Bachelor Thesis

The effects of oil supply and demand shocks on the Baltic economies: results from a global VAR model

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Abstract

We examine the economic consequences of oil supply and demand shocks on the Baltic States. The paper uses the global VAR to build the global economy model that allows capturing both direct and indirect effects of shocks. We identify the shocks of interest by the means of short-run sign restrictions. We demonstrate that the fundamental driver of the price shock is essential to determine its economic consequences. The results reveal that all Baltic States experience sizeable short-term growth in output in response to the demand shock and short-term fall in output in response to the supply shock.

Introduction

The relationship between oil price shocks and economic activity has compelled public attention since the aftermath of the recessions of the 1970s preceded by an unprecedented surge in oil prices. After Hamilton’s (1983) seminal paper where he argued that all but one of the US slowdowns were predated by oil price escalations the topic received the attention few ever see.

One of the most popular areas of research has been focused on how macroeconomic variables are affected by exogenous oil price shocks. By definition, this implicitly assumes that we can trace out the effect that comes from an oil price change, since other variables are kept constant. Until the beginning of 2000s it was a widely accepted view that oil price shocks are purely driven by exogenous supply-side forces, such as the conflicts in the Middle East, which justified the ceteris paribus assumption. The opinion about the supply-driven nature of oil prices was first challenged in the paper by Barsky and Kilian (2002), where they demonstrated that not only the demand also played its part in price changes, but also that oil price cannot be treated as an exogenous variable anymore. These findings, in turn, spurred a completely new area of research – the analysis of how differently economies are affected by supply and demand shocks. Kilian (2009) played the leading role here as well by proposing the method to assess the effects of supply- and demand-driven shocks in a monthly single-country VAR setup. A significant push for further research originated from the field of econometrics – Rubio-Ramirez, Waggoner, and Zha (2010) developed a coherent sign restrictions approach that has gained widespread popularity in structural VAR research. The sign restriction approach, however, is often criticized for inability to identify shocks in a correct manner. This problem can be solved, as was argued by Chudik and Fidora (2011), by using large-dimensional models, since they allow imposing a sizeable number of sign restrictions.

Despite the fact that the topic has received much attention for several decades and has come through significant challenges and improvements, limited evidence is available on the developing countries. This is especially surprising given that most of these countries are net-importers and therefore, by intuition, should be negatively affected by the adverse price movements.

Since the Baltic States are small open economies, they are highly dependent on the stance of global economy and its major trading partners. Furthermore, given our close ties with Russian oil price-dependent economy, we can expect to have indirect effects, apart from direct ones, stemming from the oil price changes.

Therefore, in this paper we estimate the effects of oil supply and demand shocks on the Baltic economies by the means of sign restrictions in the global VAR model. The choice of the model is motivated by existing empirical literature in two ways. First, disentanglement of supply and demand shocks is relatively complicated and there is simply no other way, apart from sign restrictions, which can identify these shocks. Second, existing literature provides evidence that energy-importing countries can have positive indirect effects and therefore one should use a global model that allows for interrelations between the countries.

Research question of the paper is formulated as follows:

How the Baltic economies are affected by supply- and demand-driven oil price shocks?

Literature review

This literature review is split into four parts. Firstly, we will present a brief historical overview of oil shocks. Secondly, the existing literature on the relationship between oil price changes/volatility and economic activity will be examined. Then the authors will discuss the main transmission channels through which oil price changes affect main macroeconomic variables. Finally, we will proceed with the overview of existing research on the topic and discuss the methods that have been employed to answer the research question of the paper.

Historical overview of oil shocks

Chuku (2012) defines oil price shock as unexpected change in level of oil prices, caused by some external factors, which is likely to have a bearing on endogenous economic variables. Hamilton (2011) points out that most of the oil shocks over the last several decades were associated with conflicts in the Middle East. The most notable events that caused supply imbalances are summarized in Table 1.

Table 1. Major oil events

Time	Event
October 1956	Suez crisis
October 1973	Ramadan War
October 1973	OAPEC oil embargo
October 1978	Islamic Revolution
September 1980	Iran-Iraq War
August 1990	Gulf War
December 2002	Political unrest in Venezuela
March 2003	Invasion of Iraq
December 2010	The Arab Spring
December 2014	OPEC overproduction

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Hamilton (2011) estimates that global supply cut caused by Ramadan War together with OAPEC embargo was equal to 7 percent, Islamic revolution and Iran-Iraq War each resulted in global supply cut of 4 percent, Gulf War and Venezuelan unrest are responsible for 6 and 2 percent slump in global supply respectively. However, there also were other forces that caused the price run-up, apart from geopolitical disruptions, such as high demand from newly industrialized countries. Hamilton (2009) concludes that falling global production together with increasing demand, growing consumption, and speculation were the main drivers of the oil shock of 2007-08.

Oil price volatility effects

Guo and Kliesen (2005) show that oil price volatility might suspend investment because of increased uncertainty (see also Bernanke (1983)) as well as cause costly resource reallocation across sectors - from more vulnerable and therefore more insecure sectors to the ones that are less affected by adverse price movements. They conclude that oil price volatility significantly harms growth in output and has negative effect on other macroeconomic variables (see also

Elder and Serletis (2010); Ferderer (1996)). Ebrahim, Inderwildi, and King (2014) find that oil price volatility might have detrimental effect on economic activity and that, in turn, reduces economic growth in future periods. Plante and Traum (n.d.) estimate stochastic volatility of oil price and document decline in durable spending, increase in investment, as a result of more savings, and real output in response to increase in volatility. However, the results of Plane and Traum should be taken with caution since it has been shown that investment can actually go down when it is irreversible (Bloom, 2009). Henriques and Sadorsky (2011) used real options to show that oil price volatility deters strategic investment. Jo (2014) finds that oil price uncertainty has destructive effect on world industrial production and consequently on global economic output. Rentschler (2013) analysed small set of developed and developing economies and found that oil price volatility has adverse effect on economic growth in both sets of countries.

Oil price shock effects

Very close attention has been paid to the topic since Hamilton's (1983) ground-breaking paper where he argues that climbing oil price was at least in part responsible for all but one post-WW2 recessions in US. Since then researchers have divided over controversy – while some believe that oil price is a significant factor that affects economic activity, others claim that the commodity has lost its might over economies.

A significant amount of literature supports the notion that oil price shocks have a significant effect on economic activity and macroeconomic variables. Jones and Paik (2004) demonstrate negative elasticity of US aggregate output to oil price. Jiménez-Rodríguez and Sánchez (2005) find non-linear impact of oil prices on economic output in the OECD countries. They provide evidence that an increase in oil price has significant effect on economic activity, while the opposite price movement has no statistically meaningful effect. As prices go up, all oil importers in their sample, except for Japan, experience a slowdown in economic activity. Gelos and Ustyugova (2012) show that economies with relatively larger shares of fuel intensities in consumption baskets and preceding inflation levels were encountering more severe inflationary pressure as a result of increase in oil prices. Feldkircher (2014) reports negative reaction of economic output in CEE countries to adverse oil price movement. He shows that trade linkages can play a significant role, since net energy-importing countries can reap benefits from close ties with economies that are highly dependent on oil revenues. Filis and Chatziantoniou (2013) document that: (i) increase in oil prices puts inflationary pressure on both oil-exporting and oil-importing countries; (ii) stock markets of oil importers react negatively to oil price shock and the opposite is true for oil exporters.

Contrarian view that oil has lost its power over time also has a handful of supporters. According to de Souza (2015) oil price changes since the mid-1980s have had a limited effect on global output. Rasmussen and Roitman (2011) document miniscule elasticity for oil-importing countries – 25 percent increase in oil price diminishes aggregate output by half a percent or even less. Belke and Dreger (n.d.) show that economic growth in MENA region is not affected by oil price changes. Some of the opponents argue that energy share in value added has been decreasing since 1970s and therefore has no significant effect on economies, but Edelstein and Kilian (2007) estimate that this share in 2005 was at the same level as in 1977.

