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**Exogenous Macroeconomic Shocks and their Propagation in  
Bosnia and Herzegovina**

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# **EXOGENOUS MACROECONOMIC SHOCKS AND THEIR PROPAGATION IN BOSNIA AND HERZEGOVINA**

Bojan Baskot

## **ABSTRACT**

Vector autoregressive (VAR) models are commonly used for macroeconomic analyses. However, there are several reasons why this tool has not been applied to the case of Bosnia and Herzegovina. As Bosnia and Herzegovina has a currency board system, I use a VAR model with exogenous variables (VARX) and consider two exogenous shocks: interest rates for countries in the Eurozone and remittances. My analysis confirms that Bosnia and Herzegovina is a small open economy highly dependent on foreign aid and remittances, and has no autonomous monetary policy because of the currency board system.

## Introduction

There are no published papers that address the effects of exogenous shocks and their propagation in Bosnia and Herzegovina. This study is the first attempt to build a vector autoregressive (VAR) model for the economy of Bosnia and Herzegovina. My objective is to determine how monetary aggregates and other macroeconomic variables in Bosnia and Herzegovina respond to exogenous shocks.

I will examine the influence of exogenous shock. My preferred specification is a VAR with exogenous variables (VARX) that includes four endogenous and two exogenous variables. The endogenous variables are output, inflation, money supply and interest rates in Bosnia and Herzegovina. The exogenous variables are remittances and the interest rates in the European Union (EU).

Monetary policy in a currency board should have the sole objective of maintaining a fixed exchange rate relative to the anchor currency. Orthodox currency board systems have no discretionary monetary policy and the money supply is driven by market forces. Furthermore, orthodox currency boards usually do not accept deposits and do not convert local deposits denominated in their currency to the pegged currency. Additionally, there are no restrictions on current-account transactions. Deviation from orthodox currency boards include lending to domestic governments, companies or banks. The currency board in Bosnia and Herzegovina is highly orthodox, with very few deviations.

Another European country with a currency board is Bulgaria. There are, however, notable differences between the currency board arrangements in Bosnia and Herzegovina and Bulgarian. In Bulgaria, the liabilities of the currency board include not only banknotes and coins but also other balances, such as government deposits. The Law on the Bulgarian National Bank states, "Upon emergence of a liquidity risk that may affect the stability of the banking system, the Bulgarian National Bank may extend to a solvent bank lev denominated credits with maturity no longer than three months, provided they are fully collateralized by gold, foreign currency or other such high-liquid assets. The terms and procedure for extension of such credits, as well as the criteria establishing the occurrence of a liquidity risk, shall be determined by an ordinance of the Bulgarian National Bank" (Law on the Bulgarian National Bank, 1997, Article 33, Paragraph 2, 1997). Therefore, the currency board in Bulgaria can play the role of a lender of last resort, which is not the case for the currency board system in Bosnia and Herzegovina.

In Bulgaria, the central bank publishes base interest rates, and there are strong relations between the central Bulgarian National Bank and the Ministry of Finance. In Bosnia and Herzegovina, this is not the case.

One similarity is that in both Bulgaria and Bosnia and Herzegovina, the currency board is allowed to set a minimum reserve requirement for commercial banks, a deviation from an orthodox currency board. In fact, this is the only dimension on which the central bank in Bosnia and Herzegovina deviates from the policies of an orthodox currency board.

The VAR framework was originally developed by Sims (1980) as a response to the perceived failures of large structural Keynesian econometric models. This methodology treats all variables as jointly endogenous.

There are several open questions if one considers the implementation of a VAR framework in a currency board regime. For instance, the first step in the process of implementation of the VAR framework is to identify monetary policy shocks. However, it is difficult to identify monetary policy shocks in currency board regimes, and it is even more difficult to define monetary shocks in an orthodox currency board regime. The only explicit instrument of monetary policy in Bosnia and Herzegovina is the rate of required reserves. In addition, interest rates on excess reserves could be conditionally considered as an additional monetary policy instrument.

This lack of monetary autonomy has led me to consider the effect of macroeconomic shocks outside the economic system of Bosnia and Herzegovina. Therefore, I use vector autoregressive model with exogenous variable(s) (VARX).

The VARX approach is an extension of the VAR model that allows for strictly exogenous variables. VARX, like the specific case of the general VAR methodology, allows imposing restrictions by setting some variables as exogenous and by also imposing certain restrictions on the relationship among endogenous variables. The VARX approach is particularly important for countries that (like Bosnia and Herzegovina) operate under a currency board and therefore are highly responsive to the interest rate shocks of the anchor currency but that have no influence on this interest rate.

There are several reasons why there is limited research on the effects of monetary policy in Bosnia Herzegovina. First, the available time series are short, characterized by structural breaks, and, in some cases, inexistent. In fact, to study how external monetary shocks are transmitted to the economy of Bosnia and Herzegovina I had to build a new series for interest rates in Bosnia and Herzegovina. The creation of such a series is, in itself, a contribution of this paper. While there is no published research that applies the VAR methodology to Bosnia Herzegovina, there are some studies that apply this methodology to countries that, like Bosnia Herzegovina, operate under a currency board. Specifically, my work is closely related to Minea and Rault's (2009) analysis of the conduct of monetary policy in Bulgaria (among other Eastern European countries).

Minea and Rault (2009) assume that neither monetary aggregates nor the domestic interest rate can be considered policy instruments under a currency board. This restriction implies that studying exogenous changes in either domestic interest rates or money aggregates, which are econometrically computable, has limited usefulness for subsequent research.

The rest of the paper is organised as follows. Section 2 summarises the stylised facts about Bosnia and Herzegovina's monetary and banking system. Section 3 describes and discusses the data. The results of the empirical undertaking are documented in Section 4. Section 5 offers concluding remarks.

## Stylized facts about Bosnia and Herzegovina's monetary and banking system

Bosnia and Herzegovina is a small and open economy which is highly dependent on the EU economy and has an orthodox currency board. The country is characterized by relatively low inflation, but high nominal interest rates.

Figure 1 shows an absence of well-defined business cycles. Bosnia and Herzegovina is a post-war country undergoing a prolonged process of transition. The investment cycle after the war was induced by foreign aid and the general post-war recovery. Additionally, the available data are relatively close to the start of the global financial crisis of 2008-09. Therefore, one structural break that is specific to only Bosnia and Herzegovina (conflict and resolution of the former Yugoslavia) was followed by a structural break that was global in its nature.

Recent growth has been slow (real GDP growth remained below 1 percent over 2012-14) partly because of the predicaments of the EU economy and partly because of large floods in 2014. Recently, there have been problems in the banking system with two banks interventions over 2015-16.

The country's main trading partners are Slovenia (16.4%), Italy (16.1%), Germany (12.8%), Austria (12.3%) and Croatia (12%). Key export commodities include metals, energy, textiles and furniture. Two of the key drivers of capital inflows are foreign aid and remittances.

<i>Data are in 2014 US dollars</i>	2009*	2010*	2011**	2012**	2013***	2014***	2015 <sup>†</sup>
<b>GDP (PPP) (in billions USD)</b>	30.23	30.56	32.8	32.8	37.89	38.29	39.46
<b>GDP - per capita (PPP) (USD)</b>	6600	6600	8200	8300	9800	9900	10200
<b>Gross national savings (% of GDP)</b>				9.3	11.2	10.1	9.9
<b>Unemployment rate<sup>2</sup></b>	24.1%	27.2%	43.3%	-	44.8%	43.9%	-

\*In 2010 USD

\*\*In 2010 USD

\*\*\*In 2012 USD

<sup>†</sup>In 2015 USD

<sup>2</sup> Official rate; the actual rate is lower because there are many technically unemployed persons working in the gray economy.

