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Europos šalių finansinių šokų tarpusavio poveikis: GVAR metodas

Transmission of financial shocks across Europe: A GVAR approach

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Santrauka

Šiame darbe analizuojamas finansinių šokų poveikis tarp Europos šalių, naudojantis GVAR metodu. Darbe detaliau nagrinėjami Baltijos ir Šiaurės šalių galimi tarpusavio finansų sistemų poveikiai. Naudojantis finansinių įsipareigojimų duomenimis atliekama finansinių sąsajų analizė tarp šalių ir naudojantis šiais rezultatais šalys yra apjungiamos į bendrą sistemą tirti impulsų atsakus makroekonominiams bei finansiniams rodikliams. Įsipareigojimų duomenys naudojami kaip sąsajų matrica. Kiekvienai šaliai vertinamas modelis su vidiniais ir išoriniais kintamaisiai, čia išoriniai kintamieji yra pasveriami pagal gautą finansinių įsipareigojimų sąsajų matrica atitinkamai kiekvienai šaliai. Gauti rezultatai parodė, kad didesni finansiniai įsipareigojimai turi įtakos atsako dydžiui. Šiaurės šalims labiau finansiškai įsipareigojusių šalių kintamieji daugiau reaguoja į Šiaurės šalių šokus.

Raktiniai žodžiai: GVAR, Europa, Baltijos, Šiaurės, finansiniai įsipareigojimai, VECMX, sąsajų matrica, globali sistema, impulsai, generalizuoti atsakai.

Transmission of financial shocks across Europe: A GVAR approach

Abstract

This thesis analyzes the impact of financial shocks across European countries using the GVAR approach. The possible effects of the mutual financial system between the Baltic and Nordic countries are analyzed in more detail. The use of financial liabilities data to analyze the financial links between countries and to use these results bringing countries together into a common framework for studying impulse responses to macroeconomic and financial variables. Financial liabilities data is used as a link matrix. For each country, a model with internal and external variables is evaluated, whereby the external variables are weighted by the link matrix. The results of combining and estimating individual models into a common system have shown that greater financial liabilities afect responses size. The countries more financially realited to Nordic countries are more responsive to Nordic shocks.

Key words: GVAR, Baltic, Nordic, financial liabilities, link matrix, VECMX, co-integration, impulse, generalized responses, global, Europe, integration, exogeneity, domestic, foreign.

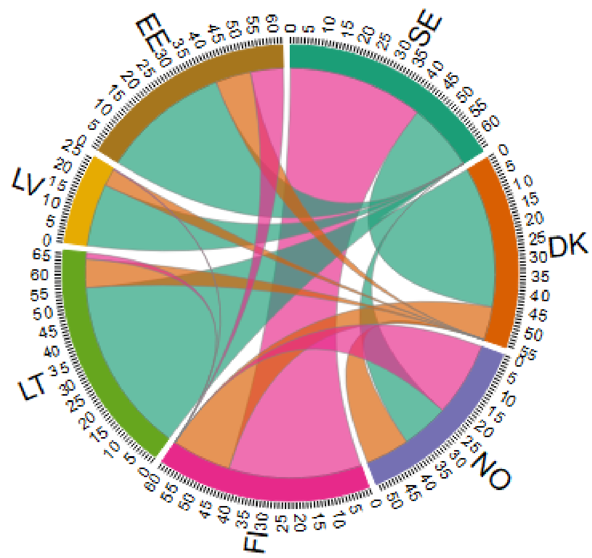
Contents

1. Introduction

Last two decades significantly increased financial and trade linkages between countries. This implyig higher risks for financial stability. BIS Annual Economic Report (2017) analyses trends of financial links and trade links between countries. All European countries are closely related by financial linkages, so it raises questions how through those linkages shocks are transmitted and how macro-economic and financial sectors interact when shocks are transmitted between countries. These questions are interesting for researchers recent years. Dees et al. (2007), Galesi and Sgherri (2009) and Sun, Heinz, and Ho (2013) and among others. This thesis provides answers to these questions by using the Global VAR (GVAR) model to estimate impacts of transmitted shocks for European countries with focus on Lithuania, Latvia and Estonia separately. In the literature, Lithuania, Latvia and Estonia are often analysed as a single Baltic region. Galesi and Sgherri (2009) and Sun, Heinz, and Ho (2013) analises Lithuania, Latvia and Estonia as a single Baltic region. The GVAR model was pioneered by Pesaran, Shuermann, and Weiner (2004) studying the problem of commercial lending. Looking at the financial crisis of 2008, we can see how quickly financial imbalances have spread to other countries and negatively affecting welfare of the economic agents. With this background in mind, the aim of this thesis is to study the role of crosscountry financial linkages and spillovers across Europe focusing on Baltic countries. When looking at financial relationships and at the financial obligations of the parties, we can see clear trends. Comparing the data on Baltic and Nordic countries, we seek to hypothesize the dependence of the financial system in the Baltic countries on the situation in Nordic countries taking into account other members of the EU, and so in this thesis we will focus on analyzing the shocks between these countries. Figure 1 shows the percentage of financial liabilities between countries. For example, Lithuania is commited for Sweden 55 percent. Less than 10 percent for Denmark and less than 5 percent for Finland. The three Baltic States have the bulk of their commitments to Sweden. Lithuania's liabilities are the highest for Sweden, larger than the other Baltic countries. For the other Nordic countries, the share of liabilities is smaller. We can also see that the Nordic countries are closely interlinked.

This paper analyse linkages between European countries using GVAR approach. This method contains an important matrix of weights and that used

Figure 1: Financial liabilities between Baltic and Nordic countries



to indicate financial relationships between the countries in Europe. A GVAR model is a two-step approach. First, the researcher evaluates separate models for each country using domestic and foreign variables. Second, separate models are combined in one system to solve Global VAR model that allows analyzing cross-border spillovers between countries. The first step of analysis is to construct domestic and foreign variables. Foreign variables in this context are determined as a weighted average of corresponding variables of its financial partners. For example, if the variable of interest is credit of country B, then its corresponding foreign variable (foreign credit) is constructed as a weighted average of the credit of its financial partners. Weights usually indicate financial relationships with other countries. In literature, selection of weights matrix varies, we use financial linkages in this analysis for financial stability purposes. In this thesis, the weights are defined as cross-border position liabilities data between countries.

The analysis covers macroeconomic and financial variables for 30 European countries. GVAR model with residuals normality assumption allows analyzing generalized responses. Asymmetric responses of the three Baltic countries

implies different liabilities size. To tackle this issues in the paper we analyzed the shocks to Sweden gross domestic product and also non private credit to households and non financial corporations and the results obtained to all tree Baltic states also for gross domestic products, consumer price index and credit.
The rest of the thesis is structured as follows. The second section reviews the literature on the estimation and dimensionality problem. The third section describes GVAR model framework. The fourth section determines link matrix. The fifth section discusses VECMX and GVAR models estimation and also tests. The Sixth section–generalized impulse response analysis and the last section conclusions.

