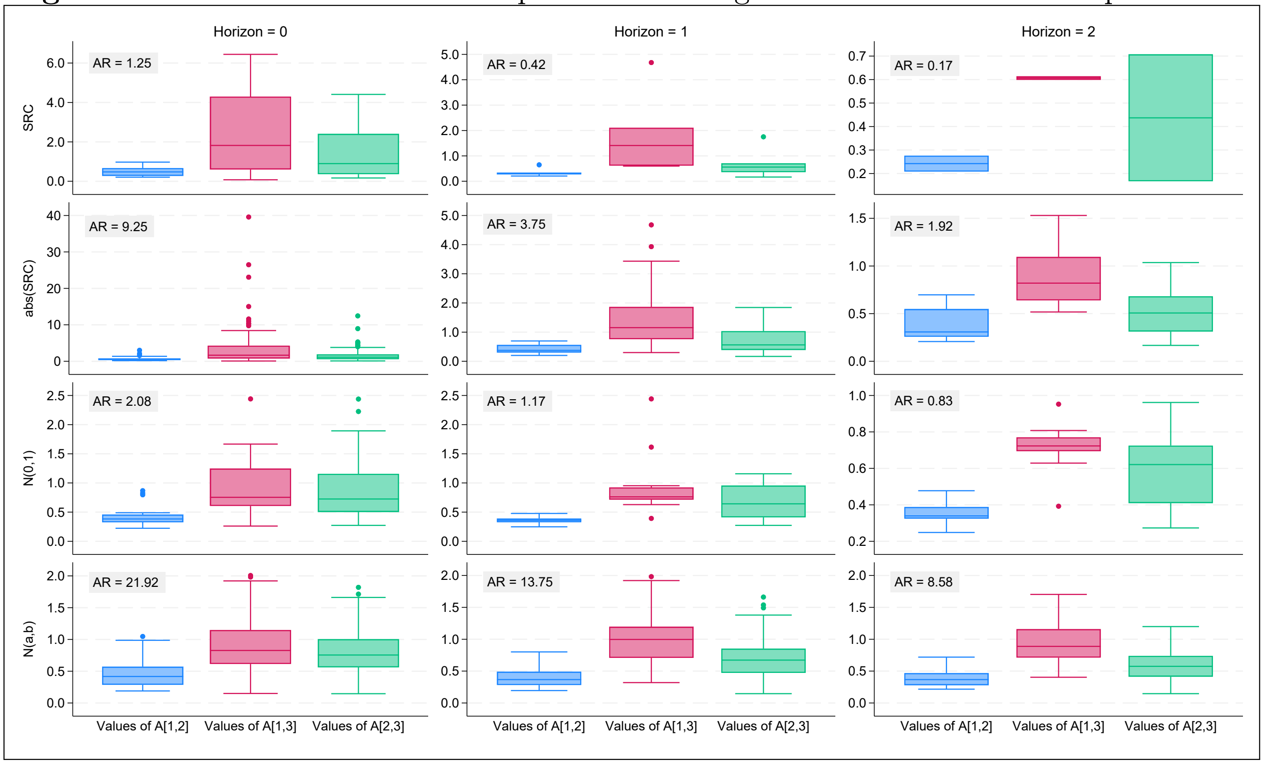
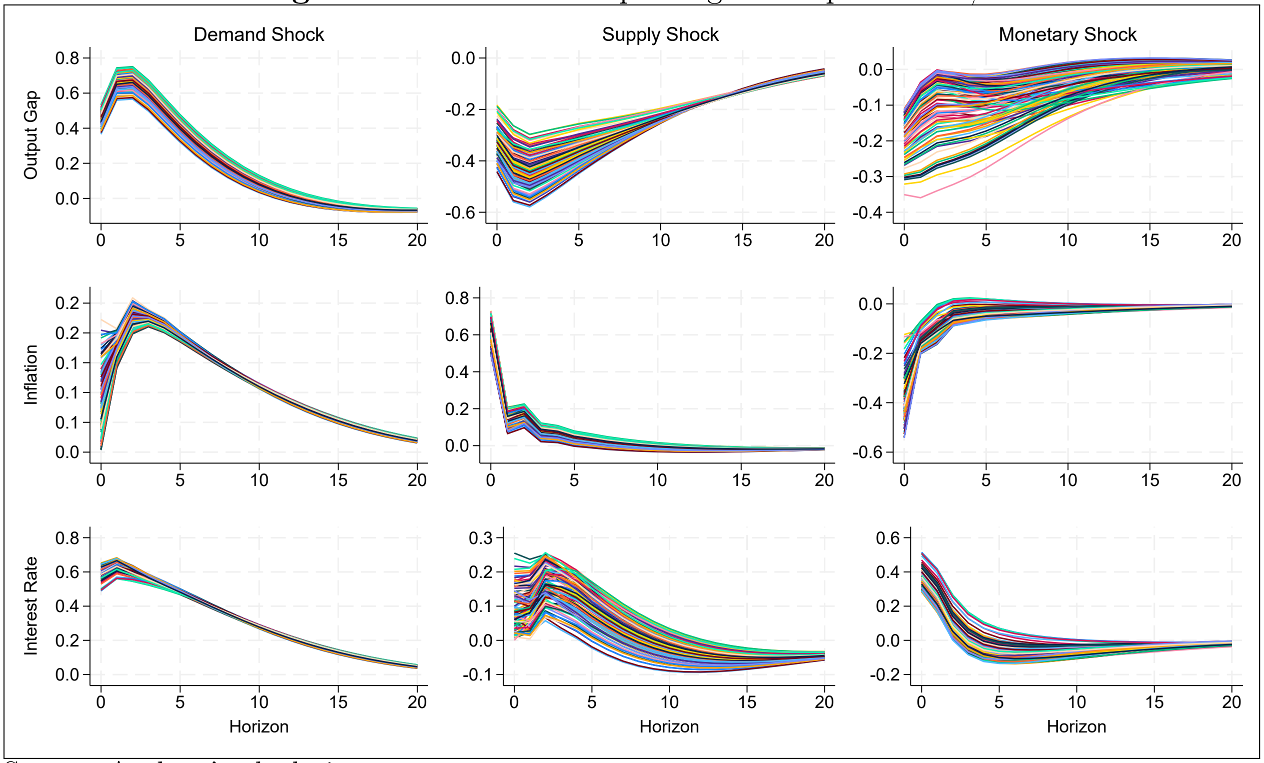


Figure 5: Distribution of restricted parameters using alternative identification procedures



Source: Authors' calculations.

Figure 6: Results from "quasi agnostic" procedure /1



Source: Authors' calculations.

/1 Acceptance rate of 8.58 percent, 1,200 simulations, and sign restrictions imposed at horizon 2.

PUBLICATIONS

Sign Restrictions with a New-Keynesian Macro Model: Results From a "Quasi-Agnostic" Identification Procedure
Working Paper No. WP/2025/162