Banco de Guatemala
Economic Research Department

Identifying Structural Shocks: The Origin of Inflationary Pressures*

Juan Carlos Arriaza

July 15, 2020

Abstract

Using the two most important methodologies to identify structural shocks with a Structural VAR model, we generate a historical decomposition for the aggregate output and the official consumer price index. The identification strategy uses the notion that the demand and supply pressures can be distinguished from each other by the direction of the respective effects on the price and quantity vectors of the goods, and services used for final consumption in the economy. The study found empirical evidence that the demand shocks in both Blanchard and Quah and Sign restrictions explains most of the behaviour of inflation in Guatemala.

***Clasificación* JEL**: E01, E31, E50.
Key Words: Structural VAR, Sign Restrictions, Guatemala.

*The opinions expressed in this document are the exclusive responsibility of the author and do not necessarily represent the opinion of the Banco de Guatemala or its authorities.

Contents

1 Introduction

For a Central Bank whose main objective is to preserve price stability, being able to distinguish between persistent sources of inflationary pressures and temporary or transitory fluctuations in the inflation rate is paramount; without the ability to determine the origin of inflationary pressures, depending on whether these are supply pressures or demand pressures, it would be difficult to choose the best course of action for monetary policy. Therefore, this document aims to find (and apply) a useful methodology to discriminate between inflationary pressures originating from aggregate demand shifts and those coming from movements in aggregate supply. The study explores main stream methodologies to identify structural shocks. Specifically, we apply Blanchard and Quah (1988) long run restrictions and other identification schemes based on signs restrictions to Guatemalan data.

The main results shows that the demand shocks in both Blanchard and Quah and Sign Restrictions methodologies explains most of the patterns of inflation in Guatemala. Also, the study found empirical evidence that the Sign Restrictions methodology explains more o the behaviour of inflation than the Blanchard and Quah methodology

The content of the paper is as follow: Section 2 presents a brief literature review of the two main methodologies considers in this study. Section 3 introduces the methodology of the Blanchard and Quah and Sign restrictions. Section 4 shows the main results of the implementation of the two methodologies in the case of Guatemala. Finally, section 5 shows the final remarks of the study.

2 Literature Review

The main methodologies to identify structural shocks could be divided in two branches: long run restrictions, and signs restrictions Uhlig (2005). Both methodologies allow to identify a supply and a demand shock. However, there are some main differences between them.

The long run restrictions methodology assumes that a supply shock only have a permanent effect on growth while a demand shock have a permanent effect on both growth and unemployment.

In the case of sign restrictions methodology, it considers that a supply shock has a positive impact on growth and negative impact on inflation while a demand shock has a positive impact on both variables. In order to check both the demand and supply shock, the methodology estimates initially an structural VAR with the Cholesky decomposition. Then, it generates the impulse response functions, and capture the set of parameters of the model which resembles the definitions of both the supply and demand shocks.

In the following subsections, it is developed the literature reviews of both the long run and sign restrictions.

2.1 Long - Run Restrictions

In a very influential paper Blanchard and Quah (1988) estimated a Structural Vector Autoregressive (SVAR) model to characterize the dynamics of output growth and unemployment when they face either demand or supply disturbances. They built the Wold moving average representation of both, output growth and unemployment, to analyze the effect of demand and supply disturbances on them. Their main assumptions are: the supply disturbances only have a permanent impact on output groth, and the demanda and supply shocks have unit variance and the covariance of them is set to be zero.

Their main findings are that the response of both output growth and unemployment to the demand disturbances vanished after three to five years, while the response of output growth remains permanent to a supply disturbances, which proved their thesis.

In addition, Cover et al. (2006) used a variant of Blanchard and Quah (1988) decomposition to identify supply and demand shocks. The system of equations proposed included an aggregate supply and an aggregate demand equation *à la* Lucas Jr (1972).

The main differences with respect Blanchard and Quah (1988) are: They estimated a SVAR model with inflation instead of unemployment, the authors use an alternative decomposition, where the covariance of the demand and supply shocks is different than zero, the demand shock has one unit effect on aggregate supply, and the supply shock has one unit effect on aggregate demand, and the slope of the aggregate demand is unity.

The main arguments to allow correlation between the supply and demand shocks is that the policymakers may consider the actual and past realizations

Their main findings were that the correlation between the demand and supply shocks was 54% in the long run and 70% in the short run, which may justify this assumptions different from Blanchard and Quah (1988).

Also, Enders and Hurn (2007), estimated a SVAR model with a small variant with respect to Cover et al. (2006) for the case of Australia. They consider Australia as a small economy with relationships with a larger foreign one. The authors added, in the aggregate supply equation, a foreign supply shock which correspond to a large country, which is not included in Cover et al. (2006). Therefore, the covariance matrix has a 3-by-3 dimension instead of a 2-by-2 one.

The main assumptions in the SVAR model are:The authors consider a foreign supply shock, a domestic shock, and a domestic supply shock. Also, it is not necessary to impose the normalization that the variances of the shocks are equal to unity, the domestic supply and demand shocks have no impact in the foreign country, and it is not necessary restrict that the covariance matrix between the demand and supply shock be zero.

The main findings were that the correlation between the aggregate demand and supply shock is 0.736, which means that they are correlated each other.

2.2 Sign Restrictions

The second methodology consists on the identification of the supply and demand disturbances with sign restrictions.

The methodology to identify whether a disturbance is a demand or supply shocks is due to the response of the output and inflation to it, in the following way: A supply shock will increase quantity and reduce prices, and a demand sock will increase both quantity and prices.

Uhlig (2005) uses the sign restrictions methodology to analyze the effects of the monetary policy on output with monthly data spanning from January 1965 to December 2003. He estimates a SVAR with the following variables: GDP, CPI, federal reserve funds, Non-borrowing reserves, and total reserves. The main assumption by Uhlig (2005) is that a contractionary monetary policy shock does not lead to: Lower prices, decrease non-borrowed reserves, raise the federal fund rate, and reduce real output.

First, he estimates a SVAR model and identify it with a cholesky decomposition. He finds that a contractionary monetary policy shock increases real output which is contrary to the conventional wisdom. The standard identification does not fully accomplish the four points above because a liquidity and price puzzle.Therefore, he estimates again the same model but imposing the first three assumptions above and leaving un-restricted the real output. He finds the correct reaction of the real output to a monetary policy shock with sign restrictions.