Oil supply and demand shock effects

Until the early 2000s it was an accepted view that oil prices are purely driven by changes in global production. This view was challenged in revolutionary papers by Barsky et al. (2002, 2004) where they managed to show that demand conditions also play significant role in determination of oil price. Moreover, Kilian (2008) further argued that demand shocks have much more considerable effect on oil prices than supply disruptions. Since then, a significant amount of literature was published with an attempt to disentangle the underlying sources behind oil price changes – whether these are driven by a shift in demand or supply of the commodity. Quite expectedly, these findings opened up a discussion about how differently economies are affected by oil supply and demand shocks. All existing research on the topic was conducted by the means of sign restrictions imposed on VAR models. Peersman and Van Robays (2012) employ sign restrictions in SVAR to differentiate between three fundamental reasons that can lead to increase in the level of oil prices: (i) oil supply disruption; (ii) growth in demand for oil driven by economic activity; (iii) increase in demand due to any other reasons (e.g. fear that price will go up because of speculations or anxiety about availability of supply of the commodity in future). They document that effects on macroeconomic variables strongly depend on the fundamental driver behind the price change. Most net oil importers experience fall in economic output and increase in inflation, however, energy-exporting countries see growth in economic activity and no inflationary pressure due to negative supply shock. On the other hand, demand shock results in short-run increase in economic activity and higher inflation in all the countries in the sample. Cashin, Mohaddes, Raissi, and Raissi (2014) document that economic output and inflation of oil-exporting and oil-importing countries react differently to supply-driven oil price shock. Baumeister, Peersman, and Van Robays (2010) analysed a sample of industrialized countries and found that negative supply shock results in a fall in output of net importers, however, the effect for net exporters in most cases is insignificant. Kilian (2008) provides evidence that supply shocks in 1973-1974 and 2002-2003 did not have significant effect on economic activity, but supply shocks in 1978-1980 and 1990-1991 lead to stagflation in the G7 countries. Güntner (2013) used Kilian's methodology and found that negative supply shock has no significant effect on stock markets in developed countries.

Transmission channels

As mentioned above, general consensus is that oil price has a significant effect on economies. Tang, Wu, and Xiang Zhang (2010) discuss main transmission channels identified in empirical research: 1) supply-side shock; 2) inflation effect; 3) wealth transfer effect; 4) sector adjustment effect; 5) real balance effect; 6) the unexpected effect. Each is now discussed in more detail:

1) Supply side shock. This theory is based on the presumption that oil is a significant production factor. Increase in oil prices boosts production costs and lowers productivity. That, in turn, damages potential growth in output and increases unemployment (see Barro (1994); Rasche and Tatom (1981)). This is typical for oil-importing countries. On the other hand, higher revenues in oil-exporting countries can induce investment, which will put upward pressure on output and employment.
2) Inflation effect. Since oil price shock affects production costs we can think of it as a simple price shock, which triggers inflation. Furthermore, increase in oil price has direct effect on inflation, since fuel is a part of commonly used inflation indices.
3) Wealth transfer effect. Wealth is transferred from oil-importing countries to oil-exporting countries; worsening terms of trade of the former (see Dohner (1981)). Transfer of purchasing power from oil importers to oil exporters reduces consumer demand in the former and increases in the latter.
4) Real balance effect. Increase in oil prices will inevitably increase nominal money demand due to inflationary pressures (Pierce, Enzler, Fand, & Gordon, 1974). If the Central Bank will fail to react by increasing money supply, interest rates will go up and demand for cash will fall, deteriorating economic growth.
5) Sector adjustment effect. Industries should adjust to change in oil price. This adjustment comes at a cost, which results in a slowdown. Consequently, the oil-intensive industries

will be depressed, while the industries that are oil-free or use oil efficiently will be better off.

6) The unexpected effect. The uncertainty channel affects investment, since consumers and producers are not certain about future price movements. This causes investment demand to go down.

Schneider (2004) proposes three more general channels through which oil affects macroeconomic variables: 1) supply side effect; 2) demand side effect; 3) terms of trade effect. Supply side channel works the same way as was described in Tang et al. (2009). Demand is negatively affected by lower income due to higher oil prices. These channels are mostly typical for net oil importers, since oil-rich countries traditionally benefit because of higher oil revenues. Worsening terms of trade produce loss in welfare because of higher import prices.

Novelty of the paper and contribution to the existing literature

As mentioned before, most attention of existing research has been paid to developed countries and limited research has been carried out on emerging economies. To our best knowledge, the topic of how the Baltics are affected by oil supply and demand shocks has not been touched upon. Furthermore, global VAR has not yet been widely utilized to differentiate between supply and demand shocks for commodities. In existing literature structural VAR (SVAR) is the most popular method. Utilization of these models, however, is constrained, since it is not possible to apply these models to the global setting because of the problem that is often referred to as curse of dimensionality (Chudik & Pesaran, 2014). This means that these frameworks like most of the VAR models cannot be solved for large numbers of cross-sectional units as there are too many parameters to be estimated. GVAR solves the problem of dimensionality by breaking down large VARs into a smaller number of conditional models that are interrelated via cross-sectional weighted averages. Furthermore, GVAR allows capturing trading interrelationships in a concise manner, which is beneficial in the Baltic context because of the close ties with Russian oil price-driven economy. Another contribution is the development of a global macro model for the Baltics that can be used in future research to see how the Baltic States can be affected by different global or country-specific shocks.

Methodology

The GVAR model

In this paper we employed the GVAR model proposed by Pesaran, Schuermann, and Weiner (2004). The model was developed in the wake of the Asian financial crisis to assess the credit risk of financial institutions. The crisis raised concerns about possible global economic meltdown; hence, a consistent global model was needed to measure the potential losses of the banking sector (Chudik et al., 2014). Since then the approach has considerably evolved and gained widespread interest since it allows modelling international linkages of countries in a single global model with relative ease and in a coherent way. It does so by linking individual country VARX* models, where X* is a country-specific foreign variable vector, with each other (Bettendorf, 2012).

The construction of the GVAR is performed in two stages. We start with estimation of the country-specific VARX* models with domestic, foreign, and global variables. Foreign variables are calculated as weighted averages of the domestic counterparts of all other countries. Weights can differ, depending on application of the model. The convention has been to use trade figures when macroeconomic data is used, however, alternatives might include equity and debt positions, direct investment positions, or international banking claims, among others (Gross, 2013). In the second stage, the country-specific models are assembled and solved simultaneously in one large system (GVAR). The model then can be used for impulse response analysis or forecasting purposes. Before the methodology is explained in more detail, we discuss the collected data and performed transformations. To build and solve the model we use the toolbox developed by Galesi & Smith. The basic procedures are discussed in the following sections.

Data and variables

Our dataset is comprised of the main macroeconomic aggregates over the period 1999Q2-2013Q4 and covers the world's largest economies in terms of economic output and international trade, key oil producers, the Baltic States, and their main trading partners, which gives us 30 countries overall that cover approximately 70% of world GDP. 17 countries are aggregated into 2 regions: Gulf Cooperation Council and Eurozone. Thus, effectively we have 15 country models in total. The full country coverage is provided in Table 2.

Table 2. Selected countries

Exporters	*Oil importers*	
GCC	**Eurozone group**	**Other importers**
Bahrain	*Austria*	*China*
Kuwait	*Belgium*	*Estonia*
Oman	*Finland*	*India*
Qatar	*France*	*Japan*
Saudi Arabia	*Germany*	*Latvia*
UAE	*Greece*	*Lithuania*
	Ireland	*Poland*
Other exporters	*Italy*	*Sweden*
Denmark	*Netherlands*	*US*
Norway	*Portugal*	
Russia	*Spain*	
UK		

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We included five domestic variables in our model that can help answering our research question and are used the most in macroeconomic applications in existing GVAR literature (see, for instance, Dees, Di Mauro, Pesaran, and Smith (2007); Pesaran et al. (2004)). These variables are real GDP, inflation rate, short- and long-term interest rates, and real equity price. To collect the data we relied on International Financial Statistics (IFS) database. More detailed description of the data can be found in Data Appendix 1. Since the data have quarterly frequency, we adjusted inflation and GDP series for seasonality using X-12-ARIMA Seasonal Adjustment Program developed by US Census Bureau.