<i>Data are in 2014 US dollars</i>	<b>2009*</b>	<b>2010*</b>	<b>2011**</b>	<b>2012**</b>	<b>2013***</b>	<b>2014***</b>	<b>2015†</b>
<b>Inflation rate (consumer prices)</b>	-0.4	1.9	3.7	2.2%	-0.1%	-0.9%	-0.6%
<b>Stock of broad money (billion USD):</b>	9.236	9.307	9.538	9.577	10.95	11.75	9.223
<b>Current account balance (billion USD)</b>	-1.283	-0.887	1.583	-1.362	-1.026	-1.404	1.205
<b>Reserves of foreign exchange and gold</b>	3.245	2.8	4.15	3.9	\$4.868 billion	\$4.744 billion	4.625
<b>Debt - external</b>	8.048	7.996	8.766	9.051	\$11.08 billion	\$11.2 billion	-
<b>Exchange rates konvertibilna markas (BAM) per US dollar</b>	1.4073	1.5088	1.407	1.52	1.4718	1.4718	1.823

**Table 1. Bosnia and Herzegovina: Macroeconomic data (Source: [www.cia.gov](http://www.cia.gov))**

Money supply reached EUR 8.9 (KM 17.4) billion in 2014, representing a 7.8% increase relative to 2013. Deposits and currency outside banks are growing. The expected growth rate of M2 for 2015-2018 is in the range of 4%-6%. At the end of 2014, foreign currency reserves reached KM 7.8 billion, representing a 10.7% increase relative to the end of 2013.

Despite slow export growth in 2014, Bosnia and Herzegovina had faster growth of foreign currency reserves compared with the previous year. The Stand-By Arrangement with the International Monetary Fund (IMF) in the second half of the year and other foreign borrowings, in addition to inflows in the form of remittances, were the factors that induced this increase in foreign currency reserves. Future trends in this aggregate are influenced by developments in foreign trade, new public sector borrowings and repayment of public external debt.

The banking sector recorded positive financial results of KM 177.6 million in 2014, although there was a slight decline in total revenues (-0.7%) and cuts in total expenditures (13.8%). The growth in lending activity was modest (2.8% in 2014). Nevertheless, total deposits recorded a significant increase over the previous year (8.5%) because of expansion of household sector deposits and general government deposits.

The foreign assets held by the currency board increased at an average annual rate of 24% over 2001-2009 period and moved in the opposite direction of the balance of trade (Gedeon, 2009, p. 103).

Required reserves are the country's only instrument of monetary policy. The CBBH has no authority to monetize fiscal deficits or to lend to any economic agents. Additionally, the CBBH cannot play the role of lender of last resort to assist banks in problems with overcoming liquidity.<sup>3</sup> Potentially, the interest rate that is paid to the banks on the excess reserves could be considered an instrument of monetary policy. The effectiveness of this instrument is, however, questionable.

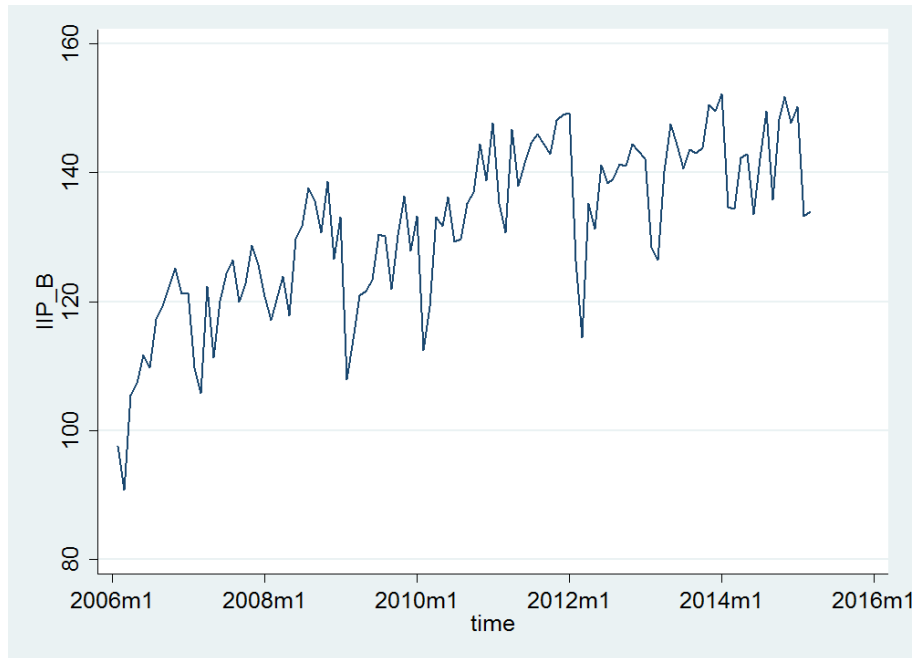


Figure 1. Index of industrial production for the period of 2006-2015

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<sup>3</sup> Some currency boards engage in lender of last resort activities (Gedeon, 2009). For instance, this situation was possible in Lithuania (now a member of the Eurozone) and Bulgaria (as mentioned earlier), where the governments hold their accounts at the central banks and thus influence the stock of reserve money.



## Data

Bosnia and Herzegovina gathers all data through two statistical institutes. One institute covers the first entity (the Federation of Bosnia and Herzegovina), and the other institute covers the second entity (Republika Srpska). All of the reports and data that have been produced by institutes at the entity level are summarized by an agency at the state level. In addition, there is one part of Bosnia and Herzegovina that is directly under the jurisdiction of the state agency when discussing statistics and data gathering; this part of Bosnia and Herzegovina is the Brcko district.

I use quarterly data from 2002Q1 to 2014Q4. Even this short time series was constructed with great effort.

To measure exogenous shocks, I use the discount rate for the Eurozone from 2002Q1 to 2014Q4 (*eurates* interest rates – the quarterly discount rate for the Eurozone). These data are not seasonally adjusted (Table 3) and are related to interest rates on loans to nonfinancial subjects in the EU. Another source of exogenous variability is remittances. Data on remittances are available from the central bank. I will show that remittances have great importance for the economy of Bosnia and Herzegovina

For quantities related to the interest rates in Bosnia and Herzegovina (*Domestic Interest*), I have the assessment of long-term lending rates for nonfinancial subjects in Bosnia and Herzegovina for period of 2002Q1-2014Q4<sup>4</sup> (table 3). This part of the data is based on estimation.

There is no standard risk-free interest rate series for Bosnia and Herzegovina. Additionally, there are no other interest rate data that are uniformly defined. The methodology for gathering interest rates suggested by the IMF was implemented in 2012.

There are some data regarding interest rates at which loans were made to nonfinancial firms in Bosnia and Herzegovina. These data are available at quarterly intervals for three different groups of banks. Hence, I take the lower bound of this interval, under the assumption that the lower bound should be that applied to high quality loans to nonfinancial firms. Restricting the data source to the specific branch that deals with two large banks allows me to avoid the influence of “suspicious” loans that are mostly related to microfinance organizations.