Fry and Pagan (2011) estimated two SVAR model with sign restrictions. The first model is a market models (demand / supply), and the second one is a small macroeconomic model. In both, they used the Given Rotation Matrices (which are used to construct an orthogonal matrix) to identify whether shocks were originated in the demand or the supply side. Then, they simulate the values of ϕ (these values are the inputs of the Given Rotation Matrices, and can take values between 0 and 2π). Each value of ϕ generates a different orthogonal matrix $Q(\phi)$ which generates a different set of impulse response functions. Finally, they chose the impulse responses functions which comply with the signs to identify either a supply or demand shock. Their main final remarks were that sign restrictions are very useful to identify multiple shocks in a quantitative analysis and make historical decomposition analysis

For the market model, with output and prices, a demand shock will generate a positive response in both the output and prices, while a supply shock will generate a positive response in output but a negative response in prices. In the case of the small macroeconomic models, with three variables: output, prices, and interest rate, a demand shock will generate a positive response in all variables, a supply shock will generate a positive response in output and interest rate, and a negative response in prices, and a interest rate shock will generate a negative response in output and prices but a positive response in interest rates.

Their main final remarks were that sign restrictions is very useful to identify multiple shocks in a quantitative analysis, and make historical decomposition analysis.

Similarly, Ouliaris et al. (2015) estimated the same two models as in Fry and Pagan (2011)−the market and the small macroeconomic model− with two different methodologies. For the first one, they generate several sets of uncorrelated shocks to produce several impulse responses and retain only those that satisfy the sign restrictions−SSR method. In the second one, the constrained elements are varied in a random way, in order to get a large set of impulse responses method which is called −SCR method. They found similar results with both methods (SSR and SCR) and both models..

Also, Dedola and Neri (2007) estimated the effect of a technological shocks with a SVAR model which is identified with a sign restrictions methodology in the case of the U.S.A. This is the main contributions of the authors to the current literature. They found that a positive technological shocks generates an increase in real wages, consumption, investment, and output in the data; and hours worked are very likely to increase. However, with sign restrictions methodology, the results are not sensitive to a number of specification assumption like the unrestricted VAR models.

3 Methodology

3.1 Sample and Variables Selection

The study considers a quarterly data with a sample spanning from 2009Q1 to 2018Q4, in the case of Inflation and consumption as a proxy of output. The use of quarterly data is due to the availability of the consumption. It also helps to reduce the volatility of the time series.

The data set consists initially only in two variables: The inter-annual variation of consumption, y_t, and the inter-annual variation of CPI, π_t

In the case of the sign restrictions methodology, there is a third variable: the inter-annual variation of the repurchase fund, i_t.

The main testable hypothesis is that supply shocks play a more important role (relative to demand shocks) in the determination of prices and output in the short-run, than what is usually acknowledged.

Also, the study includes a comparative analysis between the Blanchard and Quah and Sign Restriction methodologies.

3.2 Long-Run Restrictions

Initially, the study follow the Blanchard and Quah Decomposition, in order to estimate the Bivariate SVAR for the case of consumption and inflation, for the case of Guatemala, without exogenous variables. In the study, the inflation is used instead of unemployment and consumption is use as a proxy of output. As in the case of Blanchard and Quah (1989), it is assumed that the supply shock has a long term impact only on output but not the demand shock.

The zero - long run restrictions does not use Cholesky decomposition to identify the reduced form of the VAR. Instead, it assumes only two shocks: demand and supply, and makes the identification process by assuming that only the supply shock has a long term effect on output.

Considers a VAR(1) model, where the variables are without mean

$$A_0 z_t = A_1 z_{t-1} + \varepsilon_t \tag{1}$$

Where z_t es a vector which contains the two variables of the model, A_0 is the coefficient matrix of the variables in contemporaneous time and A_1 is the coefficient matrix of the variables in first lag.

After that, we use the supply and demand shock to perform a historical decomposition for output and CPI.

$$z_t = \begin{bmatrix} y_t \\ \pi_t \end{bmatrix}$$

$$\varepsilon_t = \begin{bmatrix} \varepsilon_t{}^{(\text{supply})} \\ \varepsilon_t{}^{(\text{demand})} \end{bmatrix}$$

The first step it to set up the model in a Vector Autoregressive Moving Average

$$z_t = F(L)\varepsilon_t \tag{2}$$

Where we have that in the case of infinity moving average representations, C(L) can be write as

$$F(L) = F_0 + F_1 L + F_2 L^{(2)} \ldots\ldots = \sum_{k=0}^{\infty} F(k) = F(1) \tag{3}$$

Where F(1) is defined as

$$F(1) = \begin{bmatrix} F_{11}(1) & 0 \\ F_{21}(1) & F_{22}(1) \end{bmatrix}$$

The constrains in matrix F(1) in order to use the Blanchard and Quah Decomposition, is $F_{12}(1) = 0$. It means that the demand shock $\varepsilon_t{}^{(\text{demand})}$ does not have a permanent effect on output.

Kilian (2013) considers that there are some limitations by using zero long- run restrictions. First, it requires an accurate estimate of the impulse responses at the infinite horizon. However, it is not possible to estimate accurately the long run behavior of an economic time series from a short time span of data.

Also, Kilian (2013) considers that the variable $I(0)$, a variable that is stationary in levels considers in the estimation of the SVAR model, is often quite persistent. Gospodinov (2010) analyze the statistical properties of the impulse response estimator in the case of a technological shock with labor productivity (as output) and hours worked (as unemployment rate) and model the variables as a near integrated process. In this context, the author proved that the estimation problem is equivalent to a weak - instrument problem, which undermined the conclusions derived from the zero long - run restrictions.

Finally, Kilian (2013) explained that the conclusion from Blanchard and Quah (1988) type VAR models are sensitive to whether the second variable (e.g., unemployment rate or hours worked) is entered in levels or differences.

3.3 Sign Restrictions Methodology

In this study, we followed the methodology of Uhlig (2005), to estimate a bivariate VAR for the case of Guatemala, with output and CPI, as we described in the previous subsections.

We start with a reduced VAR:

$$A_0 z_t = A_1 z_{t-1} + \varepsilon_t \tag{4}$$

Where z_t is a vector which contain y_t and π_t. A_1 is the coefficient matrix, and ε_t es the vector of the residuals with covariance matrix Σ

$$\varepsilon_t = \begin{bmatrix} \varepsilon_t{}^{(y_t)} \\ \varepsilon_t{}^{(\pi_t)} \end{bmatrix}$$

Also, we define the covariance matrix Σ as follow

Then, pre multiplying (4) by the inverse matrix of A_0, we find that

$$z_t = F z_{t-1} + u_t \tag{5}$$

Where $F = A_0^{-1} A_1$ and $u_t = A_0^{-1} \varepsilon_t$.

The sign restrictions methodology initially identify an structural SVAR through a Cholesky decomposition of Σ_u, which is defined as follow

$$\Sigma_u = P'P \tag{6}$$

Where P' is a lower triangular matrix. Then it must follow that $P' = A^{-1}$ which completes the identification.