2. Literature review

Two cross-country spillovers modelling frameworks are often encountered.

1. First, bilateral models are used to analize which countries have the spillover-sender and the spillover-recipient.

2. Second, some papers are set of panel VAR framework, there are spillover-sender and the more than one spillover-recipients.

While bilateral models are easy to impliment, they do not account for higher geographical dimension. Panel VAR can estimate high-dimension, but they do not capture any linkages between coutries. For example, Ioannou (2018) studies shocks in housing prices and credit outside and inside Lithuania, it focusing on Baltic and Nordic countries. The author implemented just each country endogenous variables in panel for impulse response analysis, but no linkages between countries. A GVAR, on contrary, allows the researchers to study relationships between countries and treat as separate subsystems inside global system. As all three Baltic economies are small and relatively open to trade, so in analysis is important to incorporate the size of the economy and trade related linkages as well as the financial linkages as the main of focus of current research.
There are some multilateral developed models for high-dimension modeling that also incorporate trade or financial linkages between countries. The most

prominent work in this field is the Global VAR (GVAR) model originally proposed in Pesaran, Shuermann, and Weiner (2004) that provides a relatively simple and effective way of modelling complex high-dimensional systems such as the global economy. Although the GVAR framework was originally developed for the purpose of credit risk modelling, it soon became clear that there are numerous possibilities for the application of this approach. In our case model applied for financial stability purposes to indentify financial shocks spillovers across countries. The data that is used to make the weight matrix depends on the context of the modelling backround and variables used. Many GVAR studies for financial shocks transmission use financial weights based on cross-border positions data across countries. Galesi and Sgherri (2009) find that cross-border ownership of assets exposes financial institutions such as banks to macroeconomic, financial, and asset price fluctuations in the countries where they hold positions.

Later on, the approach was developed by many other researchers. Pesaran and Smith (2006) showed that VARX* models can be derived as the solution to a dynamic stochastic general equilibrium (DSGE) model where over-identifying long-run theoretical relations can be tested and imposed if acceptable. Similarly, short-run over-identifying theoretical restrictions can be tested and imposed if accepted. The assumption of the weak exogeneity of the foreign variables for the long-run parameters can be tested, where foreign variables can be interpreted as proxies for global factors. Pesaran and Smith (2006) found that impulse response functions from a GVAR model help analysing interdepencies of the countries involved and the transsmision of the shocks across countries. Dees et al. (2007) present the first attempt to implement and test for the long-run restrictions within a GVAR approach. Mauro and Smith (2013) discuss if foreign variables are weakly exogenous. This means that every country can be estimated as single small economy. Due to weak exogeneity, country models can be estimated individually and the number of parameters decrease substantially.

There have been several studies examining the transmission chanels and impact of financial shocks based on financial linkages data between countries. Papers analysing macro-economic and financial sector interactions, use real economy and financial variables. Sun, Heinz, and Ho (2013) analize Europe as regions: West, Nord, Baltic, Central, advanced and other. Impulse and response analysis was performed, injecting negative real and financial shocks

into the system. The authors used trade weights for linkages between countries. Galesi and Sgherri (2009) analyzed also real economy and financial interactions, but they added the USA as base country to model. Linkages was cross-border positions data. They send the USA shocks through the system to analize Europe's responses to those shocks.
In described papers analyzed cross-border transmmision of the shocks across Europe, but Europe divided in regions. Our aim is to focus on Baltic states separately. Galesi and Sgherri (2009) analyzed financial and real economy shocks and used financial linkages. In this thesis we also want identify financial and real economy shocks, so also using financial links between countries. Our main aim is to incorporate global part in this research for Lithuania, Latvia and Estonia.

3. The GVAR approach

A Global VAR is a set of VARX models as shown in Pesaran and Chudik (2014). Each country has specific VARX(p_i, q_i) model, general expression for each country $i = 0, ..., N$:

$$x_{it} = a_{i0} + a_{i1}t + \sum_{j=1}^{q_i} \alpha_{ij} x_{i,t-j} + \sum_{j=0}^{q_i^*} \beta_{ij} x_{i,t-j}^* + \sum_{j=1}^{l_i} \gamma_{ij} d_{t-j} + u_{it} \tag{1}$$

where x_{it} is a $k_i \times 1$ vector of endogenous variables, x_{it}^* a $k_i^* \times 1$ is foreign variables, d_t is vector of global variables, a_{i0} constant, t linear trend and u_{it} is $k_i \times 1$ vector of errors, $u_{it} \sim iid(0, \Sigma_{u,i})$ and α_{ij}, β_{ij}, γ_{ij} are coefficient matrices. The foreign variables in a country's VARX are constructed as weighted averages of other countries' variables. There foreign variables defined:

$$x_{it}^* = \sum_{j=1}^{N} w_{ij} x_{jt} \tag{2}$$

where $w_{ii} = 0$.
Let $z_{i,t} = (x_{i,t}^{'}, x_{i,t}^{*'})^{'}$ be $k_i + k^*$ dimensional vector of domestic and country-specific foreign variables included in the submodel of country i and rewrite:

$$A_{i0} z_{it} = \sum_{j=1}^{p} A_{ij} z_{i,t-j} + \epsilon_{it} \tag{3}$$

where

$$A_{i0} = (I_{k_i}, -\Lambda_{io}), A_{ij} = (\Phi_{ij}, \Lambda_{ij})$$

for $j = 1, 2, ..., p$, $p = max_i(p_i, q_i)$, and define $\Phi_{ij} = 0$ for $j > p_i$, and $\Lambda_{ij} = 0$ for $j > q_i$. Each country-specific model can be writen in error-correction form,

$$\Delta x_{it} = \Lambda_{i0}\Delta x^*_{it} - \Pi_i z_{i,t-1} + \sum_{j=1}^{p} H_{ij}\Delta z_{i,t-1} + \epsilon_{it} \tag{4}$$

where Δ is the first difference operator,

$$\Pi_i = A_{i0} - \sum_{j=1}^{p} A_{ij}$$

and

$$H_{ij} = -(A_{i,j+1} + A_{i,j+2}, ..., A_{i,j+p}).$$

Foreign variables x^*_{it} are treated as weak exogenous variables for the purpose of specific-country models estimating. Econometric theory for estimating VARX(p_i,q_i models with weakly exogenous $I(1)$ regressors have been developed by Harbo (1998) and Pesaran, Shin, and Smith (2000). The assumption of weak exogeneity can be easy tested and typycally not rejected.
The second step of the GVAR framework consists of stacking estimated country-specific models into one large global VAR model.Using the $(k_i + k^*)$ x k dimensional link matrices $W_i = (E'_i, \widetilde{W}'_i)$, where E_i is k x k_i dimensional selection x_{it}, $x_{it} = E'_i x_t$ and $\widetilde{W}'$ is weight matrix for foreign variables construction. Collecting all the domestic variables of all the countries, we create the global vector,