Interest rates in Bosnia and Herzegovina are generally high because of country-specific risk. Figure 2 shows a lack of correlation between the Eurozone interest rates and domestic interest rates. The fact that domestic interest rates did not decline in reaction to the 2008 crisis could be a sign that the crisis interrupted the trend with which domestic interest rates were converging towards Eurozone rates. I measure economic activity with the logarithm of GDP (logGDP). GDP by expenditure approach (GDP\_E) figures are available on a quarterly basis for the period of 2008-2013. The official data from the Agency for Statistics of Bosnia and Herzegovina (BHAS) for the aforementioned period is revised for the data regarding trade balance, collected by CBBH, because there are no available data for the subsequent periods, according to the old BOP methodology. GDP\_E for the period of 2004-2007 is available on an annual level, but there are no official data for periods prior to 2004. Regarding the lack of data for the period of 2000-2003 and for 2014, the ratio of GDP\_E in GDP by production approach (GDP\_P) is used for all of the

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<sup>4</sup> Source: CBBH Bulletins Quarterly Economic Indicators

available years because GDP\_P data are available for the required time. The quarterly frequency for the period of 2000-2007 and for 2014 is based on the available quarterly frequency (2008-2013).

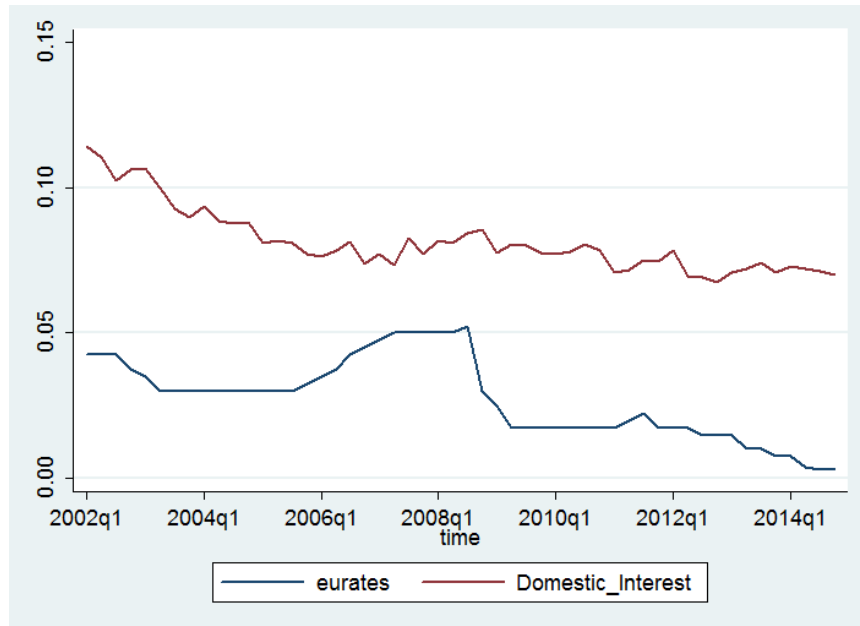


Figure 2 Domestic interest rate and the interest rate for the Eurozone

These data are seasonally adjusted, first by exponential smoothing with additive errors. The motivation for implementing an exponential smoothing method is that it makes sense to give larger weights to more recent observations as opposed to simple moving average (MA) that gives equal weights.

I have checked the results of autoregressive integrated moving average (ARIMA) seasoning adjustment procedures. There is no significant difference between this procedure and exponential smoothing (Graph 2. Exponential smoothing versus ARIMA). Therefore, I have used the (Hyndman & Khandakar, 2008) algorithm. This algorithm assumes the choice of the model order using unit root tests and the Akaike Information Criterion (AIC). According to this choice, in the end, I used the ARIMA method to manage seasonality issues.

To measure inflation for 2002Q1-2003Q3 I use the weighted average of rates of inflation of the two entities in Bosnia and Herzegovina. Weights are estimated according to estimation of each entity's proportion of total GDP. A consumer price index for Bosnia and Herzegovina was introduced in 2005. Prior to that period, there were a retail price index and cost of living index; thus, this variable (*InfQ*) is not "uniformly" defined.

I use data for M2 available from the official database of the CBBH. As was the case with GDP, I use the logarithm of M2 (*logM2*).

Because M2 is a key economic indicator used to forecast inflation, I include this variable in the model. Thus, we have M2 quarterly data from 2002Q1 to 2014Q4. The decision to address a broader money aggregate was made because I want to examine how innovation is reflected in money supply/demand.

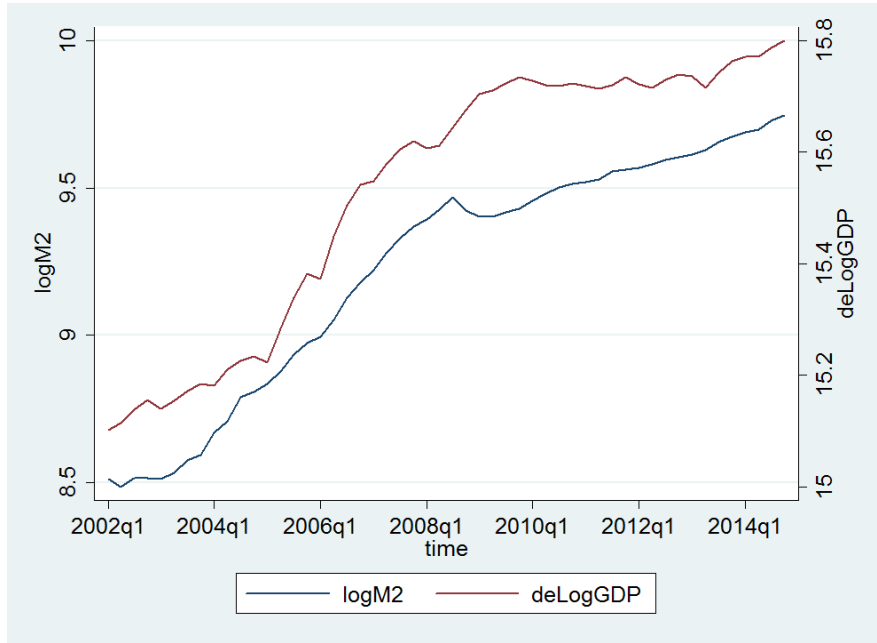
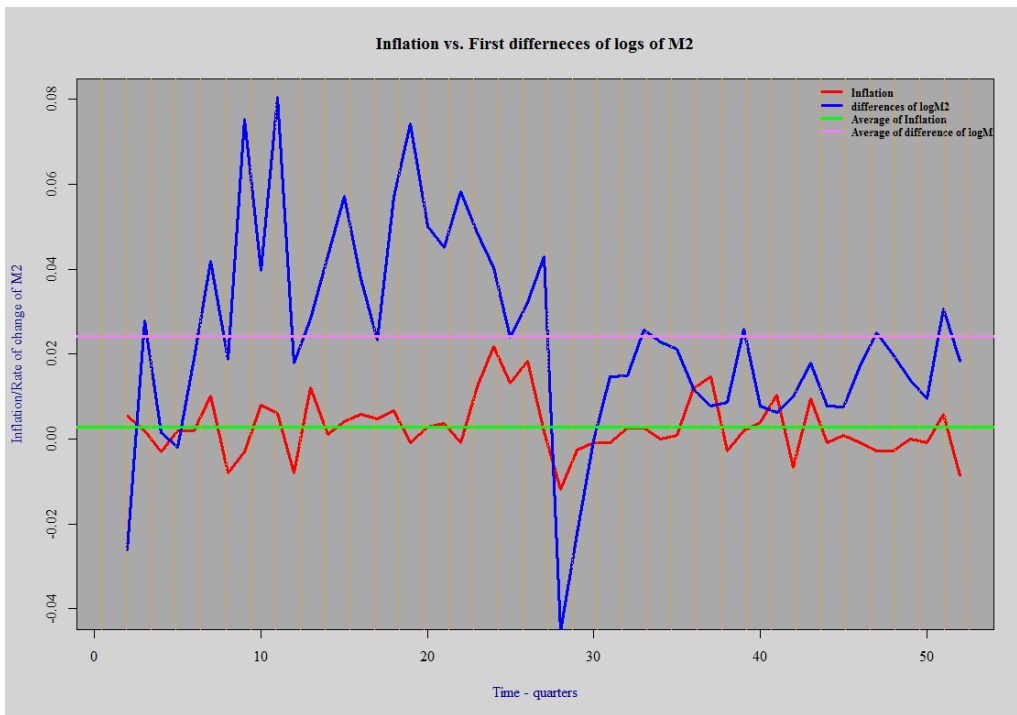