After that, for a given random orthonormal matrix (i.e., such that $S'S = I$), it follows that

$$\Sigma_u = A_0^{-1} A_0^{-1\,\prime} = P'S'SP = \mathbb{P}'\mathbb{P} \tag{7}$$

Where $\mathbb{P}'$ is generally not lower triangular anymore. Therefore, the identification process should show that $A^{-1} = \mathbb{P}'$

The next step is to check whether the impulse responses implied by S' satisfy a set of a priory (an possibly theory-driven) sign restrictions. The process can draw as many S' as necessary and construct a distribution of the solutions that satisfy the sign restrictions.

In sum, the steps to implement the sign restrictions methodology are: First, estimate from the reduced form VAR F, u_t, and S'. Second, Draw a random orthonormal matrix S', compute $P' = cholesky(\Sigma_u)$. Third, Compute the impulse responses function $IR_1 = A_0^{-1}\varepsilon_t$. Fourth, Are the sign restrictions satisfied? Yes. Store the impulse responses. Otherwise, discard the impulse responses.Finally, Perform N replications and report the median impulse response (and its confidence intervals).

Canova and De Nicolo (2002) considers that the recursive structures like cholesky decomposition and zero long restrictions are inconsistent with most of theoretical models. Therefore, the sign restrictions methodology allows to identify in a better way the economic theory by imposing the correct sign to the reaction of the variables to an specific shock.

On the other hand, Fry and Pagan (2011) explains that although the sign restrictions methodology solves the structural identification problem, it leaves unsolved the model identification problem. It means that the final model selected by the sign restrictions methodology is not necessary the best model to explain the relationship between the variables. It may be another set of variables which can explain the patterns of them.

4 Main Results

4.1 Long-Run Restrictions

In this subsection, there are the results of the estimation of an SVAR model for both inflation and output where the identification scheme is following Blanchard and Quah (1988). The results are shown below

Table 1: VAR, Blanchard and Quah

Variables	y_t	π_t
c	0.8880 **	1.3675**
	(0.3289)	(0.6048)
y_{t-1}	0.9444**	0.1383
	(0.088)	(0.1612)
π_{t-1}	-0.1741	0.4938**
	(0.068)	(0.1242)
Observations	40	40
R squared	0.7653	0.3891

Where, *,**, and *** denotes the 10%, 5%, and 1% level of significance of the coefficients. The standard errors are shown in parenthesis.

The next step is to generate the short run impulse response functions, with the identification scheme. In appendix, figure 1, a supply shock (shock1) will increase output but decrease inflation. On the other hand, a demand shock (shock2) will increase both output and inflation. Therefore, the supply and demand shock are correctly identified with the VAR model.

Also, the response of consumption to the supply shock is positive and statistically significant until approximately the seven quarter. However, the response of inflation to the supply shock is not statistically significant.

Similarly, the response of consumption to the demand shock is positive and statistically significant until approximately the second quarter, and the response to inflation to the demand shock is also positive and statistically significant until the third quarter.

The final step is to generate the historical decomposition of inflation in Guatemala. It is shown in appendix, figure 2.

From there, the inflation patterns in Guatemala are decomposed into the supply shock, the demand shock, and the baseline (it includes the initial conditions and the mean of the series).Most of the pattern of inflation is explained by the baseline. Also, the explanation of the inflation patterns is more explained by the demand shock than the supply shock in almost the entire sample. It can be seen more clearly in Appendix, figure 3. The demand shock explained more of the inflation patterns than the supply shock in most of the sample.

4.2 Sign Restrictions

In this subsection, there are the results of the estimation of an SVAR model for inflation, output and repurchase rate where the identification scheme is following Uhlig (2005).It means that there are three shocks: supply, demand, and monetary shock.

First, the model is estimated following a cholesky decomposition scheme. The results are shown below

Table 2: VAR, Sign Restriction

Variables	y_t	π_t	i_t
c	2.6643 **	4.5216***	1.1778***
	(0.7687)	(1.5198)	(0.4005)
y_{t-1}	0.7348***	-0.2056	-0.0939*
	(0.1000)	(0.1962)	(0.0512)
π_{t-1}	0.0001	0.7439***	0.0765*
	(0.0000)	(0.1439)	(0.0379)
i_{t-1}	-0.5872***	-1.0039**	0.5754***
	(0.2080)	(0.4112)	0.1084
Observations	40	40	40
R squared	0.8326	0.5041	0.6914

Where, *,**, and *** denotes the 10%, 5%, and 1% level of significance of the coefficients. The standard errors are shown in parenthesis.

the R squared of the first and second equations are higher that those of the estimation of the VAR with Blanchard and Quah scheme.

The next step is to generate the short run impulse functions with the sign restrictions scheme. First, the response of the three variables to a supply shock are shown in appendix, figure 4.

The consumption increase in response to supply shock and converges to the steady state in 40 quarters. In the case of inflation, it decreases in the beginning and converges to its steady state in approximately 20 quarters. Finally, the repurchase fund decreases and converges to its steady state around 25 quarters ahead. The results are statistically significant.

Second, the response of the three variables to a demand shock are shown in figure 5.

The consumption increase in response to demand shock and converges to the steady state approximately in 25 quarters. In the case of inflation, it also increases and converges to its steady state in approximately 4 quarters. Finally, the repurchase fund increases and converges to its steady state around 28 quarters ahead. The results are also statistically significant.

Third, the response of the three variables to a monetary shock are shown in figure 6.

The consumption decreases in response to monetary shock and converges to the steady state approximately in 40 quarters. In the case of inflation, it increases and converges to its steady state in approximately 6 quarters. Finally, the repurchase fund increases and converges to its steady state around 40 quarters ahead. The results are also statistically significant.

The next step is to analyze the historical decomposition of inflation. It is shown in Appendix, figure 7.

The inflation patterns in Guatemala are decomposed into the supply shock, the demand shock, and the baseline (it includes the initial conditions and the mean of the series).Most of the pattern of inflation is explained by the initial conditions and the mean of the series. The exception is in 2014, where the supply shock explained more of the variable than the demand shock. It is more clearly in figure 8 below

From figure 8, the supply shock only explained more of the patterns of inflation than the demand shock in 2014. In the remaining of the sample, the demand shock explains the patterns of inflation.

In the next subsection, there is a comparative analysis between the two methodologies.

4.3 Comparative Analysis

This subsection includes a comparative analysis of the contribution in the explanation of the inflation of the demand and supply shock with both Blanchard and Quah and Sign Restriction methodologies.