$$x_t = \begin{pmatrix} x_{1t} \\ x_{2t} \\ ... \\ x_{Nt} \end{pmatrix},$$

which is a $k \times 1$ vector containing all endogenous variables, where $k = \sum_{i=1}^{N} k_i$. So we have

$$z_{it} = (x'_{it}, x'^*_{it}) = W_i x_t$$

Rewriting equitions we get

$$A_{i0} W_i x_t = \sum_{j=1}^{p} A_{ij} W_i x_{t-j} + \epsilon_{it}$$

and stacking these models for each country $i = 1, ..., N$, we have

$$G_0 x_t = \sum_{j=1}^{p} G_j x_{t-j} + \epsilon_t \tag{5}$$

where $\epsilon_t = (\epsilon'_{1t}, ..., \epsilon'_{Nt})'$ and

$$G_j = \begin{pmatrix} A_{1,j} W_1 \\ A_{2,j} W_2 \\ ... \\ A_{N,j} W_N \end{pmatrix}.$$

If matrix G_0 is invertible, then by multiplying (5) G_0^{-1} from the left we obtain the GVAR model

$$x_t = \sum_{j=1}^{p} F_j x_{t-j} + G_0^{-1} \epsilon_t \tag{6}$$

where $F_j = G_0^{-1} G_j$ for $j = 1, 2, ..., p$.

4. Data and link matrix

4.1. Data

Data was collected for 30 European countries sampled from 2006 Q1 to 2019 Q2 (see Table 1). Variables description for this analysis can be found in Table 2. Foreign variables are constructed from weight matrix using financial linkages between countries. Link matrix is described below.

4.2. Link matrix

These weights are calculated in this thesis using the cross-border bank exposure data. The financial data use the external positions of international banks as published in the Bank for International Settlements (BIS) locational banking statistics. In this analysis, we use fixed weights based on the average weights for the period 2016Q1–2019Q2. Motivating that last trhee years data claiming that this is one financial cycle. Financial liabilities between countries indicate financial chanells, so this let do impulse response analysis for financial variables which are incorporated in this research. On the other hand, financial linkages are also used for real economy variables impulse response analysis. Finanacial links between countries significantlly increased over last years, so the formulation of the most recent data based matrices helps capturing more accurate links between countries. Link matrix can be found in appendix (Table 10).

Table 1: Countries in the GVAR model

Finland	Denmark	Norway
Sweden	Lithuania	Latvia
Estonia	Poland	Portugal
Spain	Czech Respublic	Hungary
Slovakia	Slovenia	Croatia
Romania	Austria	Belgium
UK	Switzerland	Cyprus
France	Germany	Greece
Ireland	Italy	Luxembourg
Malta	Netherlands	Iceland

Table 2: Variables description

Notation	Variable	Description	Transformation	Source
gdp	Real gross domestic product	Seasonally adjusted	Log	Eurostat
credit	Bank loans to the non-financial private sector	Credit to households and non financial corporations	Log	ECB SDW
inflation	Consumer price index	2015 = 100	Log	Eurostat
interest rate	Long-term interest rates	May be government bond rate or bank lending rate depending on countries	Non	ECB SDW
hpi	House price index	2015 = 100	Log	Eurostat

5. Estimation of the GVAR model

5. 1. Integration

A GVAR approach is based on cointegrating relationships that helps finding short and long run relationships between variables. Pesaran, Shuermann, and Weiner (2004), Dees et al. (2007), and Pesaran, Yamagata, and Smith (2009) showed importance of cointegrating variables in GVAR approach. The initial step in cointegration analysis is to determine the level of integration of the data. In cointegrating theory for GVAR approach variables should be integrated $I(1)$ or stacionary $I(0)$. Firsty, all countries variables were tested for unit roots with Augmented Dickey-Fuller (ADF) test using 5% significance level. In our case almost all domestic and foreign variables for all countries were integrated $I(1)$ i.e. variables diferenced one time were stacionary. Except Croatia, the Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia foreign interest rates are $I(2)$, but left not diferenced. Anyway our analysis focusing on Baltic states and Nordic countries. In literature macroeconomic and financial variables often are integrated first order as in our case. Each country model have 5 domestic and 5 foreign variables,so for 30 countries we tested 300 variables. Statistic can be found in appendix (Table 11-12).

5. 2. Lag order and co-integrating relationships

For each country-specific model estimation we have to find appropriate number of lags. Hence, for each country we have estimated VECMX (p, q) model using co-integrating relationships with weak exogenous foreign variables. For data limitations and estimation we set (q) to one, whilst for edogenous (p) variables lag selection we use Akaike Information Criterion (AIC). Furthermore, we impose a maximum lag order of 2 for p. The results of this information criterion are shown in Table 3.

Pesaran, Shuermann, and Weiner (2004) and Dees et al. (2007) set GVAR framework on co-integration theory. This helps finding out long-run relationships between foreign and domestic variables taking into account that there is stacionary combinations of variables. The number of cointegrating relations was identified using Johansen‘s trace and max eigenvalues statistics. Trace statistics are more powerfull than max eigenvalue in the case of small sample size. In this thesis we conduct the co-integration analysis with a specification of unrestricted intercept in the co-integration relations. The co-integration results are based on trace statistic at the 95% significance level, with critical values from MacKinnon, Haug, and Michelis (1999). Test results are also published in Table 3.

Table 3: Co-integrating relationships and lag order

Country	co-integrating relationships	p	q
Sweden	3	2	1
Denmark	3	1	1
Norway	2	1	1
Finland	4	1	1
Lithuania	3	2	1
Latvia	4	2	1
Estonia	3	2	1
Poland	3	2	1
Portugal	4	2	1
Spain	4	2	1
Czech Respublic	1	2	1
Hungary	3	1	1
Slovakia	3	1	1
Slovenia	3	2	1
Croatia	1	2	1
Romania	1	2	1
Austria	1	2	1
Belgium	2	1	1
UK	3	2	1
Switzerland	1	2	1
Cyprus	5	2	1
France	2	2	1
Germany	3	2	1
Greece	3	2	1
Ireland	2	2	1
Italy	3	2	1
Luxembourg	3	2	1
Malta	5	2	1
Netherlands	4	2	1
Iceland	1	2	1