Figure 3. Output (log GDP) and log of M2



Graph 1. Inflation

## Results

This model includes four endogenous variables and two exogenous variables. I use the following ordering for the endogenous variables:

1. interest rates in Bosnia and Herzegovina;
2. output (GDP);
3. Inflation; and
4. M2.

Therefore, in the short-run output, inflation and M2 respond to interest rates in Bosnia and Herzegovina, but not vice versa. Furthermore, inflation and M2 do not have contemporaneous effects on output, and M2 does not have contemporaneous effects on inflation.

EU interest rates and remittances are set as exogenous variables.

The next step consists of defining the optimal lag length. According to LR testing (using the Akaike Information Criteria and the final prediction error, hereafter FPE), I conclude that the optimal lag length is 5, although the Hannan-Quinn information criterion and Schwartz Bayesian information criterion suggested that the optimal lag length is 1. Additionally, I have quarterly data; therefore, it is reasonable to use 5 as lag length, although BIC suggested that I should use 1. Standard tests show that the parameter estimates imply stationarity.

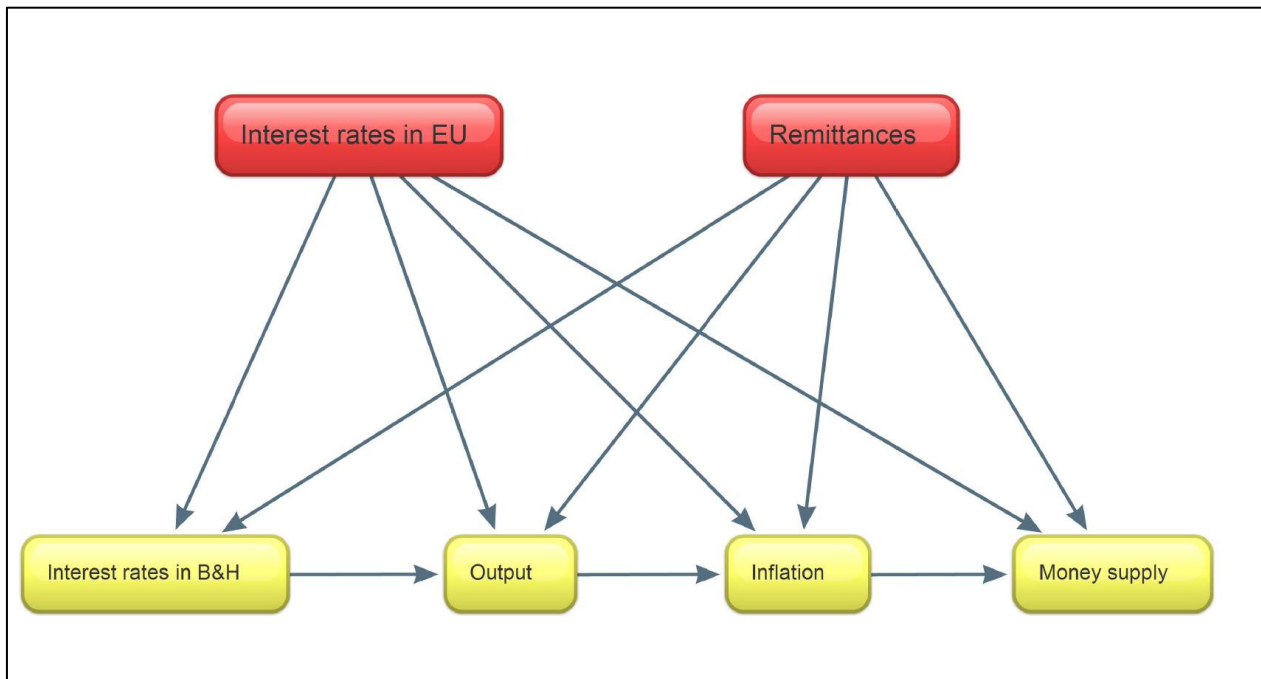


Diagram 1. Identification scheme for the VARX model with two exogenous variables

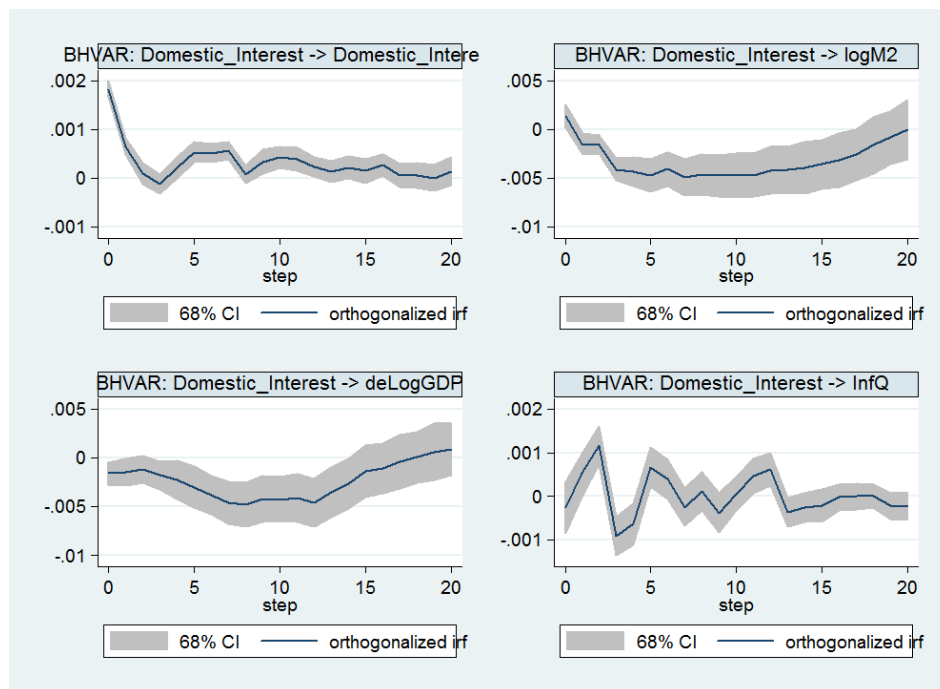


Figure 4. IRF VARX with Eurozone interest rates and remittances as exogenous: Output, M2, interest rates, inflation for Bosnia and Herzegovina

My estimations yield the following results

1. The characteristics of the currency board system are confirmed in the sense that monetary aggregates do not have such a significant impact on inflation and output.
2. The adjustment process between the goods market and financial markets lacks synchronization.
3. Remittances are highly important in maintaining the short run balance for the economy of Bosnia and Herzegovina.