To get the domestic variables, the data is transformed as:

$$y_{it} = \ln(RGDP_{it})$$

$$\Delta p_{it} = p_{it} - p_{i,t-1},\ p_{it} = \ln(CPI_{it})$$

$$r_{it}^{S} = 0.25\ln(1 + R_{it}^{S}/100)$$

$$r_{it}^{L} = 0.25\ln(1 + R_{it}^{L}/100)$$

$$eq_{it} = \ln(EQ_{it}/CPI_{it})$$

where $RGDP_{it}$ is real Gross Domestic Product, CPI_{it} is Consumer Price Index, R_{it}^{S} is short-term rate, R_{it}^{L} is long-term rate, and EQ_{it} is nominal Stock Market Index. The domestic variables for the regions are calculated as weighted averages of the country-specific domestic variables included in the region using average Purchasing Power Parity GDP weights for the period 2011-2013. Pesaran et al. (2004) claim that for this transformation PPP-weighted GDPs are more reliable than dollar-denominated GDPs. Annual PPP-GDP figures were retrieved from the World Bank database. Transformation looks as follows:

$$y_{it} = \sum_{l=1}^{N_i} w_{il}^0 y_{ilt}\,, \qquad \Delta p_{it} = \sum_{l=1}^{N_i} w_{il}^0 \Delta p_{ilt}$$

$$r_{it}^S = \sum_{l=1}^{N_i} w_{il}^0 r_{ilt}^S\,, \qquad r_{it}^L = \sum_{l=1}^{N_i} w_{il}^0 r_{ilt}^L\,, \qquad eq_{it} = \sum_{l=1}^{N_i} w_{il}^0 eq_{ilt}$$

where w_{il}^0 is the weight of country l in region i.

Each domestic variable in our model has a corresponding foreign variable; therefore, we have 5 foreign variables in total. The foreign variables are calculated as cross-sectional weighted averages of domestic variables in all other countries:

$$y_{it}^* = \sum_{j}^{N} w_{i,j} * y_{jt}, \qquad \Delta p_{it}^* = \sum_{j}^{N} w_{i,j} * \Delta p_{jt},$$

$$r_{it}^{S*} = \sum_{j}^{N} w_{i,j} * r_{jt}^S, \qquad r_{it}^{L*} = \sum_{j}^{N} w_{i,j} * r_{jt}^L, \qquad eq_{it}^* = \sum_{j}^{N} w_{i,j} * eq_{jt}$$

where $w_{i,j}$ is the trade weight, i is the country index, and j is the index of trading partner. We used Direction of Trade Statistics (DOTS) database to collect the data on exports and imports in order to construct the trade weights. We followed standard GVAR approach (see, for, instance, Dees et al. (2007)) and constructed the trade weight matrix using average of weights for the period 2011-2013:

$$w_{ij} = \frac{T_{ij2011} + T_{ij2012} + T_{ij2013}}{T_{i2011} + T_{i2012} + T_{i2013}}$$

where T_{ijt} is the bilateral trade between countries during a period t and is calculated as:

$$Trade_{ij} = \frac{(Exports_{ij} + Imports_{ij})}{2}$$

and T_{it} is the total trade of country during the same period which can be expressed as:

$$T_{it} = \sum_{j=0}^{N} T_{ijt}$$

The fixed trade weight matrix is provided in Table 3.

Table 3. Trade weight matrix

Country	CHINA	DENMARK	ESTONIA	EURO	GCC	INDIA	JAPAN	LATVIA	LITHUANIA	NORWAY	POLAND	RUSSIA	SWEDEN	UK	USA
CHINA	0.000	0.052	0.031	0.164	0.200	0.169	0.358	0.020	0.014	0.051	0.042	0.170	0.047	0.079	0.338
DENMARK	0.006	0.000	0.023	0.033	0.002	0.003	0.003	0.032	0.022	0.055	0.021	0.008	0.088	0.017	0.006
ESTONIA	0.001	0.004	0.000	0.004	0.000	0.001	0.000	0.113	0.055	0.004	0.004	0.009	0.014	0.001	0.001
EURO	0.252	0.477	0.383	0.000	0.185	0.197	0.136	0.291	0.307	0.434	0.670	0.525	0.495	0.603	0.302
GCC	0.092	0.011	0.002	0.055	0.000	0.372	0.187	0.003	0.003	0.003	0.004	0.006	0.011	0.030	0.072
INDIA	0.042	0.007	0.003	0.030	0.197	0.000	0.019	0.004	0.002	0.004	0.005	0.018	0.009	0.019	0.039
JAPAN	0.200	0.014	0.004	0.044	0.219	0.043	0.000	0.003	0.001	0.017	0.006	0.057	0.013	0.021	0.129
LATVIA	0.001	0.005	0.104	0.003	0.000	0.001	0.000	0.000	0.097	0.003	0.006	0.019	0.004	0.001	0.001
LITHUANIA	0.001	0.006	0.079	0.006	0.000	0.001	0.000	0.202	0.000	0.005	0.015	0.014	0.006	0.002	0.001
NORWAY	0.004	0.074	0.023	0.039	0.001	0.003	0.004	0.015	0.012	0.000	0.011	0.005	0.107	0.045	0.007
POLAND	0.009	0.035	0.052	0.082	0.002	0.004	0.003	0.085	0.097	0.025	0.000	0.055	0.034	0.022	0.005
RUSSIA	0.052	0.018	0.089	0.108	0.004	0.015	0.036	0.143	0.291	0.015	0.102	0.000	0.042	0.021	0.025
SWEDEN	0.008	0.155	0.153	0.058	0.004	0.006	0.004	0.049	0.039	0.102	0.034	0.018	0.000	0.028	0.010
UK	0.039	0.091	0.035	0.208	0.034	0.038	0.022	0.032	0.041	0.221	0.062	0.042	0.080	0.000	0.066
USA	0.293	0.052	0.020	0.166	0.151	0.147	0.228	0.009	0.018	0.061	0.019	0.056	0.050	0.109	0.000

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Global variables

Since the main purpose of the paper is to assess macroeconomic implications of global oil shocks on the economies, we added oil price and world oil production as global variables. Oil prices were obtained from US Energy Information Administration and oil production figures were taken from International Energy Statistics. We then took the logarithm of both series, as it was done previously with domestic and foreign variables.

Country specific VARX models

In our global VAR setup we consider a set of N+1 countries labeled by *i=0,1…N* to build the global economy model. The US is treated as a reference country given its economic dominance, while other countries are assumed to be small open economies. Each country-specific model is constructed in the form of VAR augmented by a vector containing foreign variables that are treated as weakly exogenous, thus it becomes possible to investigate linkages between the countries. The general structure of individual country $VARX^*$ model is expressed in the equation (1):

$$x_{it} = a_{i,0} + a_{i,1}t + \Phi_{i,1}x_{i,t-1} + \ldots + \Phi_{i,p_i}x_{i,t-p_i} + \Lambda_{i,0}x^*{}_{i,t} + \Lambda_{i,1}x^*{}_{i,t-1} + \ldots + \Lambda_{i,q_i}x^*{}_{i,t-q_i} + u_{it} \quad (1)$$

where $a_{i,0}$ is the vector of intercepts, $a_{i,1}$ is the coefficient matrix of time trend, x_{it} is a $k\ x$ 1 vector of domestic variables, and x^*_{it} is a k^*x 1 vector of foreign variables. Φ_{i,p_i} and Λ_{i,q_i} are coefficient matrices associated with domestic and foreign variables respectively. Country specific shocks, which are denoted as u_{it} ,are assumed to be uncorrelated across time dimension, with a zero mean, and with a non-singular covariance matrix (Pesaran et al., 2004).