5. 3. Weak Exogeneity

In GVAR approach an important property is weak exogeneity of the country-specific foreign variables $x^*_{t,i}$. Johansen (1992) and Harbo (1998) described weak exogeneity test importance in model estimation. We test weak exogeneity of the estimated error corection terms in country-specific models for the foreign variables. For each j element of x^*_{ti} in each country i model:

$$\Delta x^*_{it,j} = \mu_{ij} + \sum_{l=1}^{r_i} \gamma_{il,j} ECM^l_{i,t-1} + \sum_{k=1}^{s_i} \varphi_{ik,j} \Delta z_{i,t-k} + \eta_{it,j}$$

where $ECM^l_{i,t-1}$, $l = 1, 2, ..., r_i$ are the estimated error correction terms corresponding to the r_i cointegrating relations found for the i country model and $\Delta z_{i,t-k} = (\Delta x^{'}_{i,t-k}, \Delta x^{'*}_{i,t-k})'$. The test for weak exogeneity is an F test of the hypothesis that jointly $\gamma_{il,j} = 0$, $l = 1, 2, ..., r_i$ in the regression.
Table 4 presents the F-statistics of the weak exogeneity tests. In results we can see that, the weak exogeneity is not rejected with some exceptions. Couple of countries have rejected weak exogeneoty assumption with 5% significance level. For example Czech Respublic, Iceland or Romania, but those countries are not in this analysis focus the impacts on main question of interest will be minimal, so we leave as firstly. In our analysis most important Nordic countries and Baltic states have not rejected weak exogeneity for all foreign variables. Foreign x^*_{it} variables estimated as weak exogenous helps reduce dimensionality.

5. 4. Pair-wise Cross Section Correlations: Variables and Residuals

Other important assumption in GVAR modeling is that the shocks of the individual country models should be cross sectionally weakly correlated, so that $Cov(x^*_{i,t}, u_{i,t}) \longrightarrow 0$, when $N \longrightarrow \infty$ and the weak exogeneity of the foreign variables is guaranteed. Prevously tested weak exogeneity indirectly shows that shocks are weak correlated. In literature is shown that weak exogeinity implies that shocks can be just weak correlated. The same idea is to the cross section dependence test proposed in Pesaran, Shuermann, and Weiner (2004). By the country-specific models independences on weakly exogenous foreign variables, viewed as proxies for the common global factors, it is reasonable to expect that the degree of correlation of the remaining shocks

across countries will be modest. Our aim is to test between variables and residuals cross section correlations.
In our case we tested indepencies between countries, testing the domestic variables and country-specific models residuals average pair-wise correlations. Domestic variables as gdp, credit, hpi, inflation and interest rate levels are tested. Results of average pair-wise correlations of endogenous domestic variables and models residuals can be seen in Table 5 - Table 9. Some coutry-specific models do not have all variables, so in table is shown as –.

Table 4: F Statistics for testing the weak exogeneity of the country-specific foreign variables

Country		gdp^*	$credit^*$	$inflation^*$	$interestrate^*$	hpi^*
Sweden	F(3,39)	0.10	1.19	0.06	2.05	1.01
Denmark	F(1,47)	1.56	1.02	0.48	0.03	0.90
Norway	F(3,44)	0.15	1.46	1.33	2.01	0.88
Finland	F(4,43)	1.82	2.06	0.13	0.66	0.13
Lithuania	F(3,39)	0.56	1.98	0.05	1.13	0.98
Latvia	F(3,44)	2.01	0.56	0.62	0.55	1.87
Estonia	F(2,40)	0.23	1.17	0.03	0.94	2.01
Poland	F(3,41)	1.53	0.18	0.96	0.07	1.02
Portugal	F(4,38)	1.23	1.01	0.19	0.52	0.13
Spain	F(1,43)	1.06	3.05	0.49	0.23	1.03
Czech Respublic	F(1,45)	2.03	0.12	4.31	0.98	1.27
Hungary	F(2,47)	1.59	1.16	0.69	2.05	0.18
Slovakia	F(3,44)	1.76	2.66	0.25	0.06	0.37
Slovenia	F(2,48)	0.58	1.54	0.65	1.15	0.97
Croatia	F(1,49)	0.14	1.37	0.89	1.01	0.55
Romania	F(4,41)	0.09	2.02	1.06	3.21	0.88
Austria	F(2,49)	0.45	1.36	0.86	1.09	1.88
Belgium	F(1,49)	1.13	1.32	0.96	2.97	0.21
UK	F(3,44)	0.85	1.41	1.87	0.15	0.64
Switzerland	F(2,41)	2.22	0.52	0.63	0.78	1.37
Cyprus	F(1,48)	0.05	0.68	1.41	1.58	0.95
France	F(3,42)	0.69	1.29	0.03	2.01	0.76
Germany	F(2,46)	0.55	0.12	1.22	2.07	2.05
Greece	F(3,40)	2.01	0.89	0.68	0.04	1.67
Ireland	F(2,47)	0.55	1.06	1.13	0.56	1.38
Italy	F(1,47)	2.23	0.86	0.03	0.15	1.74
Luxembourg	F(1,48)	0.81	1.44	0.12	0.26	1.06
Malta	F(3,41)	0.56	1.25	0.02	2.06	0.22
Netherlands	F(2, 46)	0.06	1.58	1.24	1.89	0.02
Iceland	F(3,42)	0.39	1.23	3.05	1.84	2.59

Table 5: Average Pair-wise Cross Section Correlations of GDP and Associated Model's Residuals

Country	Levels	Model Residuals
Sweden	0.58	-0.08
Denmark	0.43	-0.07
Norway	0.52	0.03
Finland	0.33	0.00
Lithuania	0.47	-0.04
Latvia	0.26	0.03
Estonia	0.77	0.00
Poland	0.49	0.02
Portugal	0.05	0.00
Spain	0.14	0.01
Czech Respublic	0.50	0.09
Hungary	0.26	0.02
Slovakia	0.43	0.07
Slovenia	0.15	0.08
Croatia	0.17	-0.03
Romania	0.35	0.05
Austria	0.50	0.02
Belgium	0.59	-0.05
UK	0.57	-0.01
Switzerland	0.16	-0.03
Cyprus	0.17	-0.00
France	0.54	-0.01
Germany	0.59	0.02
Greece	-0.01	-0.02
Ireland	0.38	-0.02
Italy	0.04	-0.09
Luxembourg	0.48	-0.06
Malta	0.54	0.04
Netherlands	0.45	0.00
Iceland	-	-

Table 6: Average Pair-wise Cross Section Correlations of HPI and Associated Model's Residuals

Country	Levels	Model Residuals
Sweden	0.59	-0.06
Denmark	0.42	0.04
Norway	0.51	0.02
Finland	0.46	0.01
Lithuania	0.41	-0.05
Latvia	0.29	0.03
Estonia	0.71	0.00
Poland	0.41	0.06
Portugal	-	-
Spain	0.32	0.01
Czech Respublic	-	-
Hungary	-	-
Slovakia	-	-
Slovenia	-	-
Croatia	-	-
Romania	-	-
Austria	-	-
Belgium	0.62	-0.03
UK	0.55	-0.05
Switzerland	-	-
Cyprus	0.04	-0.00
France	0.53	0.01
Germany	0.59	-0.00
Greece	-	-
Ireland	0.11	-0.03
Italy	-	-
Luxembourg	-	-
Malta	0.57	0.02
Netherlands	0.26	0.01
Iceland	-	-