First, the comparative analysis of the contribution of the supply shock is shown in appendix, figure 9,

From figure 9, the direction of the contribution of the supply shock to explain the inflation patterns is the same in most of the sample with both methodologies. In 2009Q4, the supply shock has a positive contribution, in 2010Q3 and 2012Q3 it has a negative contribution, from 2013Q3 to 2014Q3 it has a negative contribution, from 2015Q1 to 2015Q4 it has a negative contribution, from 2016Q1 to 2016Q3 it has a positive contribution, and from 2017Q2 to 2017Q4 it has a positive contribution.

In the remaining of the sample, the direction of the shock differs depending on the methodology applied.

Also, the contribution of supply shock to the explanation of inflation is biggest in most of the sample applying Sign Restriction methodology.

Second, the comparative analysis of the contribution of the demand shock is shown in figure 10.

From figure 10, the direction of the demand shock in both methodologies is almost the same in the sample. However, the contribution of the demand shock to explained the inflation patters is biggest when Sign Restrictions methodology is is implemented as in the case of the supply shock.

5 Final Remarks

This study aimed to test if the contribution of the supply shock to explained the inflation patterns in Guatemala is bigger than the demand shock with two methodologies: Blanchard and Quah and Sign Restrictions.

In both methodologies, the study found empirical evidence that the demand shock dominates the explanation of the inflation patterns in the case of Guatemala. Therefore, the initial hypothesis is rejected.

Also, the contribution of both the supply and the demand shock in the explanation of the inflation patterns is bigger with Sign Restriction than with Blanchard and Quah methodology.

However, the assumptions of the two methodologies are different. First, Sign Restrictions methodology imposes the direction of the shocks in order to identify the model. Therefore, the results are more accurate than Blanchard and Quah. However, it does not allow to find the best model in terms of variables.

Second, Blanchard and Quah methodology imposes a long run restriction on output but not in inflation, which means that the explanation of inflation may be less accurate than with Sign Restrictions

Finally, both methodologies may be used as a satellite models, to analyze different scenarios to take advantages of the different assumptions.