The lag order in the equation (1) is denoted as p_i for the domestic variables and as q_i for the foreign variables. The Akaike Information (AIC) and the Schwarz Bayesian criterions (SBC) are the two prevailing lag order selection methods. We used AIC to determine the appropriate number of lags because it is inclined to select more lags than BIC, and by doing so reduces serial correlation in residuals (Davier & Carstensen, 2007)

As previously discussed the global VAR succeeds in dealing with the curse of dimensionality problem by splitting a large VAR into multiple models that are further transformed to the vector error correction form and separately estimated. A VARX model can be rewritten to the vector error correction form with exogenous variables (VECMX) as shown in the equation (2). This form allows accounting for cointegration (long-run relations) within country's endogenous variables denoted by x_{it}, between foreign specific variables x_{it}^* and the country's endogenous variables x_{it}, as well as between country's domestic variables x_{it} and endogenous variables of another country x_{jt}(Di Mauro & Pesaran, 2013).Variables can only be cointegrated if they are integrated of order one; therefore, we assume that the variables used in the model are unit root processes. We test this assumption further and explain why it is a reasonable presumption.

$$\Delta x_{it} = c_{i0} - \alpha_i \beta_i' \left(z_{i,t-1} - \gamma_i (t-1) \right) + \Lambda_{i0} \Delta x_{it} + \Gamma_i \Delta z_{i,t-1} + u_{it} \tag{2}$$

where $z_{it} = \binom{x_{it}}{x_{it}^*}$, β_i is a $(k_i + k_i^*) \times r_i$ matrix, and α_i is a $k_i \times r_i$ matrix.

After the estimation of country-specific VECMX models the following estimates are obtained: r_i which represents the number of cointegrating relations, α_i which is the speed of coefficients alignment, and cointegrating vectors β_i for all country models (Di Mauro et al., 2013).

Solution of the GVAR model

The GVAR model can be perceived as a system of the whole world, which implies that all variables are endogenous to the system (Di Mauro et al., 2013). The estimated individual country models are combined together into the global VAR model. County-specific models have to be solved simultaneously with respect to the domestic variables. In order to solve the model the equation (1) should be rearranged as follows:

$$x_{it} - \Lambda_{i,0}x^*{}_{i,t} = a_{i,0} + a_{i,1}t + \Phi_{i,1}x_{i,t-1} + \Lambda_{i,1}x^*{}_{i,t-1} + \ \dots + \Phi_{i,p_i}x_{i,t-p_i} + \Lambda_{i,q_i}x^*{}_{i,t-q_i} + u_{it} \quad (3)$$

Subsequently, in order to get the equation (4) we substitute the matrices (6-9) into the equation (3).

$$z_{it} = \binom{x_{it}}{x^*_{it}} \quad (6) \qquad A_{i0} = (I_{ki}\,, -\Lambda_{i0}) \quad (7)$$

$$A_{i1} = (\phi_{i1}\,, \Lambda_{i1}) \quad (8) \qquad A_{ij} = \left(\phi_{ij}\,, \Lambda_{ij}\right) \quad (9)$$

$$A_{i0} * z_{it} = a_{i,0} + a_{i,1}t + A_{i1} * z_{it-1} + \ \dots + A_{ij} * z_{it-q} + u_{it} \quad (4)$$

Using link matrices W_i determined by trade weights, w_{ij}, we can define z_{it} as $W_i \times x_t$. Therefore, the equation (4) can be rearranged into:

$$A_{i0} * W_i * x_t = a_{i,0} + a_{i,1}t + A_{i1} * W_i * x_{t-1} + \ \dots + A_{ij} * W_i * x_{t-q} + u_{it} \quad (5)$$

$$G_h = \begin{pmatrix} A_{0h}W_0 \\ A_{1h}W_1 \\ \dots \\ A_{Nh}W_N \end{pmatrix} (10) \qquad a_e = \begin{pmatrix} a_{0e} \\ a_{1e} \\ \dots \\ a_{Ne} \end{pmatrix} (11) \qquad u_t = \begin{pmatrix} u_{0t} \\ u_{1t} \\ \dots \\ u_{Nt} \end{pmatrix} \ (12)$$

The next step requires arranging all individual country models into the single global model. Using the matrices (10-12) we can rewrite the equation (5) as:

$$G_0x_t = a_0 + a_1t + G_1x_{i,t-1} + \ldots + G_qx_{i,t-q} + u_{it} \quad (13)$$

Finally, as G_0 is an invertible matrix we can get the equation (14) by multiplying both sides of equation (13) by G_0^{-1}. Then using the matrices 16-18 we can simplify the equation 14 to the final equation (19), which can be solved in a recursive manner (Di Mauro et al., 2013).

$$x_t = \ G_0^{-1}a_0 + \ G_0^{-1}a_1t + \ G_0^{-1}G_1x_{i,t-1} + \ldots + G_0^{-1}G_qx_{i,t-q} + \ G_0^{-1}u_{it} \quad (14)$$

$$d_y = \ G_0^{-1}a_y \ \ (16) \qquad F_q = \ G_0^{-1}G_q \ \ (17) \qquad \varepsilon_t = \ G_0^{-1}u_t \ \ (18)$$

$$x_t = d_0 + d_1t + F_1x_{i,t-1} + \ldots + F_qx_{i,t-q} + \varepsilon_t \quad (19)$$

Shock identification

In most existing GVAR literature generalized impulse responses developed by Pesaran and Shin (1998) are used (see, for instance, Dees et al. (2007)). Main advantage of GIRFs is that they do not require any ordering of variables and show the most probable responses to shocks. The problem with GIRFs, however, is that they show responses to non-orthogonal shocks, which complicates their economic interpretation. One option is to use orthogonalized impulse responses that provide economically meaningful results. This approach, however, is very disputable in the context of global models, since coherent and justifiable ordering is required for each country model (Lütkepohl, 2005). To address the issue we use the sign restrictions approach suggested by Eickmeier and Ng (2015) to identify oil supply and demand shocks. The same approach is followed in Cashin et al. (2014) to identify the oil shocks in the GVAR. The benefit of the approach is that shocks are not correlated inside countries and have weak correlation across countries. Effectively, our identification scheme becomes a symbiosis of GIRFs and orthogonalized shocks. Furthermore, as it follows from the literature review, there is no other feasible way of identifying supply and demand shocks.

To impose sign restrictions on the short-run impulse responses we follow the approach proposed by Rubio-Ramirez et al. (2010).

We perform a Cholesky decomposition of the variance-covariance matrix of the vector of residuals u_{it} for each country-specific model i to get the lower triangular Cholesky matrix P_i for model i. Then we create a matrix

$$P = \begin{pmatrix} P_0 & 0 & \dots & \dots & 0 \\ 0 & \ddots & & & \vdots \\ \vdots & & P_i & & \vdots \\ \vdots & & & \ddots & 0 \\ 0 & \dots & \dots & 0 & P_N \end{pmatrix}$$

which allows us to get the impulse responses to shocks to the residuals $v_t = (v_{0t}, \dots, v_{it}, \dots, v_{Nt})' = P^{-1} G_0 \varepsilon_t$ as $\psi^h = \phi^h G_0^{-1} P$. We then draw random orthogonal matrices and carry out QR-decompositions. This gives us unique matrices Q_i that fulfill $Q_i Q_i' = I$. After that we perform the rotation of Q_i to get 2000 successful rotations that give us impulse responses that satisfy the imposed sign restrictions which are imposed on lags 0-3. The impulse responses are then given by $\Psi_i^h = (\psi_i^h Q_i')'$.