Table 7: Average Pair-wise Cross Section Correlations of Credit and Associated Model's Residuals

Country	Levels	Model Residuals
Sweden	0.59	-0.04
Denmark	-	-
Norway	-	-
Finland	0.47	-0.00
Lithuania	0.56	-0.04
Latvia	0.39	0.00
Estonia	0.78	-0.00
Poland	0.52	0.00
Portugal	0.38	0.00
Spain	0.33	0.00
Czech Respublic	0.52	0.07
Hungary	0.47	0.01
Slovakia	0.45	-0.04
Slovenia	0.40	0.03
Croatia	-	-
Romania	-	-
Austria	0.50	-0.00
Belgium	0.60	-0.06
UK	0.52	0.00
Switzerland	-	-
Cyprus	0.35	-0.00
France	0.53	-0.01
Germany	0.60	0.02
Greece	0.48	-0.01
Ireland	0.37	-0.02
Italy	0.30	-0.11
Luxembourg	0.51	-0.05
Malta	0.58	0.05
Netherlands	0.33	0.00
Iceland	-	-

Table 8: Average Pair-wise Cross Section Correlations of Interest rates and Associated Model's Residuals

Country	Levels	Model Residuals
Sweden	-0.52	0.02
Denmark	-0.23	0.04
Norway	-0.40	-0.02
Finland	-0.40	-0.00
Lithuania	-0.18	0.01
Latvia	-0.04	0.01
Estonia	-	-
Poland	-0.23	0.01
Portugal	0.26	-0.01
Spain	0.20	-0.02
Czech Respublic	-0.30	-0.06
Hungary	-0.22	0.01
Slovakia	-0.27	0.04
Slovenia	0.07	-0.04
Croatia	0.06	0.06
Romania	-0.12	0.03
Austria	-0.42	-0.00
Belgium	-0.49	0.07
UK	-0.46	-0.02
Switzerland	0.01	0.07
Cyprus	0.14	0.01
France	-0.43	0.02
Germany	-0.51	-0.03
Greece	0.40	0.01
Ireland	-0.24	0.03
Italy	0.20	0.10
Luxembourg	-0.38	0.05
Malta	-0.47	-0.02
Netherlands	-0.29	-0.01
Iceland	-0.13	0.09

Table 9: Average Pair-wise Cross Section Correlations of Inflation and Associated Model's Residuals

Country	Levels	Model Residuals
Sweden	0.58	-0.02
Denmark	0.19	-0.07
Norway	0.51	0.01
Finland	0.46	-0.00
Lithuania	0.41	-0.03
Latvia	0.28	0.00
Estonia	0.70	-0.00
Poland	0.49	-0.01
Portugal	0.26	-0.00
Spain	-0.12	0.01
Czech Respublic	0.51	0.06
Hungary	0.44	0.02
Slovakia	0.43	-0.05
Slovenia	0.33	0.02
Croatia	0.12	-0.05
Romania	0.35	-0.06
Austria	0.49	-0.01
Belgium	0.61	-0.09
UK	0.50	0.02
Switzerland	0.39	-0.09
Cyprus	0.30	0.00
France	0.53	-0.02
Germany	0.56	0.02
Greece	0.24	-0.02
Ireland	0.31	-0.01
Italy	0.12	-0.17
Luxembourg	0.49	-0.05
Malta	0.56	0.04
Netherlands	0.33	0.01
Iceland	0.26	-0.09

The average cross section correlations are strong for variables with some exceptions. Endogenous variables like GDP in Nordic and Baltic countries are pretty high, it ranges from 26% to 77%. House price index is also high varies from 29% to 71%, we can see that credit is also high, this varies from 39% to 78%. Variables inflation which varies in Nordic and Baltic from 19% to 70% and interest rates varies from -52% to -4% are exceptions with less correlation. In general cross correlation in GVAR model is significant, but it

depends on which country is analyzed.
Looking in models residuals statistics we can see that cross correlations are really small and do not depend on the choice of the variable or country, this implies countries independencies. This let use easily identiffy each country independent responses to shocks.

6. Generalized Impulse Response Functions

A GVAR model with his high dimesionality and cross-country interactions bring difficulties for identification of shocks across countries. With those difficulties, Pesaran, Shuermann, and Weiner (2004), Pesaran and Smith (2006), Dees et al. (2007) adopted the generalized impulse response function (GIRF) approach, advanced in Koop, Pesaran, and Potter (1996), Pesaran and Shin (1998) and Pesaran and Smith (1998). Unlike the orthogonolized impulses, the generalized impulses are invariant to ordering variables and the countries in the GVAR model—clearly an important consideration. Even if a suitable ordering of the variables in a given country model derives from economic theory or general a priori reasoning, it is not clear how to order countries when applying the orthogonolized impulses to the GVAR model. Dees et al. (2007) provide a way to compute the generalized impulse responses. On the assumption that the error term ϵ_t has a multivariate normal distribution. We will use this assumption in our impulse response analysis.
This GIRF approach does not aim identification of shocks, it gives historical correlations of impulses. Vector $k \times 1$ of GIRFS is given

$$g_{\epsilon,j}(h) = E(X_{t+h}|\epsilon_{j,t} = \sqrt{\sigma_{j,j}}, I_{t-1}) - E(X_{t+h}|I_{t-1}) = \frac{R_h G_0^{-1} \sum e_j}{\sqrt{e_j' \sum e_j}}$$

for $j = 1, 2, ..., k$, $h = 0, 1, 2, ...$, where $\sqrt{\sigma_{j,j}} = \sqrt{E(\epsilon_{j,t}^2)}$ is the size of shock, which is set to one standard deviation (s.d.) of $\epsilon_{j,t}$. The GIRFs can also be obtained for global or country specific shocks, defined by $\epsilon_{m,t}^g = m'\epsilon_t$, where the vector of weights m relates to a global aggregate or a particular country. The vector of GIRF for the global shock, $\epsilon_{m,t}^g$ conditional on

$$g_m(h) = E(X_{t+h}|\epsilon_{m,t}^g = \sqrt{m' \sum m}, I_{t-1}) - E(X_{t+h}|I_{t-1}) = \frac{R_h G_0^{-1} \sum m}{\sqrt{m' \sum m}}$$

Closely related to the impulse–response analysis is the forecast-error variance decomposition, which shows the relative contributions of the shocks to reducing the mean square error of forecasts of individual endogenous variables at a given horizon h. In the case of non-orthogonal shocks, the forecast-error variance decompositions need not sum to unity. Generalized forecast error variance decomposition x_{it} is given by

$$GFEVD(x_{it}, \epsilon_{jt}, h) = \frac{\sigma_{jj}^{-1} \sum_{l=0}^{h} [e_i' F^h G_0^{-1} \sum e_j]^2}{\sum_{l=0}^{h} e_i' F^h G_0^{-1} \sum G_0^{-1'} F^{h'} e_i}$$

In focus of Nordic and Baltic countries will be done impulse response analysis for those countries. Two possible shocks chanells are real economy shock and financial shock, GDP, inflation and HPI impulses for real economy and credit and interest rates for financial impulses analyzed.