A Figures

Figure 1: Short Run Impulse Response Functions

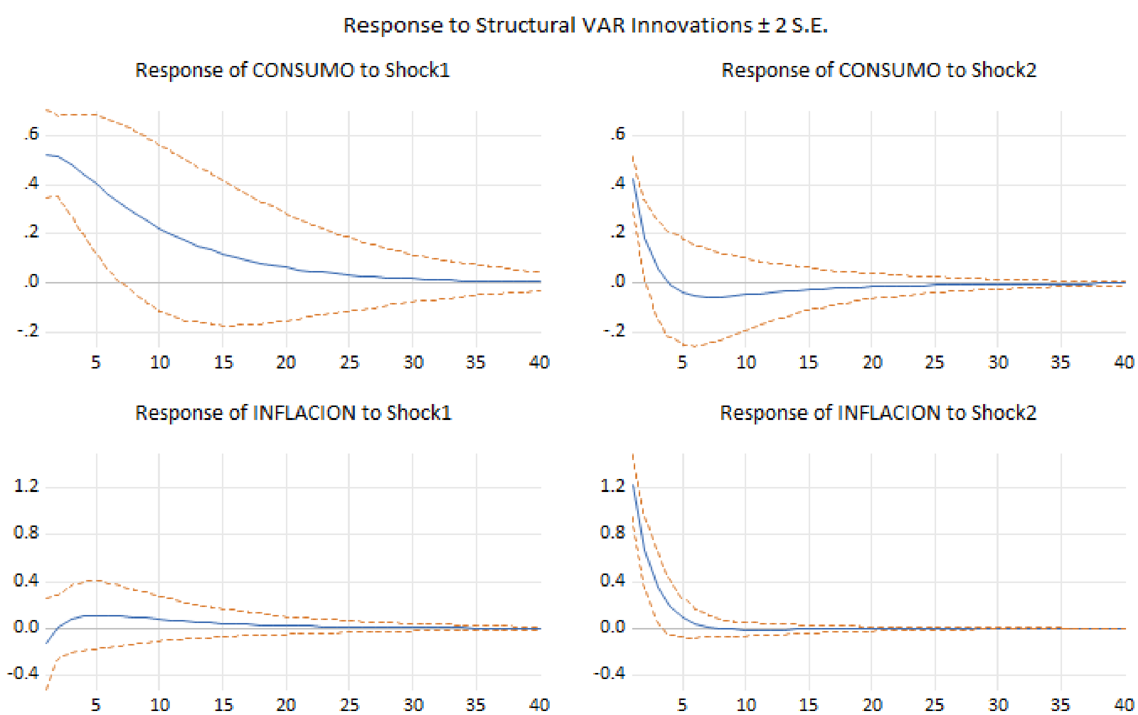


Figure 2: Historical Decomposition of Inflation, Blanchard and Quah

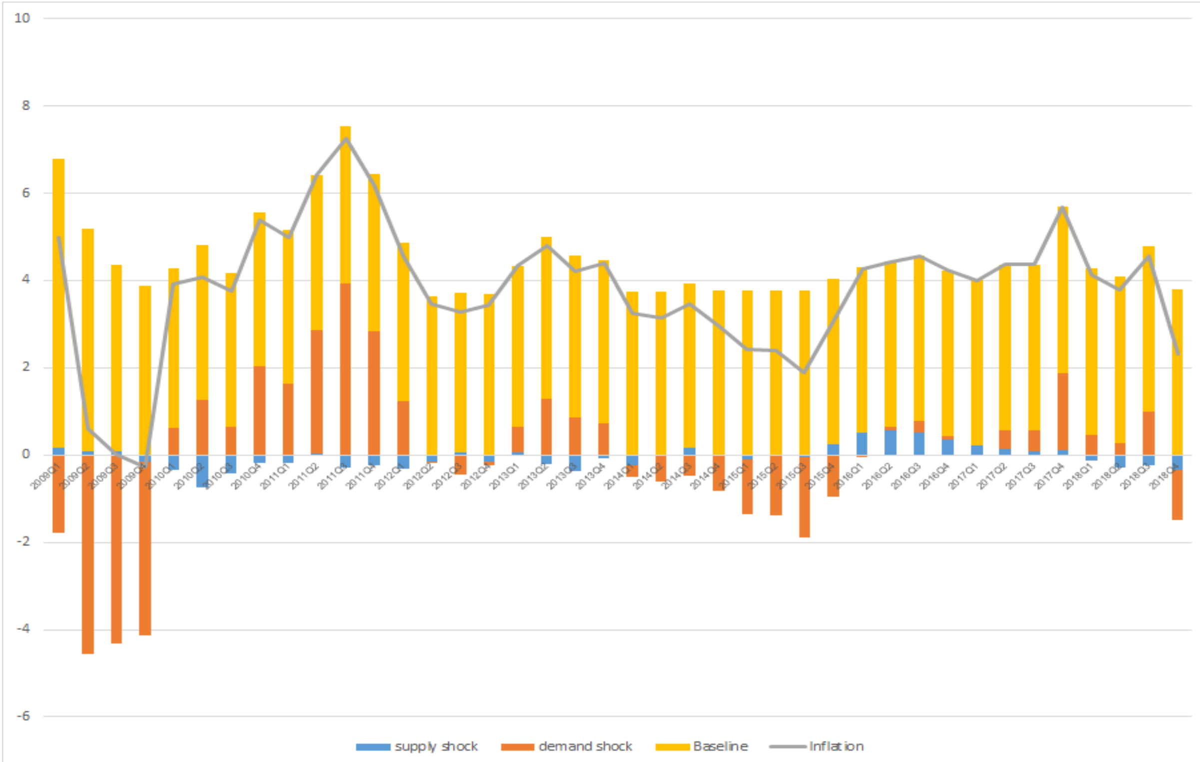


Figure 3: Historical Decomposition of Inflation, Supply and Demand Shocks, Blanchard and Quah