Figure 4 presents the impact of domestic interest rates on output, monetary aggregate and inflation. As expected for the currency board system, domestic capital markets, and therefore domestic interest rates, have relatively little influence on the main macroeconomic parameters. Nevertheless, the direction of each individual impact is in agreement with basic macroeconomic logic and other examples of currency boards.

Interest rates have very little impact on output, which is also in agreement with the assumptions imposed by the currency board system. Interest rates increase results in money going into the banks and therefore the money supply decreasing.

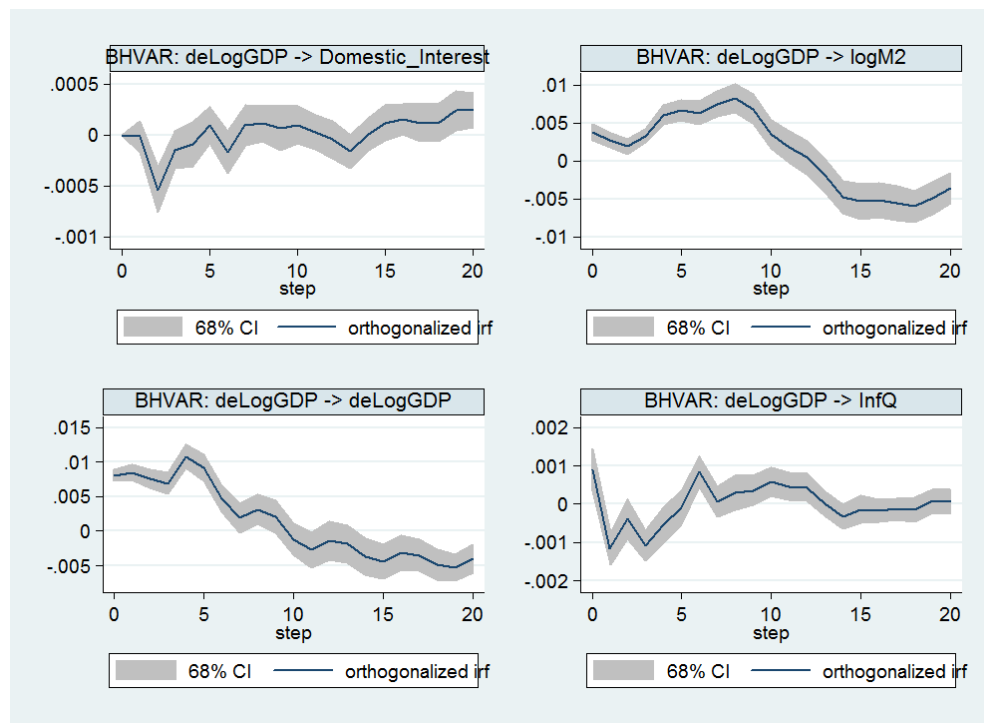


Figure 5. VARX model with EU interest rates and remittances as exogenous: GDP as impulse and domestic interest rates, inflation and M2 as responses

Figure 4 shows that interest rates are meaningless as targets for monetary authorities for imposing a direction of the economical path. All efforts in that direction will have no real effect on the physical output. The only conclusion to be drawn from Figure 4 is that interest rates are a tool that lacks significance in the context of monetary and macroeconomic policy in Bosnia and Herzegovina. This finding is in line with the currency board system.

Figure 5 shows a very low level of dependence between capital markets and goods markets. However, there is an expected but very small relationship between output and interest rates in the sense that the shifts in GDP in one direction cause shifts in interest rates in the opposite direction.

GDP initially induces positive shifts in M2 and inflation. Later, there is a relatively normal process of stabilization. Additionally, the effect of GDP is small, not only for interest rates but also for the two other endogenous variables. Nevertheless, I have the impression that GDP represents a much more significant quantity than is the case with interest rates. It leaves sufficient room for doubt regarding the ability of the economy of Bosnia and Herzegovina to be 'autonomous'. Therefore, not only is the monetary policy not autonomous; rather, the whole economy of Bosnia and Herzegovina could be considered as not 'autonomous'.

As Figure 6 shows, inflation has little impact on the other endogenous variables because it has very low variability. Again, this is a feature of the currency board system.

The relationship between inflation and output is as expected. The impact of inflation is small, but an increase in inflation causes an increase in output. The conclusion that inflation is not very important for interest rates in Bosnia and Herzegovina is in agreement with the country having a currency board system.

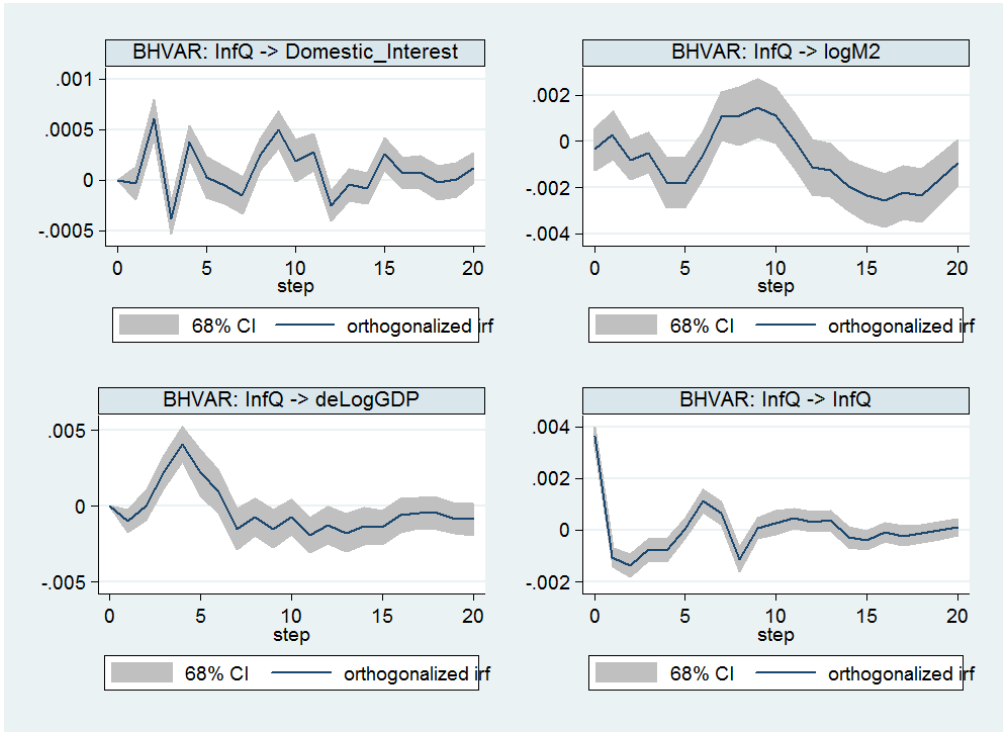


Figure 6. VARX with EU interest rates and remittances as exogenous: Inflation as impulse and domestic interest rates, GDP and M2 as responses