6. 1. Real economy shocks

The shock we consider is negative first period shock to gross domestic product in Sweden, it means a 1% decrease in the first quarter. We find how this impulse affect Baltic states. Figure 2 shows the effect of this shock for Lithuania, Latvia and Estonia. The greatest impact is in Lithuania, followed by Estonia. Latvia is not significantly affected by the shock. In thesis we use financial liabilities data for weight matrix which shown Latvia's lower connection with Sweden than other two: Lithuania and Estonia. One percent negative impulse in Sweden implies about two percent effect for gross domestic product in Lithuania and about 1.5 percent in Estonia possible response.

Same negative shock to gross domestic product in Sweden. Real economy variable inflation responses of Baltic countries are shown in figure 3. This analysis shown that inflation has positive responses for Baltic countries. Consumer prices increase after shock less than one percent. Sweden inflation one positive percent shock responses to Baltic countries are shown in figure 4. All three countries response negatively about 0.5 but then reverts back to zero.

Figure 2: Baltic states gross domestic product responses to negative Sweden gross domestic product impulse

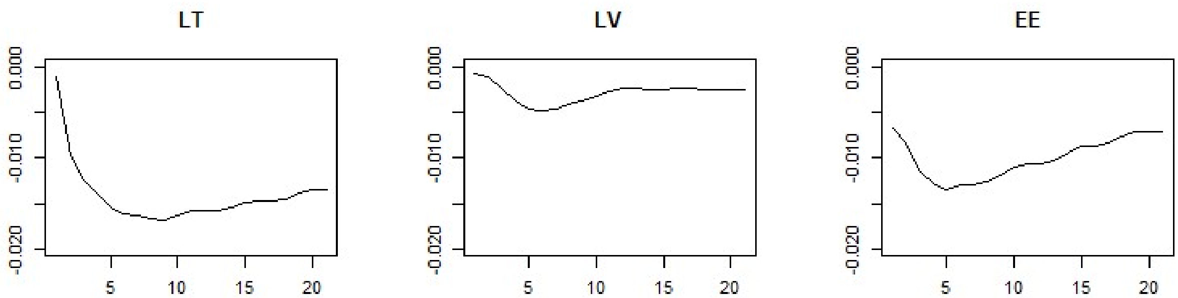


Figure 3: Baltic states inflation responses to negative Sweden gross domestic product impulse

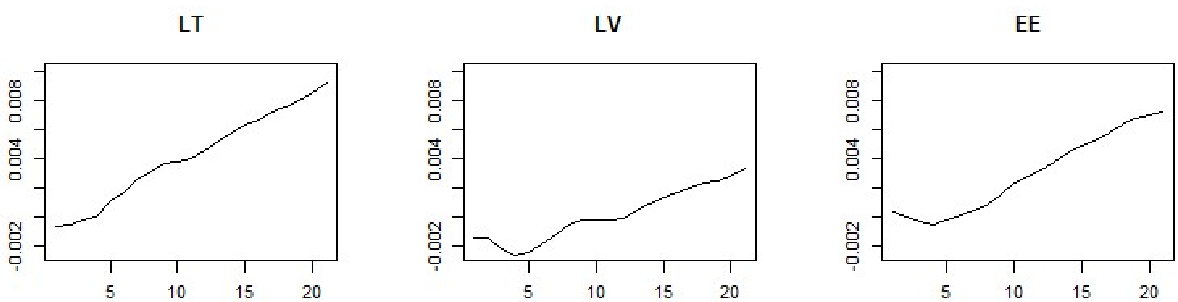
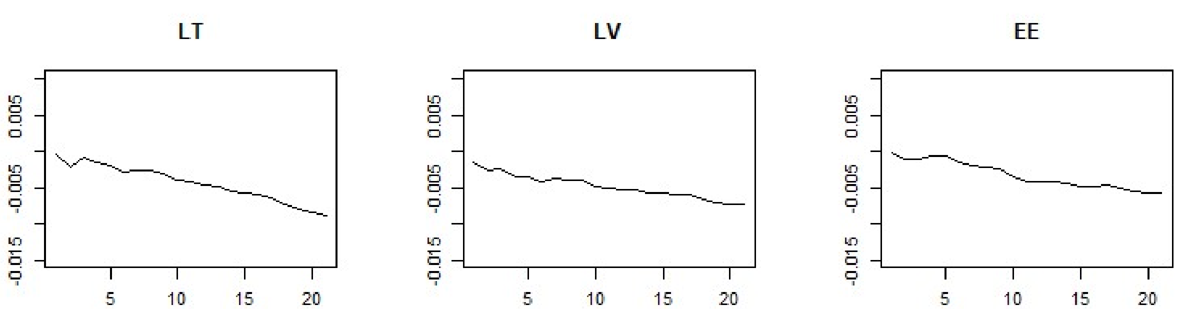


Figure 4: Baltic states inflation responses to positive Sweden inflation impulse



6. 2. Financial shocks

The second shock we consider is financial shock to non private credit to households and non financial corporations in Sweden. This impulse one percent negative shock responses for Lithuania, Latvia and Estonia are shown in figure 5. All three countries response negatively. Effect is the gretest in Lithuania about 4 percent. In Estonia effect is less 2 percent and in Latvia just 1 percent negative response from credit impulse in Sweden. Interest rates positive impulse for Sweden and responses for Baltic countries is shown in figure 6. Interest rates have positive effect from results can conclude that Lithuania respond more than Latvia.