Although the sign restrictions method in structural VARs has recently gained in popularity, the approach has its critics (for summary see Fry and Pagan (2011)). Most of the criticism is based on the argument that in some cases sign restrictions fail to provide exact identification because they do not narrow down a distinct structural model. Instead, they require impulse responses to move in a way supported by economic theory. In spite of that, as a number of sign restrictions increases it should be expected that we will get a better comprehension of structural shocks of interest (Chudik et al., 2011). A multi-country setting of the model allows us to impose a sizeable number of sign restrictions to significantly scale down the number of permissible models (see Chudik et al. (2011); Paustian (2007)).

Sign restriction choices

We base our choice of sign restrictions on structural and empirical literature that identified the same structural shocks. In pioneering work on identification of oil supply and demand shocks Kilian (2008) uses contemporaneous exclusion restriction. He identifies supply shock as a perturbation that has contemporaneous effect on global oil production. Demand shock, however, affects oil production only with a lag, which implies a vertical short-run oil supply curve. The idea is that oil production is instantly affected by the supply shock; however, it fails to immediately react to the unexpected increase in demand. As pointed out in further research, this scheme is appropriate when monthly data are used, but is of limited usefulness when dealing with quarterly data (see Kilian and Murphy (2013)). Therefore, we follow the more agnostic sign restrictions scheme used by Baumeister et al. (2010), Cashin et al. (2014), Chudik et al. (2011), among others. We identify global oil supply and demand shocks by imposing the following restrictions on global level of oil prices, global oil production level, and real output of oil-importing and oil-exporting countries:

Structural shocks	Q_{oil}	P_{oil}	Y_{imp}	Y_{exp}
Oil supply	$\leq$	$\geq$	$\leq$	$-$
Oil demand	$\geq$	$\geq$	$\geq$	$\geq$

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The identification scheme is based on a simple supply and demand framework of the oil market. Oil supply shock shifts the supply curve, sending oil production and oil price in opposite directions. Typical examples that can produce this kind of shift, for example, are a military showdown in the Middle East or a proclamation of embargo by the OPEC. As a result of an adverse supply shock, the global economic output will either fall or remain unchanged. Oil demand shock affects the demand curve, and therefore will send oil production and oil price in the same direction, since oil exporters usually intensify the production in response to increase in oil prices driven by demand. This shift can be the result of growing economic activity, which demands more energy. Thus, this is the demand shock that that is driven by economic activity and that is why we impose positive restriction on the global economic output. Typical example can be the demand that comes from newly industrialized economies (e.g. China). We follow Cashin et al. (2014) and impose sign restrictions not on individual impulse responses of oil-importers like it was done in Chudik et al. (2011), but rather on the sum of impulse responses of oil-importing countries. By so doing our identification scheme should allow us to distinguish oil supply and demand shocks from a number of other shocks (Cashin et al., 2014).

Model specifications

Particular model specifications were deliberately chosen for the US and GCC. The reasoning behind that decision is discussed further in this section. Models of the other countries contain all variables, for which the data is available. General model specifications are shown in Table 4. Individual models are provided in Data Appendix 2.

Table 4. Model specifications

	US		GCC		Other countries	
Variable	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
y	✓	✓	✓	✓	✓	✓
π	✓	✓	✓	✓	✓	✓
eq	✓			✓	✓	✓
r_S	✓		✓	✓	✓	✓
r_L	✓			✓	✓	✓
p_{oil}	✓			✓		✓
q_{oil}		✓	✓			✓

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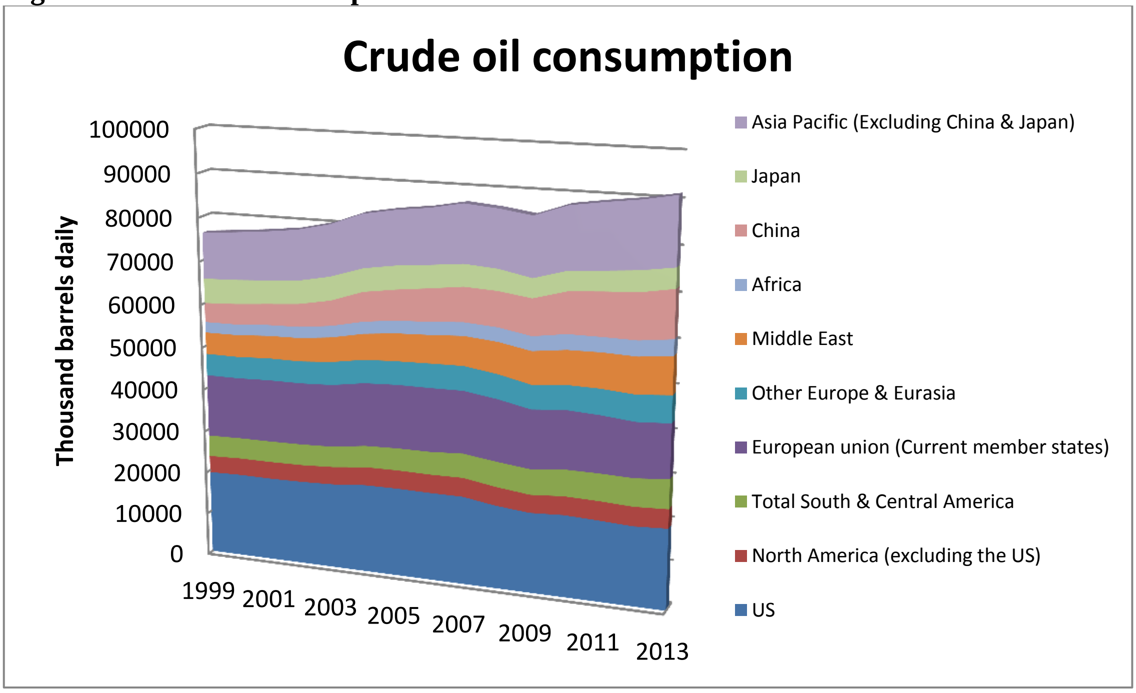
In what follows now we refer to the structural literature and arguments made by Cashin et al. (2014).

The US model

By construction, the countries in the GVAR are treated as small open economies, since the vector of foreign variables enters the country-specific models as weakly exogenous. This assumption, however, is dubious for the US. In existing GVAR literature it is commonly accepted to exclude real equity prices, short-, and long-term interest rates from the vector of foreign variables in the US because of its economic dominance (Dees et al., 2007).

Another distinctive feature of the US model specification is that oil price entered the model as endogenous variable. The US average crude oil consumption level was approximately 23.5% of the total world consumption for the sample period from 1999 to 2013 (BP, 2015). It can be seen in Figure 1 below, where detailed split of consumption by regions is provided. Furthermore, Kilian (2008) argued that crude oil prices have been endogenously determined by the US economic development, which implies that there is two-way causal relationship between them, which is a strong argument in favor of inclusion of this variable as endogenous in the country-specific model.