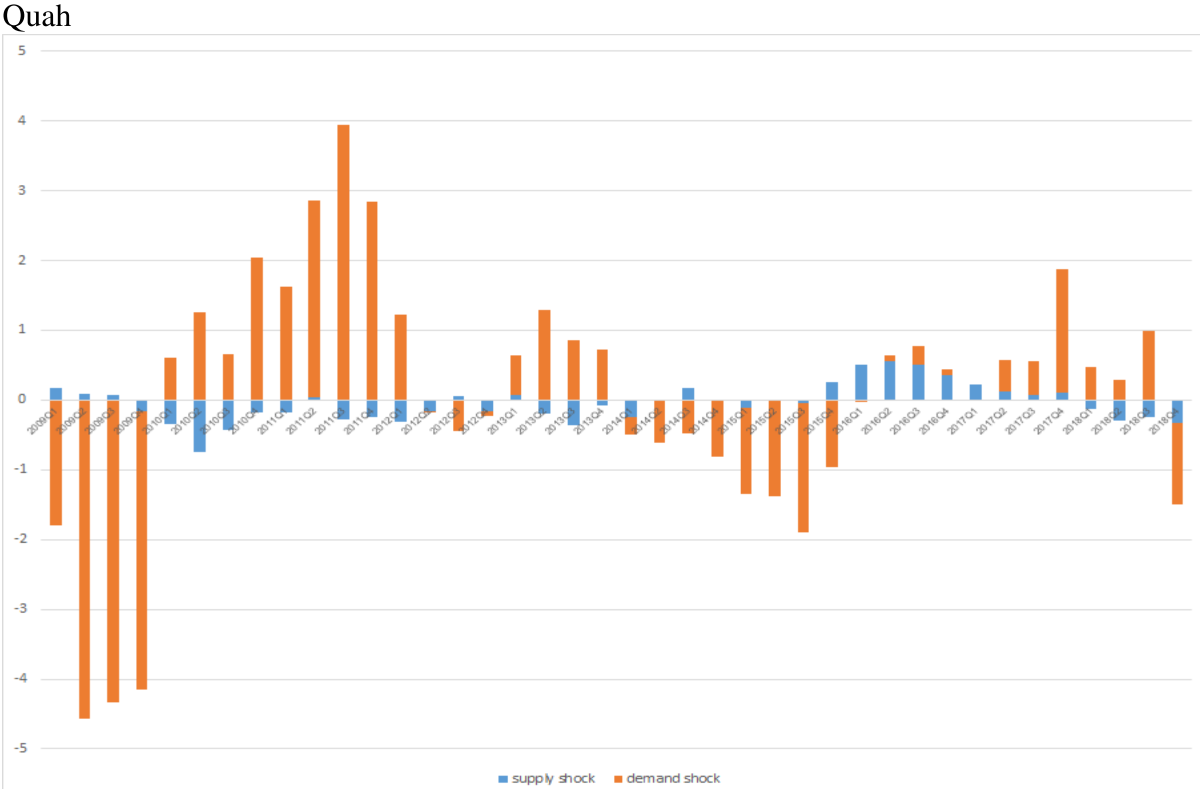


Figure 4: Short Run Impulse Response, Supply Shock, Sign Restrictions

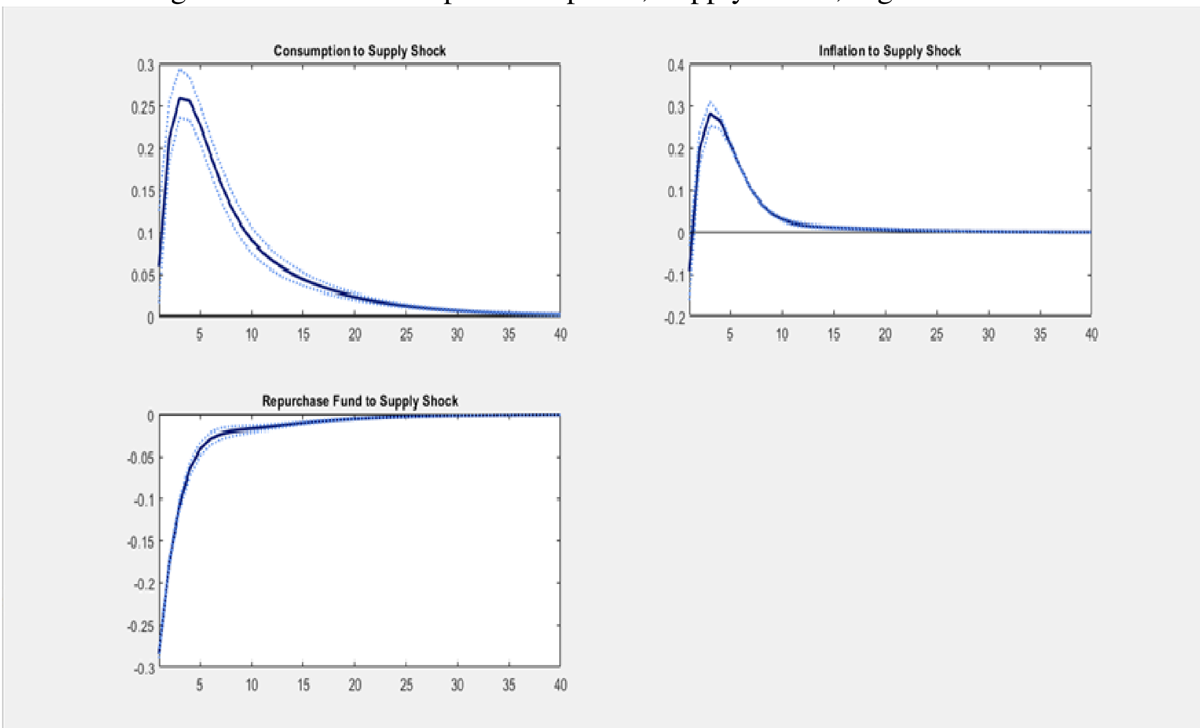


Figure 5: Short Run Impulse Response, Demand Shock, S ign Restrictions

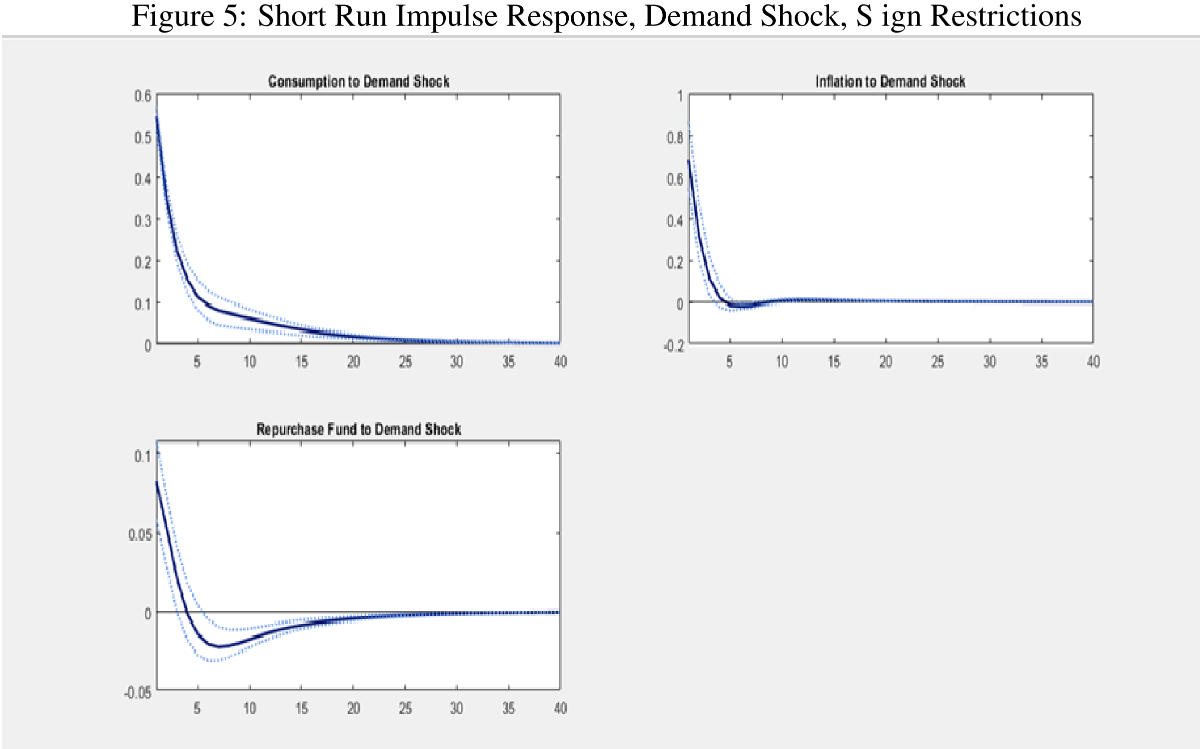