Figure 5: Baltic states credit responses to negative Sweden credit impulse

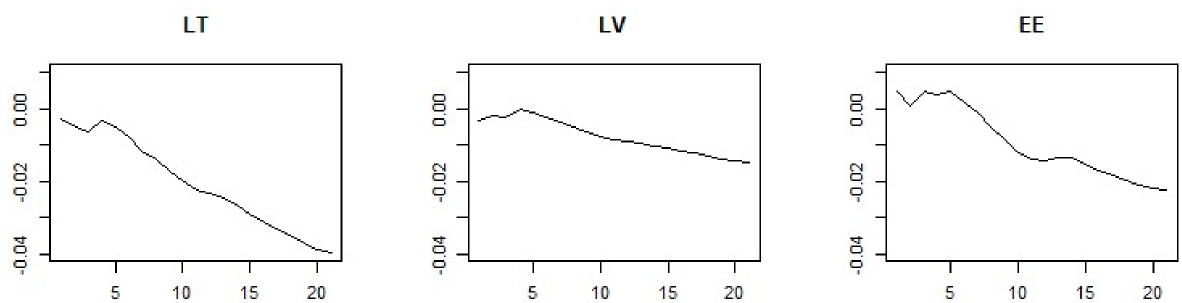
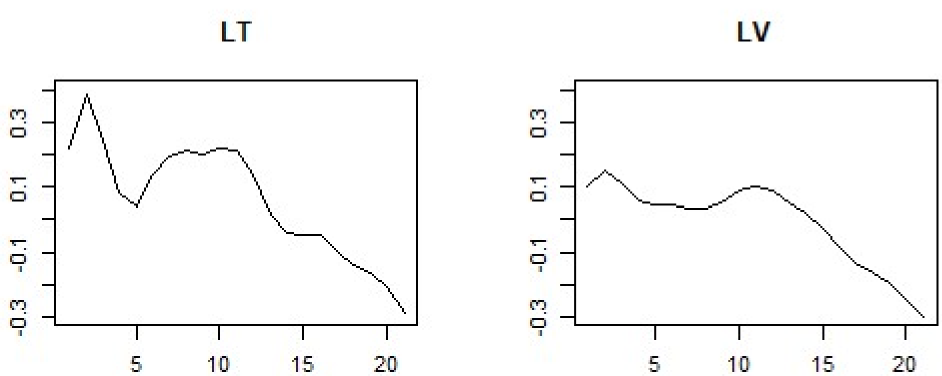


Figure 6: Baltic states interest rates responses to positive Sweden interest rates impulse



7. Conclusions

Greater global financial integration and increasing cross-border liabilities between countries arises higher posibility to financial and real economic imbalances. We tested the mutual dependence of the financial system in the Baltic countries on the situation in Nordic countries taking into account other members of the EU. Cross-border bank exposure data of Baltic and Nordic countries shows relationships among these countries. Baltic states are quite dependent on the Nordic countries. Sweden accounts for more than half of Lithuania's liabilities 55 percent followed Estonia with 40 percent and Latvia 20 percent.

This thesis showed that greater liabilities implies greater responses to shocks. Lithuania react more to Sweden financial and real economic shocks than other Baltic countries. Baltic countries most react to Sweden negative financial shock to non private credic followed gross domestic product real economic shock.

From a financial stability analysis perspective, a number of interesting results emerge. Impulse response analysis show that financial and real economic shocks are transmitted relatively quicly in Baltic states.

The GVAR modelling framework employed in this paper presents a reasonable and manageable spatio-temporal structure for the analysis of the Nordic transmission of financial and real economic shocks and second-round effects, which can be easily modified and extended further according to financial stability interests. This method let analyse independentlly responses for each country incorporating global part and taking into account other members of the EU.

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Table 10: Link matrix

Countries	SE	DK	NO	FI	LT	LV	EE	PL	PT	ES	CZ	HU	SK	SI	HR	RO	AT	BE	GB	CH	CY	FR	DE	GR	IE	IT	LU	MT	NL	IS
SE	0.00	0.22	0	0.43	0	0	0	0	0	0.00	0	0	0	0	0	0	0.00	0.01	0.15	0.01	0	0.04	0.07	0.00	0.00	0.00	0.02	0	0.04	0
DK	0.45	0.00	0	0.11	0	0	0	0	0	0.00	0	0	0	0	0	0	0.00	0.01	0.10	0.00	0	0.10	0.18	0.00	0.01	0.00	0.01	0	0.02	0
NO	0.15	0.14	0	0.24	0	0	0	0	0	0.00	0	0	0	0	0	0	0.00	0.01	0.30	0.01	0	0.08	0.04	0.00	0.01	0.01	0.01	0	0.01	0
FI	0.42	0.19	0	0.00	0	0	0	0	0	0.00	0	0	0	0	0	0	0.01	0.03	0.17	0.01	0	0.08	0.03	0.00	0.00	0.01	0.01	0	0.03	0
LT	0.56	0.09	0	0.02	0	0	0	0	0	0.01	0	0	0	0	0	0	0.01	0.01	0.07	0.05	0	0.09	0.04	0.00	0.00	0.00	0.04	0	0.00	0
LV	0.20	0.06	0	0.00	0	0	0	0	0	0.01	0	0	0	0	0	0	0.12	0.05	0.16	0.11	0	0.11	0.12	0.00	0.00	0.00	0.05	0	0.01	0
EE	0.41	0.11	0	0.10	0	0	0	0	0	0.02	0	0	0	0	0	0	0.05	0.01	0.02	0.08	0	0.12	0.04	0.00	0.00	0.00	0.03	0	0.01	0
PL	0.02	0.03	0	0.00	0	0	0	0	0	0.06	0	0	0	0	0	0	0.04	0.07	0.42	0.08	0	0.09	0.09	0.00	0.01	0.01	0.02	0	0.05	0
PT	0.01	0.01	0	0.00	0	0	0	0	0	0.29	0	0	0	0	0	0	0.01	0.03	0.20	0.09	0	0.22	0.04	0.00	0.01	0.01	0.06	0	0.04	0
ES	0.00	0.01	0	0.00	0	0	0	0	0	0.00	0	0	0	0	0	0	0.01	0.05	0.25	0.07	0	0.35	0.08	0.00	0.02	0.12	0.03	0	0.01	0
CZ	0.00	0.11	0	0.00	0	0	0	0	0	0.00	0	0	0	0	0	0	0.24	0.06	0.13	0.12	0	0.13	0.16	0.00	0.02	0.01	0.01	0	0.00	0
HU	0.00	0.02	0	0.00	0	0	0	0	0	0.02	0	0	0	0	0	0	0.22	0.16	0.14	0.06	0	0.08	0.11	0.00	0.03	0.14	0.01	0	0.00	0
SK	0.00	0.02	0	0.00	0	0	0	0	0	0.00	0	0	0	0	0	0	0.26	0.01	0.27	0.05	0	0.22	0.06	0.00	0.04	0.03	0.02	0	0.00	0
SI	0.00	0.01	0	0.00	0	0	0	0	0	0.01	0	0	0	0	0	0	0.26	0.02	0.16	0.03	0	0.25	0.18	0.00	0.00	0.03	0.01	0	0.04	0
HR	0.01	0.00	0	0.01	0	0	0	0	0	0.02	0	0	0	0	0	0	0.17	0.09	0.13	0.07	0	0.14	0.26	0.00	0.00	0.08	0.01	0	0.02	0
RO	0.00	0.01	0	0.00	0	0	0	0	0	0.02	0	0	0	0	0	0	0.24	0.04	0.12	0.09	0	0.05	0.14	0.10	0.01	0.16	0.02	0	0.00	0
AT	0.00	0.03	0	0.00	0	0	0	0	0	0.02	0	0	0	0	0	0	0.00	0.01	0.13	0.10	0	0.24	0.36	0.00	0.00	0.05	0.01	0	0.03	0
BE	0.00	0.00	0	0.22	0	0	0	0	0	0.01	0	0	0	0	0	0	0.00	0.00	0.16	0.03	0	0.21	0.09	0.00	0.02	0.02	0.03	0	0.19	0
GB	0.03	0.02	0	0.01	0	0	0	0	0	0.04	0	0	0	0	0	0	0.01	0.05	0.00	0.10	0	0.27	0.17	0.01	0.05	0.06	0.02	0	0.16	0
CH	0.01	0.02	0	0.01	0	0	0	0	0	0.01	0	0	0	0	0	0	0.01	0.02	0.40	0.00	0	0.20	0.12	0.00	0.01	0.01	0.11	0	0.07	0
CY	0.01	0.00	0	0.00	0	0	0	0	0	0.00	0	0	0	0	0	0	0.04	0.02	0.21	0.41	0	0.05	0.05	0.10	0.00	0.00	0.08	0	0.02	0
FR	0.01	0.01	0	0.01	0	0	0	0	0	0.12	0	0	0	0	0	0	0.01	0.08	0.28	0.07	0	0.00	0.08	0.00	0.04	0.14	0.08	0	0.07	0
DE	0.01	0.01	0	0.01	0	0	0	0	0	0.05	0	0	0	0	0	0	0.06	0.02	0.28	0.05	0	0.24	0.00	0.00	0.03	0.05	0.09	0	0.09	0
GR	0.00	0.00	0	0.00	0	0	0	0	0	0.01	0	0	0	0	0	0	0.01	0.02	0.43	0.19	0	0.07	0.15	0.00	0.01	0.01	0.08	0	0.02	0
IE	0.01	0.01	0	0.00	0	0	0	0	0	0.01	0	0	0	0	0	0	0.00	0.05	0.49	0.01	0	0.20	0.03	0.00	0.00	0.06	0.03	0	0.08	0
IT	0.00	0.00	0	0.00	0	0	0	0	0	0.04	0	0	0	0	0	0	0.01	0.02	0.24	0.07	0	0.40	0.10	0.00	0.06	0.00	0.05	0	0.00	0
LU	0.02	0.00	0	0.00	0	0	0	0	0	0.01	0	0	0	0	0	0	0.02	0.06	0.16	0.05	0	0.44	0.14	0.00	0.01	0.06	0.00	0	0.03	0
MT	0.02	0.01	0	0.00	0	0	0	0	0	0.02	0	0	0	0	0	0	0.05	0.04	0.19	0.28	0	0.14	0.06	0.01	0.01	0.02	0.12	0	0.04	0
NL	0.01	0.00	0	0.01	0	0	0	0	0	0.03	0	0	0	0	0	0	0.00	0.11	0.39	0.02	0	0.24	0.10	0.00	0.06	0.02	0.02	0	0.00	0
IS	0.06	0.08	0	0.00	0	0	0	0	0	0.01	0	0	0	0	0	0	0.00	0.07	0.56	0.03	0	0.06	0.07	0.00	0.02	0.00	0.03	0	0.00	0