Figure 1. Global oil consumption



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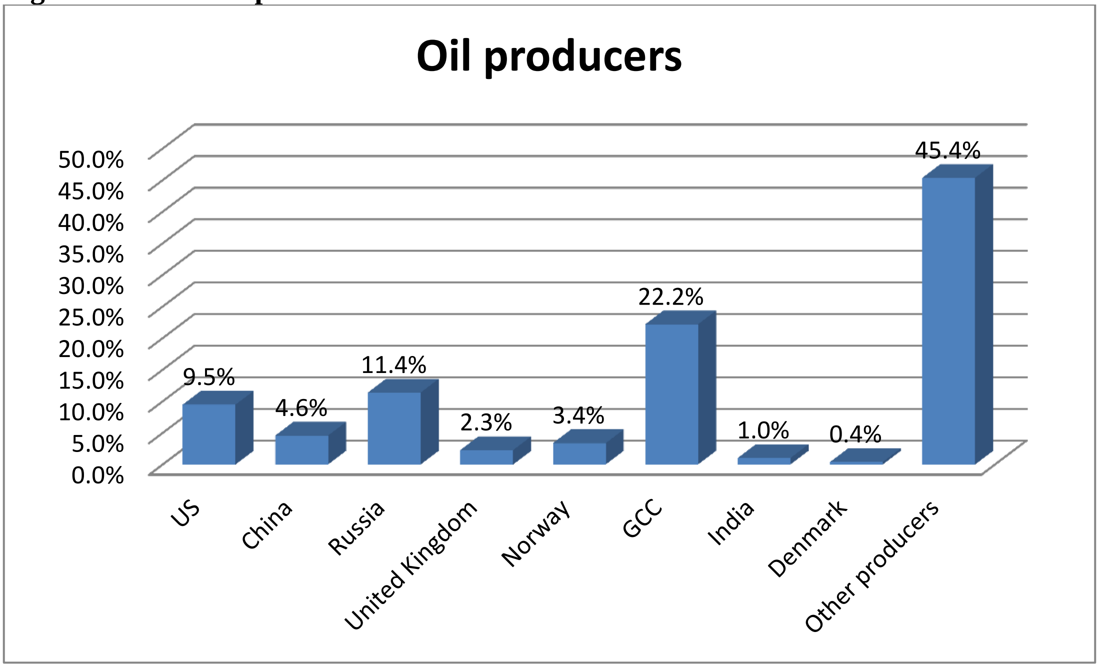
The GCC model

We aggregated all GCC members into one region because these countries are similar in many respects. The union itself was established back in the 1980 and since then the members have been implementing a number of policies in order to facilitate integration of their economies. This leaded to the establishment of the customs union in 2003 (Thepeninsulaqatar, 2015). Moreover, the members are now thinking about creation of a single currency, and local businesses already use currency which is made up from the basket of GCC currencies, which is similar to European currency unit used prior to the introduction of the euro in 1999 (Susris, 2015). Finally, all the countries pursue the same exchange rate policy, fixing their currencies vis-à-vis US dollar.

The average production share of crude oil in this region was more than 22% of total world production during the sample period. Shares of world oil production are summarized in Figure 2. According to BP statistical review of world energy (2015), at the end of 2013 the share of proven oil reserves of GCC countries amounted for more than 29% of world reserves. Given similarities of this countries and their significance in the oil production industry we included quantity of oil produced as an endogenous variable into the GCC individual model.

Figure 2. Global oil production



Created by the authors using data from BP Statistics (2014)

Data analysis

Estimation of the individual VARX* models relies on the following assumptions: 1) all country-specific variables are integrated of order one (or $I(1)$); 2) foreign variables are weakly exogenous; 3) the parameters are time-invariant. Since these assumptions need to hold to coherently build the global VAR model, we now assess the validity of each assumption.

Unit root test

Even though the GVAR can be solved for stationary and/or non-stationary variables, we follow Dees et al. (2007) and assume that all variables are integrated of order one to allow for both short- and long-run relationships with the latter interpreted as cointegration relations. Although an ADF test is probably the most popular choice in the literature, it has been shown that it has weak statistical power (see, for instance, Leybourne, Kim, and Newbold (2005)), struggling from the near observation equivalence problem (for more details see Campbell and Perron (1991); Cochrane (1991)). That is why we instead employ a weighted symmetric ADF test developed by Fuller and Park (1995). The WS-ADF takes into account the time reversibility of stationary AR processes and therefore has higher statistical power than the traditional ADF test (Fuller et al., 1995). Pantula, Gonzalez-Farias, and Fuller (1995), among others, support this argument by showing that weighted symmetric version is more statistically powerful than the conventional ADF and other alternatives. Optimal lag length for the test is chosen with AIC to avoid the autocorrelation problem in the residuals. Test results suggest that most variables under study are integrated of order one, which allows us to proceed with estimation of cointegration relationships. Tables with results for both domestic and foreign variables are provided in Data Appendix 3.

Weak exogeneity test

Since foreign variables are treated as exogenous, we tacitly assume that domestic variables have no effect on their foreign counterparts in the long run. We check the legitimacy of this assumption by performing the weak exogeneity test described in Johansen (1991) and Harbo, Johansen, Nielsen, and Rahbek (1998). Theoretical foundations of the test are explained in Technical Appendix 1 and the results are reported in Table 5. Weak exogeneity is rejected for foreign inflation in Japan and oil price in Poland and Russia. There is little reason, however, to believe that Japan has an influence on global inflation and that oil is endogenous in Poland. Although Russia is an energy superpower that produces approximately 12 percent of the global output (BP, 2015), time has shown that it has no pricing power unlike US and OPEC (see, for instance, Greenspan (2015)), therefore we can reasonably assume that oil is exogenous in Russia. These strange results can possibly be explained by the small sample size (Brüggemann, 2002) and thus should not affect our model.

Table 5. Weak exogeneity test

Country	F test	y^*	π^*	eq^*	$r_S{}^*$	$r_L{}^*$	p_{oil}	q_{oil}
China	F(2,38)	0.35	1.27	2.48	0.49	1.65	0.67	0.54
Denmark	F(3,35)	0.50	0.36	1.03	1.09	1.35	0.29	0.20
Estonia	F(1,43)	0.09	0.88	0.91	0.67	1.00	1.49	0.03
EU	F(2,36)	1.35	0.03	1.42	0.53	3.06	0.14	0.60
GCC	F(2,39)	0.79	1.81	2.58	0.13	0.81	0.22	-
India	F(2,38)	0.31	0.02	0.81	0.85	0.29	0.02	0.04
Japan	F(2,36)	0.33	3.68^*	0.34	0.05	0.70	2.19	0.91
Latvia	F(2,40)	0.42	0.31	0.73	0.79	0.14	0.67	0.47
Lithuania	F(2,40)	0.69	0.23	1.60	0.51	0.89	0.12	1.33
Norway	F(3,41)	0.14	0.76	0.11	0.19	0.66	0.48	0.36
Poland	F(1,39)	1.63	2.71	0.72	0.00	0.02	8.79^*	1.00
Russia	F(1,39)	0.10	1.89	1.90	0.01	2.33	5.02^*	0.06
Sweden	F(1,37)	0.48	0.44	0.31	0.89	1.80	1.49	0.41
UK	F(1,42)	0.03	1.20	0.00	0.00	0.37	1.15	0.19
US	F(2,38)	0.81	0.67	-	-	-	-	0.01

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Structural stability test

The presence of structural breaks has been among the most significant problems in econometric modelling for decades (see, for instance, Hashimzade and Thornton (n.d.); Lucas (1976)). The problem is especially pronounced for emerging economies that have gone through a handful of political and social changes. Even though, it is a widely known fact that estimation procedures are complicated by the presence of structural breaks, there is no acknowledged method that can be applied to model breaks yet. Even if breaks can be found in data, it is extremely difficult to construct a model that will incorporate the possibility of breaks occurring in future periods (see, for instance, Clements and Hendry (1998)).

Dees et al. (2007) accentuate that the global VAR is also not immune to this problem. The GVAR, however, is more renitent to breaks than simple reduced-form single-equation models because of the presence of foreign variables in country-specific $VARX^*$ models (Dees et al., 2007). The reason for that is the so-called co-breaking which was first discussed by Hendry (1996). The idea is that if a structural break is passed on to foreign countries, then this information is already incorporated into exogenous variables in the model. This holds because in the GVAR setting foreign variables can contemporaneously affect domestic variables (see also Osorio and Unsal (2013)).