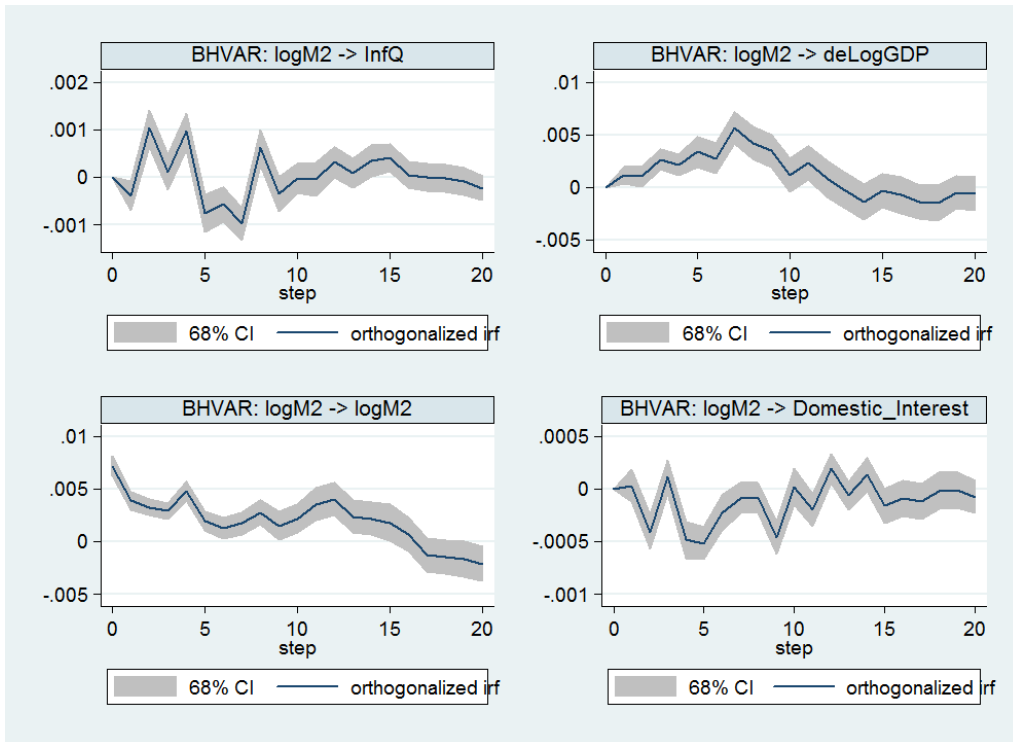
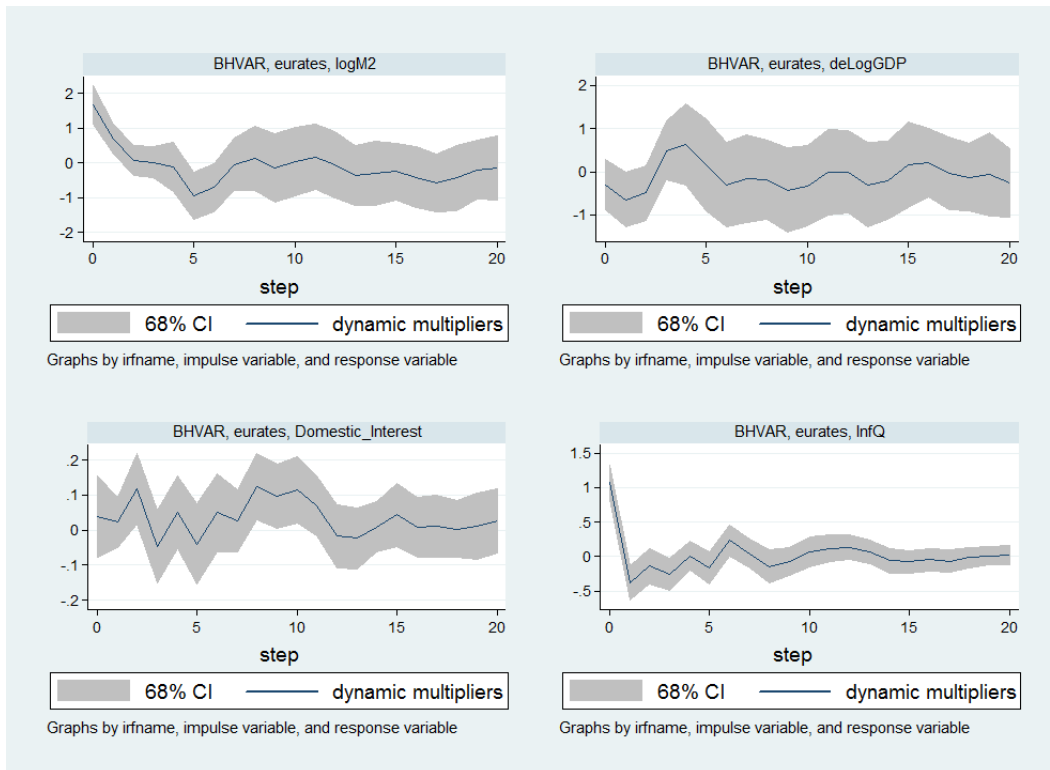


Figure 7. VARX with EU interest rates and remittances as exogenous: M2 as impulse and domestic interest rates, GDP and inflation as responses

Figure 7 confirms that monetary authorities do not have an influence on the economy in a currency board system. M2 has little impact on output, inflation and interest rates.

Figure 8 uses the Eurozone interest rates as exogenous variables, together with their bootstrapped 68% confidence intervals. An exogenous increase in Eurozone rates has some initial effect on the rates in Bosnia and Herzegovina. M2 responds initially positively and later negatively to the shock produced by Eurozone rates (Figure 8).



**Figure 8. VARX with EU interest rates and remittances as exogenous: impact of interest rates in the EU on M2, output, interest rates and inflation in Bosnia and Herzegovina**

Increased interest rates in the Eurozone lead to a negative, but not statistically significant, response of output in the short run.

As presented in Figure 9, remittances have positive impacts on interest rates. Therefore, it is expected that remittances have negative impacts on M2 and that positive effects on output are postponed. Thus, remittances require some time to induce an increase in GDP. As we can see from Table 1, in Bosnia and Herzegovina, there has been an increasing trend in savings. It could be that a substantial part of the remittances is put into savings contemporaneously, and it requires some time to go into consumption.

Additionally, it seems that there is a mildly positive effect of domestic interest on the shock induced by remittances. The intensity of this effect is relatively low. Therefore, reaction of interest rates in Bosnia and Herzegovina to remittances has low intensity and there is no significant relationship. However, remittances come when the economy is bad. Therefore, remittances are induced by the bad results of Bosnia and Herzegovina's economy. Bad results are unconditionally related to decreased output. It is known that output and interest rates have opposite directions of reaction. Additionally, Figure 9 shows that the reaction of output to the



shock induced by remittances is consistent with a previous conclusion – when the economy is bad, there are increased remittances.