Table 11: Unit Root Tests for the Domestic Variables p-values

Country	gdp	hpi	credit	interest rate	cpi
Sweden	0.99	0.99	0.99	0.15	0.99
Denmark	0.98		0.92	0.13	0.99
Norway	0.99		0.99	0.24	0.99
Finland	0.92	0.99	0.99	0.13	0.99
Lithuania	0.90	0.94	0.25	0.30	0.99
Latvia	0.96	0.91	0.70	0.41	0.99
Estonia	0.97	0.93	0.99		0.41
Poland	0.99	0.77	0.99	0.31	0.86
Portugal	0.95		0.75	0.42	0.99
Spain	0.99	0.58	0.68	0.34	0.99
Czech Respublic	0.98		0.99	0.32	0.51
Hungary	0.96		0.99	0.85	0.99
Slovakia	0.94		0.99	0.26	0.99
Slovenia	0.90		0.98	0.33	0.16
Croatia	0.93			0.42	0.15
Romania	0.94			0.38	0.80
Austria	0.96		0.63	0.15	0.77
Belgium	0.72	0.23	0.12	0.84	0.65
UK	0.94	0.82	0.55	0.81	0.29
Switzerland	0.74			0.15	0.89
Cyprus	0.97	0.77	0.69	0.39	0.21
France	0.99	0.81	0.83	0.93	0.56
Germany	0.90	0.99	0.99	0.22	0.70
Greece	0.11		0.87	0.43	0.98
Ireland	0.99	0.56	0.95	0.37	0.98
Italy	0.53		0.42	0.44	0.99
Luxembourg	0.35		0.34	0.99	0.38
Malta	0.87	0.12	0.99	0.76	0.99
Netherlands	0.85	0.12	0.78	0.11	0.75
Iceland	0.99			0.47	0.41

Table 12: Unit Root Tests for the Foreign Variables p-values

Country	gdp*	hpi*	credit*	interest rate*	cpi*
Sweden	0.99	0.99	0.11	0.99	0.99
Denmark	0.99		0.99	0.12	0.99
Norway	0.99		0.99	0.11	0.99
Finland	0.95	0.22	0.12	0.54	0.76
Lithuania	0.98	0.90	0.60	0.13	0.99
Latvia	0.93	0.99	0.15	0.12	0.99
Estonia	0.99	0.80	0.34		0.49
Poland	0.99	0.86	0.45	0.11	0.99
Portugal	0.92		0.99	0.17	0.99
Spain	0.96	0.99	0.28	0.14	0.48
Czech Respublic	0.99		0.74	0.12	0.54
Hungary	0.87		0.99	0.16	0.55
Slovakia	0.86		0.46	0.13	0.66
Slovenia	0.90		0.55	0.12	0.58
Croatia	0.97			0.93	0.57
Romania	0.98			0.27	0.49
Austria	0.97		0.84	0.92	0.52
Belgium	0.98	0.91	0.11	0.93	0.48
UK	0.99	0.99	0.53	0.88	0.56
Switzerland	0.96			0.13	0.44
Cyprus	0.97	0.95	0.12	0.16	0.39
France	0.91	0.86	0.98	0.17	0.47
Germany	0.99	0.23	0.99	0.99	0.47
Greece	0.99		0.51	0.91	0.43
Ireland	0.99	0.96	0.41	0.12	0.44
Italy	0.41		0.15	0.46	0.99
Luxembourg	0.91		0.15	0.95	0.99
Malta	0.88	0.99	0.11	0.99	0.99
Netherlands	0.36	0.97	0.12	0.99	0.99
Iceland	0.99			0.36	0.98