Since there is no general agreement on the best way to test for structural stability, we follow Dees et al. (2007) and use a set of parameter stability tests. Theoretical foundations of the tests can be found in Technical Appendix 2. For all the tests except for $PK_{sup}$and PK_{msq} we also provide heteroskedasticity-robust modifications. The results are provided in the Table 6 below. It can be seen that they are quite volatile; particularly, QLR, MW, and EW reject parameter constancy in more than 30 percent of the cases. Nevertheless, heteroskedasticity-robust versions of EW and QLR fail to reject parameter stability in 100 percent of the cases and MW identifies breaks in less than 2 percent of the cases. Both PK_{sup} and PK_{msq} reject parameter stability in less than 18 percent of the cases and Nyblom in 11 percent of the cases. When allowing for heteroskedasticity, the results for Nyblom do not significantly change (9 percent of rejections). Based on that, we can conclude that most of the identified breaks can be attached to the error variance, rather than model parameters (Di Mauro et al., 2013). Thereupon, we follow Dees et al. (2007) and use the bootstrap procedure to compute values and confidence bands for the construction of impulse response functions, since point estimates would provide inaccurate results.

Table 6. Structural stability test

Test statistics	y	π	eq	r_S	r_L	Total
PK_{sup}	1 (6.7)	3 (20)	2 (20)	0 (0)	3 (30)	9 (14.3)
PK_{msq}	1 (6.7)	4 (26.7)	1 (10)	0 (0)	5 (50)	11 (17.5)

$Nyblom$	1 (6.7)	1 (6.7)	1 (10)	2 (15.4)	2 (20)	7 (11.1)
$Robust\ Nyblom$	0 (0)	1 (6.7)	1 (10)	3 (23.1)	1 (10)	6 (9.5)
QLR	4 (26.7)	2 (13.3)	4 (40)	7 (53.8)	5 (50)	22 (34.9)
$Robust\ QLR$	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
MW	3 (20)	2 (13.3)	4 (40)	6 (46.2)	5 (5)	20 (31.7)
$Robust\ MW$	0 (0)	0 (0)	0 (0)	1 (7.7)	0 (0)	1 (1.6)
EW	4 (26.7)	2 (13.3)	5 (0.5)	8 (61.5)	5 (50)	24 (38.1)
$Robust\ EW$	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

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Long-run relationships and model stability

Integrated time series processes are said to be cointegrated if a linear combination of them has a lower level of integration. To find cointegration relationships we use Johansen test (1991). We use the critical values reported in MacKinnon, Haug, and Michelis (1999) and choose trace statistics over maximum eigenvalue because it has been shown that the former is more statistically powerful when applied to small samples (see, for instance, Lütkepohl, Saikkonen, and Trenkler (2001)) and is more robust to departures from normal errors (see Cheung and Lai (1993)). To check the validity of estimated long-run relationships we looked at the time profiles of their responses to a system wide shock that are known in the literature as persistence profiles. Persistence profiles are derived from the GVAR expressed as a moving average process (Dees et al., 2007) and were first introduced by Pesaran and Shin (1996). In line with Cesa-Bianchi, Pesaran, Rebucci, and Xu (2012) and Feldkircher (2014) we then adjust the cointegration rank for each individual model until all persistence profiles converge to 0 within the space of 10 to 15 quarters. This is done to ensure stability of the model and to lower the possibility of overestimation of the number of cointegration vectors, since Johansen test monumentally relies on asymptotic properties (Johansen, 1988). Moduli of obtained eigenvalues suggest that the constructed model is stable, as they all are less than or equal to one. Impulse responses support that as well, since they all approach some asymptotes as time passes, which means that the shock does not have a persistent effect.

Lag orders and cointegrating relations for each country-specific model are reported in Table 7.

Table 7. Cointegration relations and lag orders

	$VARX^*$ orders		Cointegrating relations (r_i)
Country	p_i	q_i	
China	2	1	2
Denmark	2	1	3
Estonia	1	1	1
EU	2	1	2
GCC	2	1	2
India	2	1	2
Japan	2	1	2
Latvia	2	1	2
Lithuania	2	1	2
Norway	1	1	3
Poland	2	1	1
Russia	2	1	1
Sweden	2	1	1
UK	1	1	1
US	2	1	2

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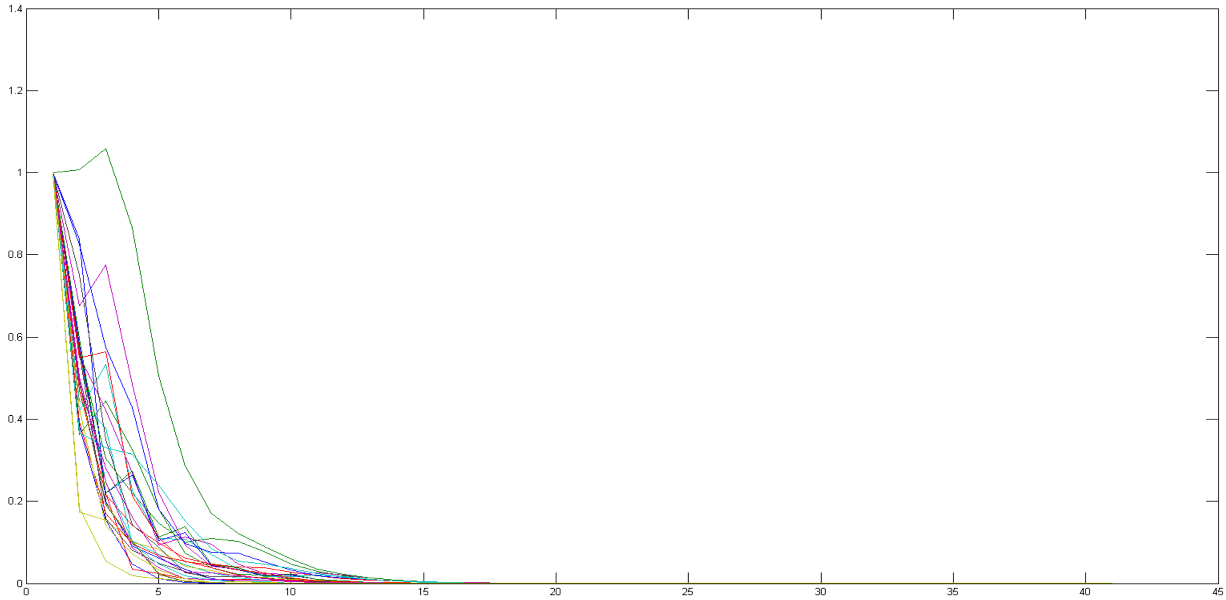
Persistence profiles are provided in Figure 3 below.

Figure 3. Persistence profiles



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Analysis and discussion

This section is split into two main parts each containing the analysis of supply and demand shocks. Discussion provided in these subsections is based on results of impulse response functions from our GVAR model. For conciseness, we depict only several figures containing impulse response functions in this section. All other impulse response functions scrutinized in order to build up the analysis part are provided in Data Appendices 4 and 5, for oil supply and demand shocks respectively.

Supply-driven shock

Real GDP

Short-term effects of a negative oil supply shock on the real economy noticeably differ for various groups of countries, while in the long run all countries in the sample experience a fall in economic activity. Following an oil supply disruption developed net oil-importing countries experience a decrease in level of real output. The obtained result coincides with previous findings of Peersman et al. (2012) discussed in the literature review section. Furthermore, as previously mentioned in the literature review part devoted to transmission channels increase in oil prices might negatively affect output of oil-importing countries through raised production costs and dampened level of productivity, which harms growth prospects and the rate of employment (Tang et al., 2009).

The EU and the US are the major oil consumers in the world, on average constituting approximately 40 percent of the world oil consumption during the period 1999-2013 (BP, 2015). In spite of similarities between these economies, real GDP response to the shock is two times higher in the EU. This might be partially explained by the fact that the US does possess considerably higher amount of proven oil reserves (BP, 2015). The US has strong trading relationships with China, but the EU group trades relatively more within itself and with other European countries. In comparison to Europe Chinese economy performs well after a supply shock. Thus, adverse shock effects on the US economy might be mitigated through trade linkages with China.