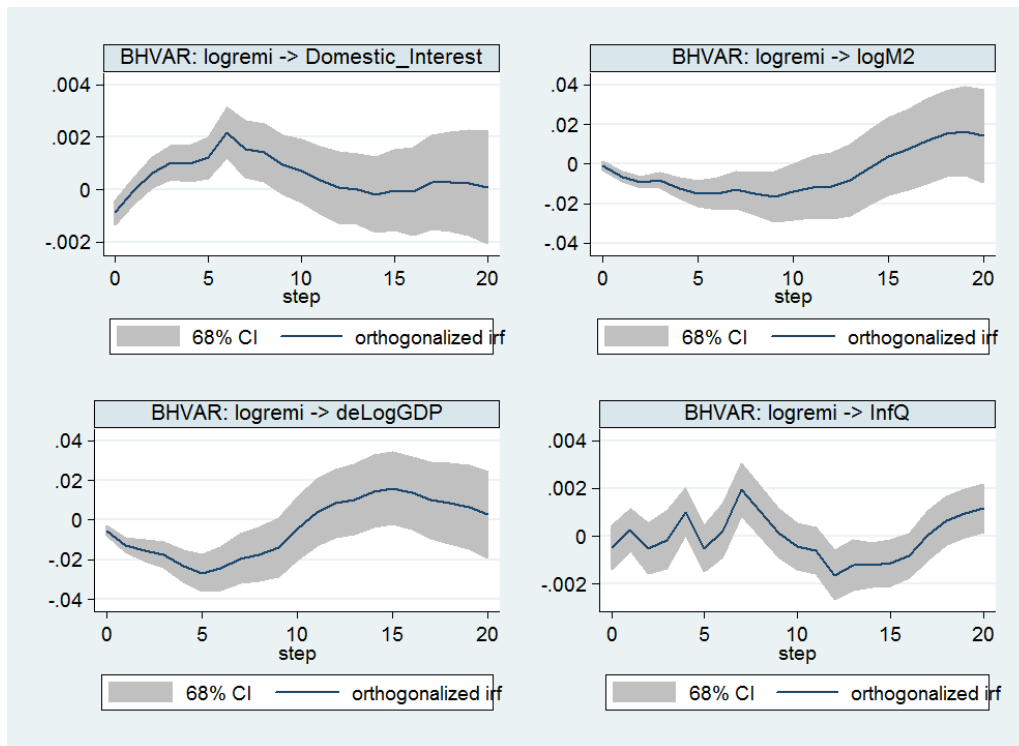


Figure 9. VARX with EU interest rates and remittances as exogenous: impact of remittances on M2, output, interest rates and inflation in Bosnia and Herzegovina

Figure 9 shows that shock due to remittances results in a mildly positive effect of inflation.

It seems that remittances play significant roles in the economy of Bosnia and Herzegovina.

Here, I posit that monetary autonomy can be called into question only when the general autonomy of the economy is set at a certain level. It is difficult to define this level, but it seems that the status of Bosnia and Herzegovina's economy is still far from that level.

## Conclusions

A relatively small number of authors have developed macroeconomic models for currency board systems. And, so far, nobody had built such a model for Bosnia Herzegovina.

Bosnia and Herzegovina is a post-war country that has been isolated from the main transition processes since the last decade of the 20<sup>th</sup> century. During the first five to ten years after the war ended, an intensive investment process started. As a result, it is difficult to define what the steady state for the economy of Bosnia and Herzegovina is. In addition, it is difficult to define exactly the impact of macroeconomic shocks because very little is known about deviations from a steady state.

I have attempted to measure how the economy of Bosnia and Herzegovina reacts to two exogenous shocks: interest rates in the EU and remittances from the diaspora.

I find that that the monetary authority has limited power and that remittances play a key role.

Interest rates have very little impact on movement of the economy of Bosnia and Herzegovina, suggesting that there is a weak link between capital markets and goods markets. Additionally, exogenous shocks have more influence on interest rates than output, inflation and M2.

Transfers from the diaspora can cause (not contemporaneously) increased interest rates. In the long run, remittances will also have positive effects on output. Because we have a currency board, market forces drive the money supply, but personal transfers drive market forces significantly. Therefore, foreign money supply drives money supply, as confirmed by the results. Once again, this effect is not contemporaneous.

## Appendix A

### VAR model

In principle, the VAR model is a seemingly unrelated regression model – indeed, a particularly simple model because each equation has the same set of regressors (Greene, 2002). The VAR model in standard (matrix) form can be defined as follows:

$$x_t = B^{-1}\Gamma_0 + B^{-1}\Gamma_1x_{t-1} + B^{-1}\varepsilon_t \quad (1)$$

Hence, for a simple bivariate model, we can write

$$x_t = A_0 + A_1x_{t-1} + e_t \quad (2)$$

where

$$A_0 = \begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix}^{-1} \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix}; A_1 = \begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix}^{-1} \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix};$$

$$e_t = \begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix}^{-1} \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{zt} \end{bmatrix}$$

If we set  $A_0 = \begin{bmatrix} a_{10} \\ a_{20} \end{bmatrix}$ ,  $A_1 = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$  and  $e_t = \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix}$ , then we can rewrite relation (2) as follows:

$$\begin{aligned} y_t &= a_{10} + a_{11}y_{t-1} + a_{12}z_{t-1} + e_{1t} \\ z_t &= a_{20} + a_{21}y_{t-1} + a_{22}z_{t-1} + e_{2t} \end{aligned} \quad (3)$$

Two shocks produce the error term  $\begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} = \begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix}^{-1} \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{zt} \end{bmatrix}$ . From here, it is possible to obtain

the variance covariance matrix  $\begin{vmatrix} \text{var}(e_{1t}) & \text{cov}(e_{1t}e_{2t}) \\ \text{cov}(e_{1t}e_{2t}) & \text{var}(e_{2t}) \end{vmatrix} = \begin{vmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{vmatrix}$ .

It is relatively simple to extend the model to the multivariate case. Generally, we assume that the VAR model is described by a structural form equation

$$G(L)y_t = e_t \quad (4)$$

In relation (4),  $G(L)$  is a matrix polynomial in terms of the lag operator  $L$ ,  $y_t$  is an  $n \times 1$  data vector, and  $e_t$  is an  $n \times 1$  disturbances vector. Additionally,  $e_t$  is serially uncorrelated (Kim & Roubini, 2000). Further, we can estimate the following reduced-form equation:

$$y_t = B(L)y_t + u_t \quad (5)$$

In relation (5),  $B(L)$  is a matrix polynomial (without a constant term) in terms of lag operator  $L$  and  $\text{var}(u_t) = \Sigma$ .

Hence, we have an exogenous variable(s). The model is of the following form:

$$y_t = a_0 + A_1 Y_{t-1} + \dots + A_p Y_{t-p} + B_0 X_t + B_1 X_{t-1} + \dots + B_q X_{t-q} + U_t \quad (6)$$

Next, assuming a VAR model for  $X_t$  itself, we can write

$$X_t = c_0 + C_1 X_{t-1} + \dots + C_r X_{t-r} + V_t \quad (7)$$

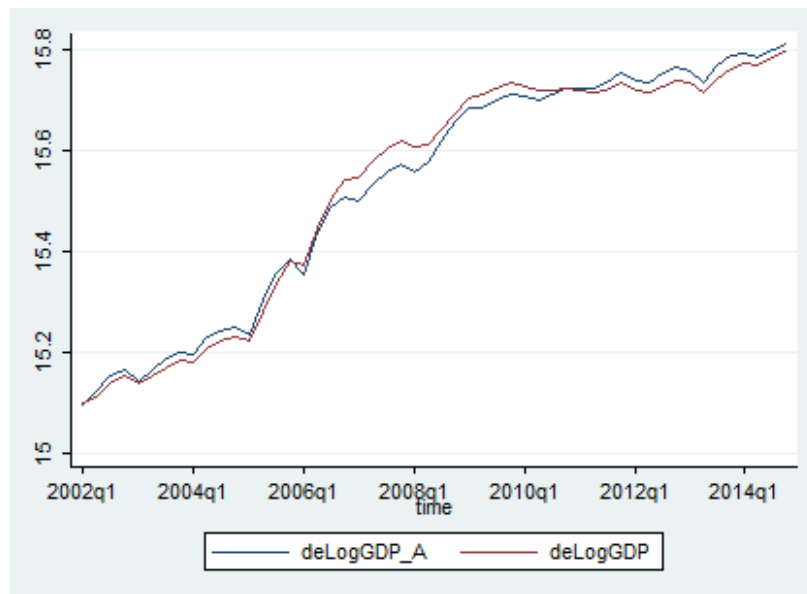
Further, we can write a reduced form VARX by inserting (7) into (6):

$$y_t = a_0 + B_0 c_0 + A_1 Y_{t-1} + \dots + A_p Y_{t-p} + B_0 (C_1 X_{t-1} + \dots + C_r X_{t-r}) + B_1 X_{t-1} + \dots + B_q X_{t-q} + U_t + B_0 V_t \quad (8)$$