Figure 6: Short Run Impulse Response, Monetary Shock, Sign Restrictions

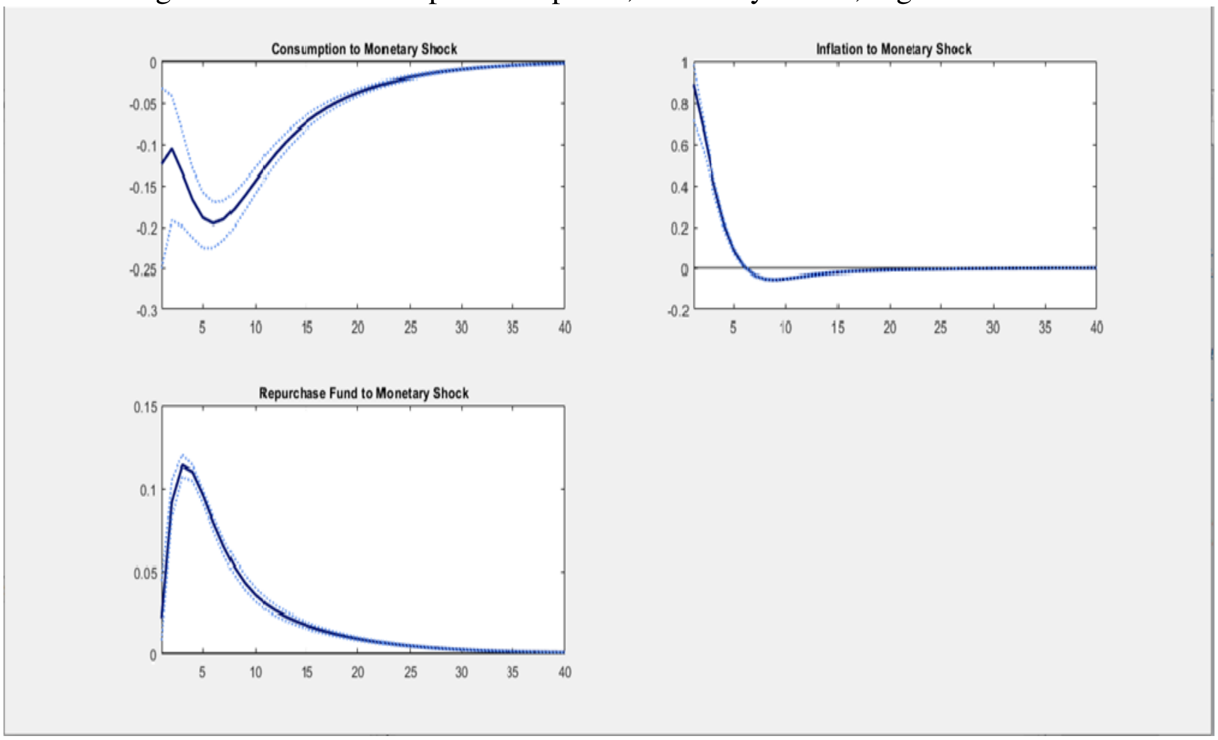


Figure 7: Historical Decomposition of Inflation, Sign Restrictions

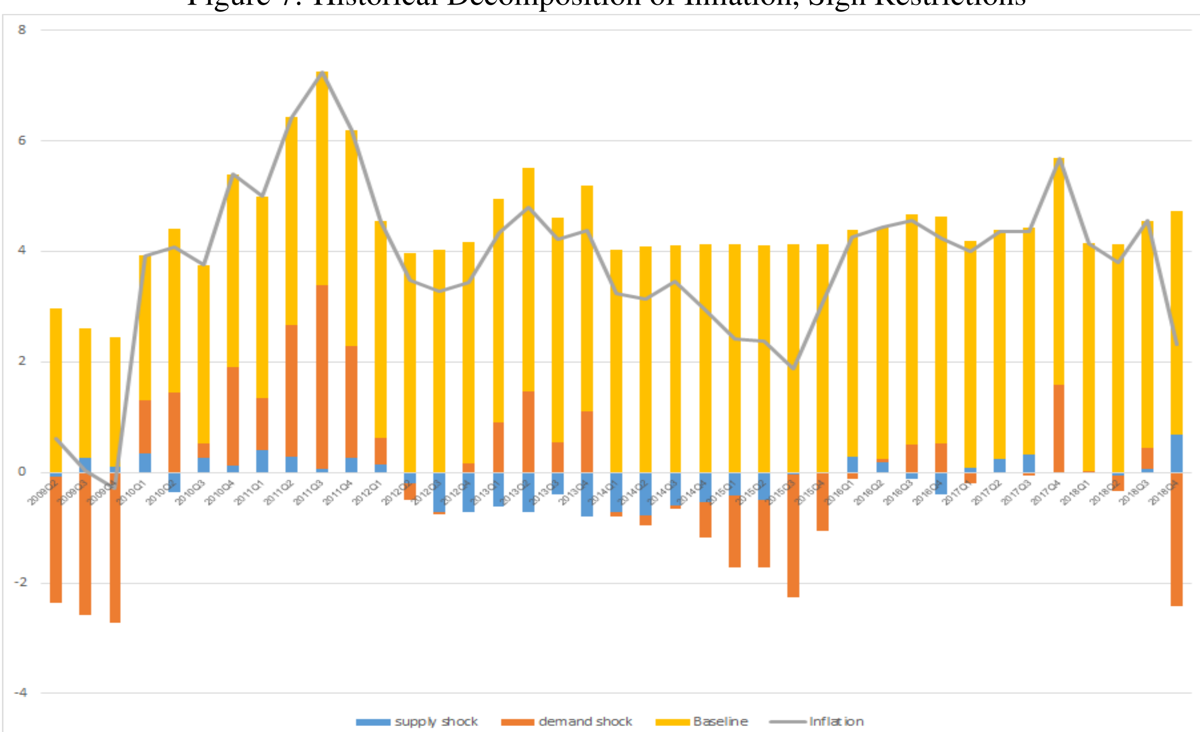


Figure 8: Historical Decomposition of Inflation, Supply and Demand Shocks, Sign Restrictions