## Appendix B

### ARIMA versus exponential smoothing and other data issues

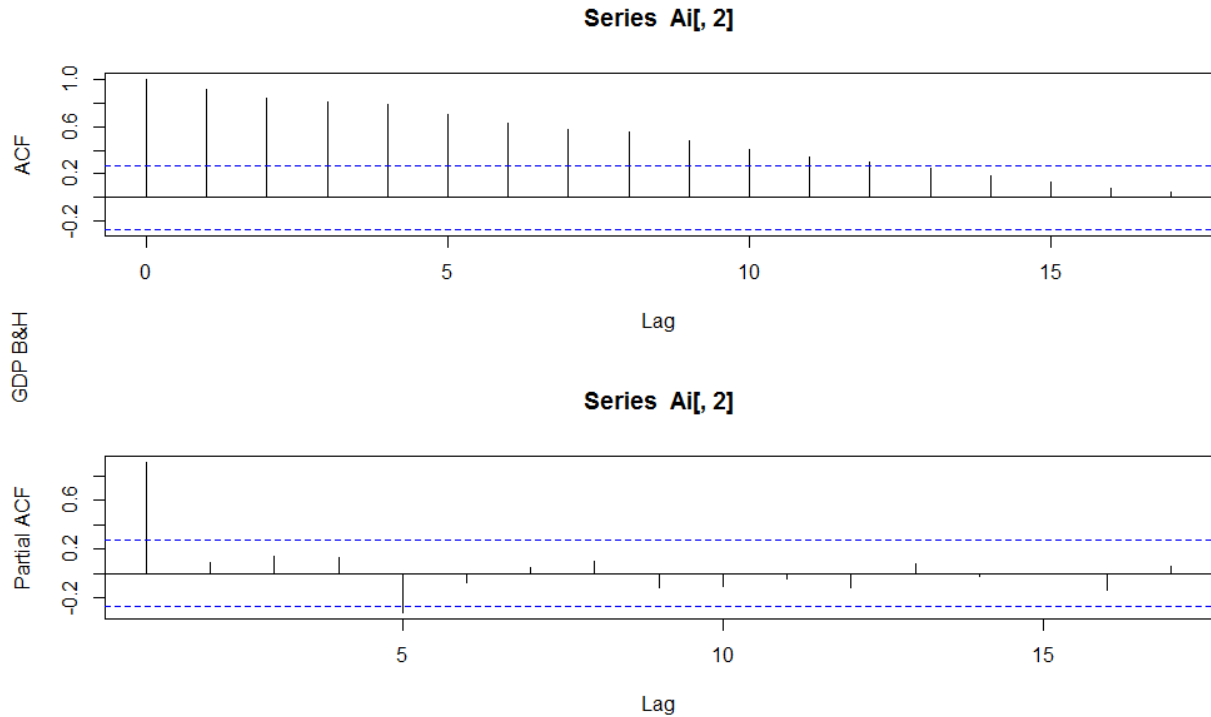
In this section, I discuss in greater detail the problem of deseasoning or, to be more specific, the issue of the ideal method of deseasoning for the data set that I use.



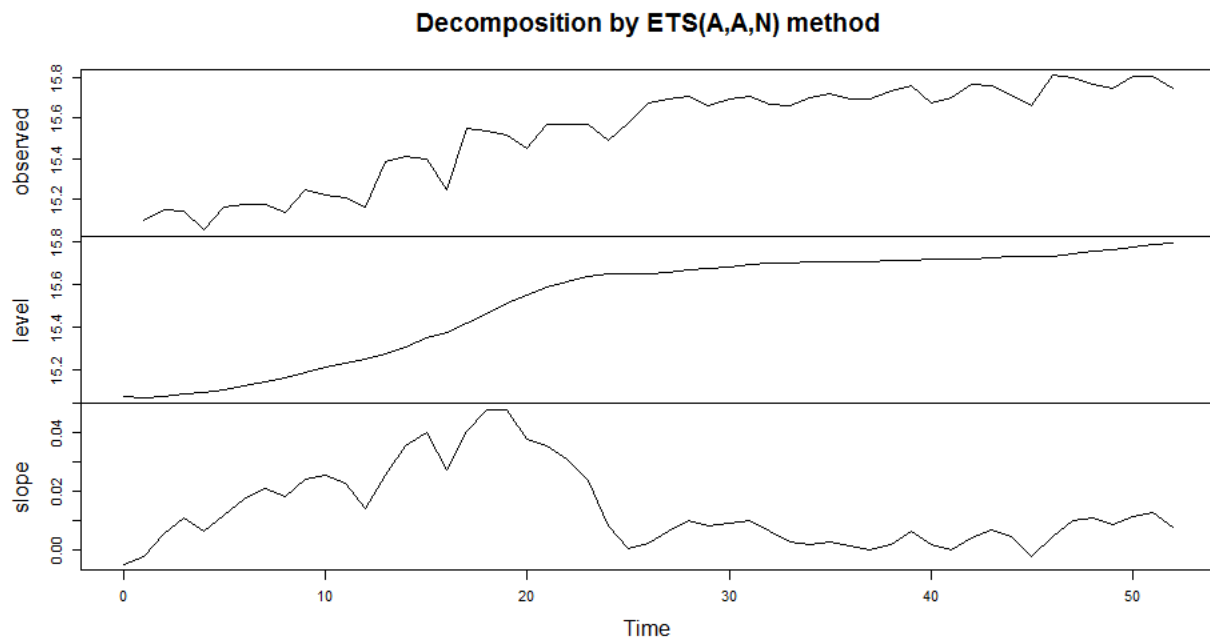
Graph 2. Exponential smoothing versus ARIMA

Variable	<i>eurates</i>	<i>Domestic_Interest</i>	<i>InfQ</i>	<i>logGDP</i>	<i>logM2</i>
Observation	52	52	52	52	52
Mean	0.027356	0.081430769	0.002852	15.53167	9.224493
Variance	0.000196	0.000122686	4.61E-05	0.056216	0.167471
St. Dev.	0.013995	0.011076393	0.006786	0.2371	0.409232
Min	0.003	0.0676	-0.01191	15.04709	8.486555
Max	0.0525	0.1141	0.021918	15.80679	9.747161

Table 1. Descriptive statistics



The ARIMA class of models assumes homoscedasticity. In contrast, the exponential smoothing algorithm does not assume homoscedasticity. Furthermore, the exponential smoothing method assumes that the world is non-stationary. ARIMA models are better for stationary models. Additionally, ARIMA models provide more possibilities when one is using seasonal data.



Graph 3. Decomposition by ETS method

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