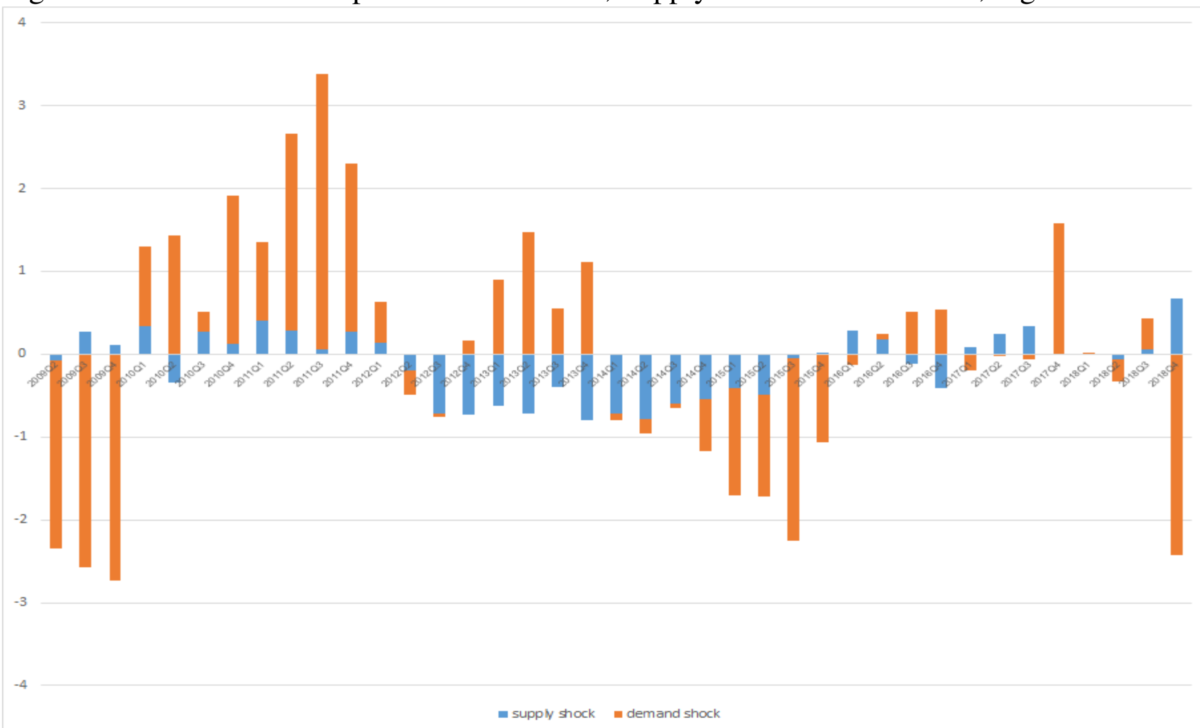


Figure 9: Comparative Analysis, Supply Shock, inflation

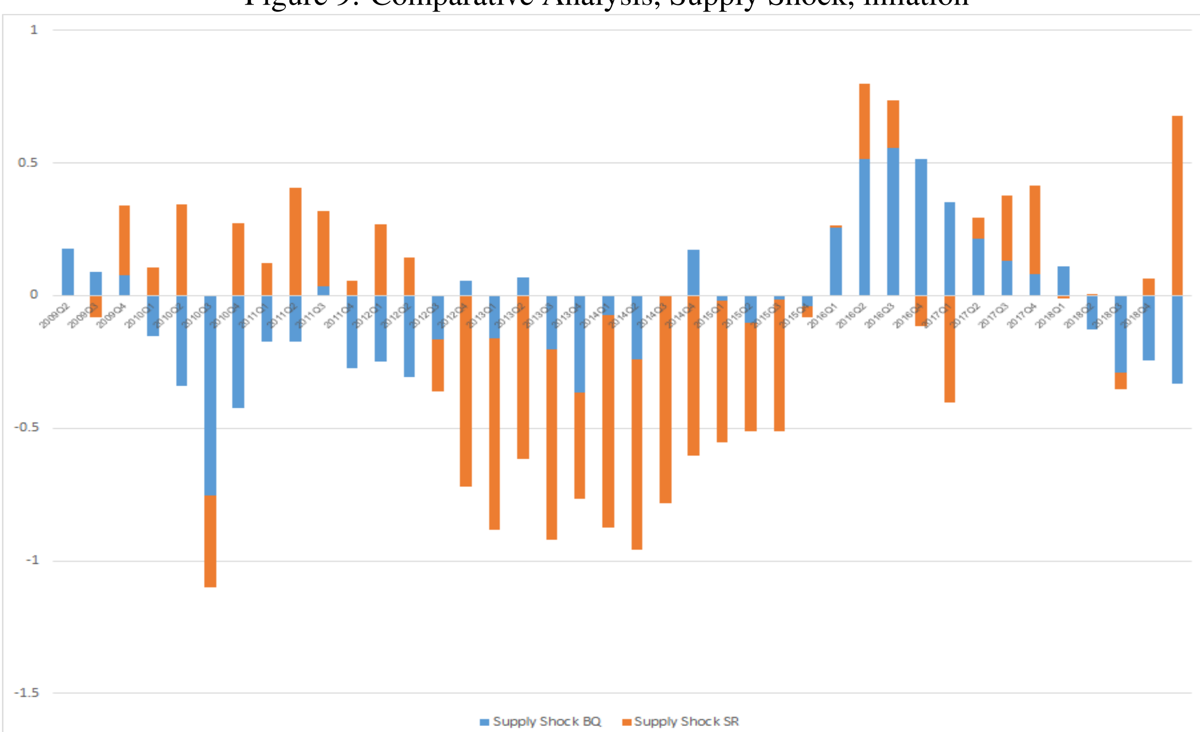
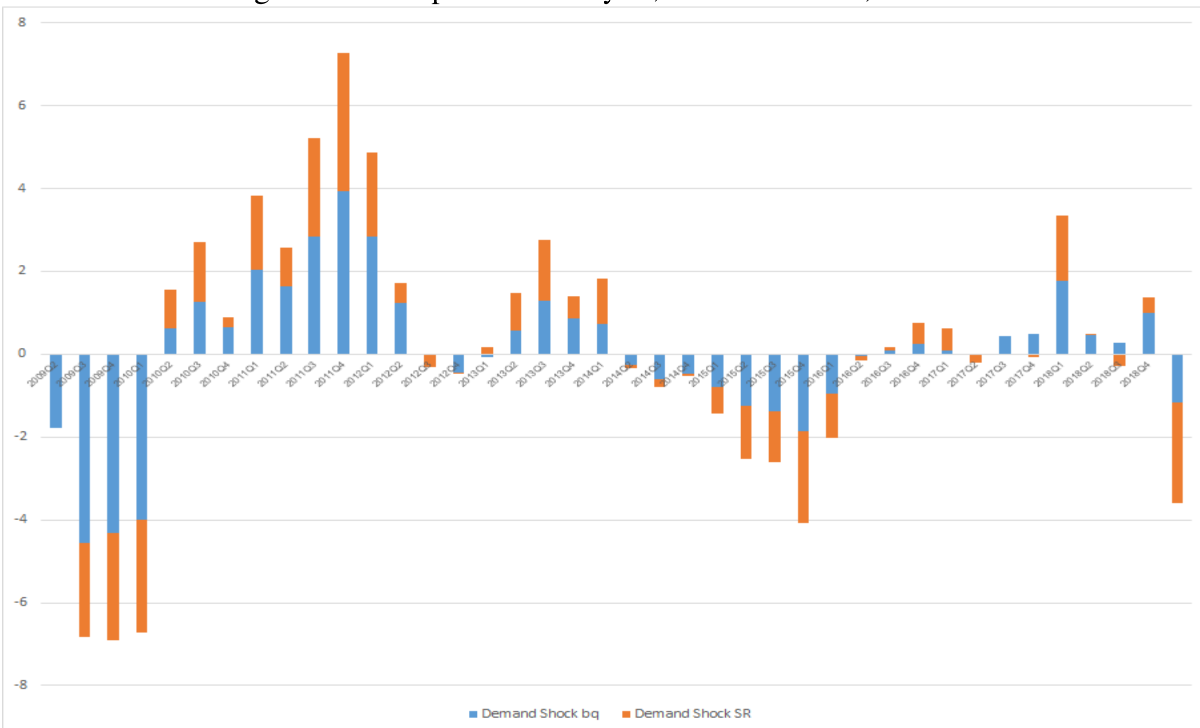


Figure 10: Comparative Analysis, Demand Shock, inflation



References

Olivier J Blanchard and Danny Quah. The dynamic effects of aggregate demand and supply disturbances. 1988.

Fabio Canova and Gianni De Nicolo. Monetary disturbances matter for business fluctuations in the g-7. *Journal of Monetary Economics*, 49(6):1131–1159, 2002.

James Peery Cover, Walter Enders, and C James Hueng. Using the aggregate demand-aggregate supply model to identify structural demand-side and supply-side shocks: Results using a bivariate var. *Journal of Money, Credit, and Banking*, 38(3):777–790, 2006.

Luca Dedola and Stefano Neri. What does a technology shock do? a var analysis with model-based sign restrictions. *Journal of Monetary Economics*, 54(2):512–549, 2007.

Walter Enders and Stan Hurn. Identifying aggregate demand and supply shocks in a small open economy. *Oxford Economic Papers*, 59(3):411–429, 2007.

Renee Fry and Adrian Pagan. Sign restrictions in structural vector autoregressions: A critical review. *Journal of Economic Literature*, 49(4):938–60, 2011.

Nikolay Gospodinov. Inference in nearly nonstationary svar models with long-run identifying restrictions. *Journal of Business & Economic Statistics*, 28(1):1–12, 2010.

Lutz Kilian. Structural vector autoregressions. In *Handbook of research methods and applications in empirical macroeconomics*. Edward Elgar Publishing, 2013.

Robert E Lucas Jr. Expectations and the neutrality of money. *Journal of economic theory*, 4(2): 103–124, 1972.

S Ouliaris, Adrian Pagan, et al. A new method for working with sign restrictions in svars. Technical report, National Centre for Econometric Research, 2015.

Harald Uhlig. What are the effects of monetary policy on output? results from an agnostic identification procedure. *Journal of Monetary Economics*, 52(2):381–419, 2005.