Chinese and Indian economies perform remarkably well relatively to other economies. In the short-term China even displays a rise in real GDP. In 2013 China's crude oil consumption share of all fuel types used to meet its energy demand was only 17.8 percent (BP, 2015). This indicates that as opposed to other energy importing countries China is less dependent on crude oil and its price level. Moreover, throughout the sample period China has become more dependent on coal and has managed to produce the amount of coal almost equal to the domestic consumption. To be more precise, in 1999 China constituted 30.1 percent of the total world coal production share and 29.8 percent of coal consumption share, and in 2013 these shares changed to 47.4 and 49.9 percent respectively, and both average consumption and production shares over the studied period are close to 39.4 percent (BP, 2015). As shown in the trade matrix both China and especially India are intensively trading with oil exporting countries. The latter has even established a free trade agreement with the GCC countries.

Initially, the most pronounced positive reaction of GDP to a negative oil supply shock is observed in Russia. The GCC region also has a positive response of GDP to this shock in the short-term. This result is as expected from review of previous studies, and might be explained by higher oil revenues gained by oil exporting countries. As a result of wealth transfer effect described previously in this paper the consumer demand of oil exporters might increase (Tang et al., 2009). Nevertheless, positive effects disappear over time and the impact of a negative supply shock on the economies of the aforementioned oil exporting countries becomes negative in the long run. Initial hike of Russian real output is followed by a sufficiently significant drop of GDP in the long run, with a magnitude of decrease similar to majority of European countries. As shown in the trade weight matrix Russia trade intensively with other EU country members, and thereby might be negatively affected due to the decreased foreign economic activity in the long run.

Since 1999 the crude oil production level in the UK has been constantly decreasing, and net exports of oil has been falling as well (BP, 2015). In 2005 the level of oil production approximately aligned with consumption in the country, and after that year the UK became oil importing country rather than exporting. Norway and Denmark represent countries that have been net oil exporters throughout the whole sample period, but their economies are negatively affected as a result of oil supply disruption. While Norway is performing better than most of European countries, the reaction of Denmark is similar to European peers in the long run. Despite being a net oil exporting country Denmark's negative reaction might be attributed to the small oil production share in comparison to main oil producers, and to the fact that petroleum products do not comprise a significant proportion of exports (The Atlas of Economic Complexity, 2015). Crude oil production amount in Norway has decreased by 41.5 percent from 1999 to 2013 (BP, 2015). Besides, both Denmark and Norway are heavily involved in trading with European countries, which might have negative impact on their own GDPs trough deteriorated foreign demand.

Inflation and interest rates

In the aftermath of oil supply shock the US, UK, and India tend to have comparatively strong and long-lasting inflationary pressures. In the short run most of European oil importing countries also tend to have inflationary pressures, however, the rate of inflation reverts afterwards. On the one hand, initial increase might be explained by inflation effect. Oil price can directly affect inflation as they might be included into inflation indices. Also, as oil is a significant factor of production costs are pushed up, which should lead to a higher level of prices as firms may decide either to produce less or increase their prices. On the other hand, deteriorating economic activity might signal a drop in aggregate demand which might be used as an explanation of decreasing rate of inflation in most European countries afterwards. As for main oil exporters their reactions differ substantially. The inflation rate of GCC region constantly decreased due to a negative supply shock, while the Russia's rate of inflation initially hiked before the subsequent reduction.

As mentioned above the US had one of most strong positive reactions of the inflation rates to a supply shock. Short-term interest rate in this country increased, which might be done in order to alleviate inflationary pressure. In the EU country group long-term interest rate was slightly positive in very short run, and the long-term rate has continued to gradually decrease until the seventh quarter in which the inflation rate began to stabilize as well. Majority of short-term as well as long-term rates reduced as a result of a supply shock. Given that in the long term many countries experienced a deflationary pressures due to possible drop in the aggregate demand level, this finding might be interpreted as an action performed by countries to boost their economies.

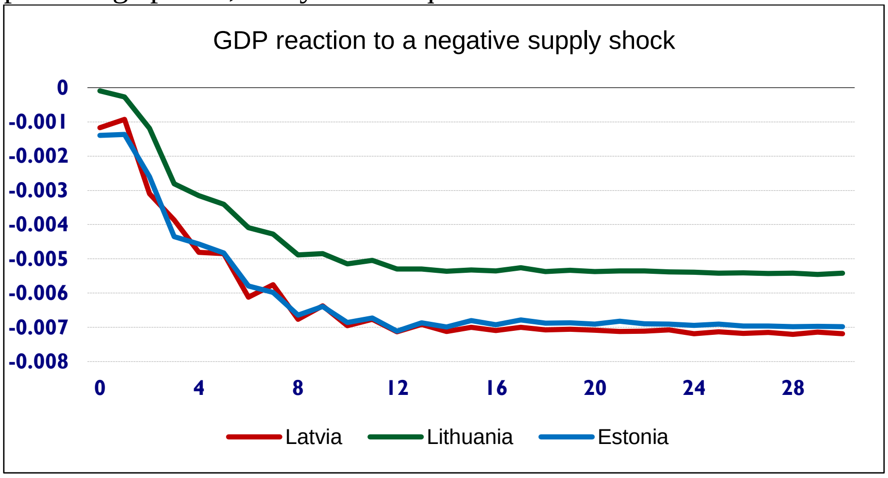
Stock market

A negative oil supply shock has a significant impact on stock market price developments. The long-term changes in stock market prices are relatively larger when comparing them to changes in other variables. This happens because equities are inherently volatile, and are significantly dependent on future expectations of investors. As noted above a negative supply shock has adverse effects on output of most countries already in the short term. Deteriorating economic conditions might discourage investors and compel them to temporary reallocate their equity holdings to safer types of assets. Moreover, through the unexpected effect previously explained in the transmission channels part, investment demand might also decrease as a result of overall uncertainty of future prices.

The Baltic countries

The Baltic countries face a long-term decline in output as a result of a negative supply shock. The reaction of real GDP is similar among these countries, and in general, decline in output is more severe than in any other countries included in the sample. This possibly could be explained by the openness of the Baltic countries and high dependence on its trading partners; therefore the countries suffer not only from direct effect, but also are affected indirectly because of worsening conditions of their neighbours. Even though, shares of renewable energy in final energy consumption for Latvia, Lithuania and Estonia are 37.1, 23, and 25.6 percent respectively it does not help avoiding the harmful consequences of a supply shock (Eurostat, 2015). Moreover, these countries rely quite heavily on oil and other fossil fuel types, prices of which might highly correlate. As shown in Figure 4 below our impulse responses suggest that Latvia and Estonia suffer the most, and the economy of Lithuania is less affected. A possible reason for the reaction of Lithuanian GDP might be partially explained by highest share of trade with the Russian Federation. Furthermore, another reason for that reaction might be that until the end of 2009 Lithuania has been generating approximately 77% of electricity on the nuclear power plant (IES, 2015).

Figure 4. IRFs of GDP reaction to a negative supply shock. x-axis measured in percentage points, and y-axis in quarters



Source: created by the authors

Out of three countries Estonia has the highest inflation spike in the short-term, and both long- and short-term interest rates increased in this country to combat it. The reason behind the spike could be that a significant proportion of power in Estonia is generated using petroleum and gas obtained from oil shale (IES, 2015). At first the inflation rate in Lithuania is positive, however, in comparison to Estonia and Latvia this rate moderately decreased and turned out to be negative in the long-run. The short-term interest rate in Lithuania became negative after the inflation rate reversed. Latvia is one Baltic country that does not experience inflationary pressure after supply shock. Latvian inflation rate started to steadily decrease after a negative supply shock which corresponds to the reaction of a negative reaction of inflation rate.

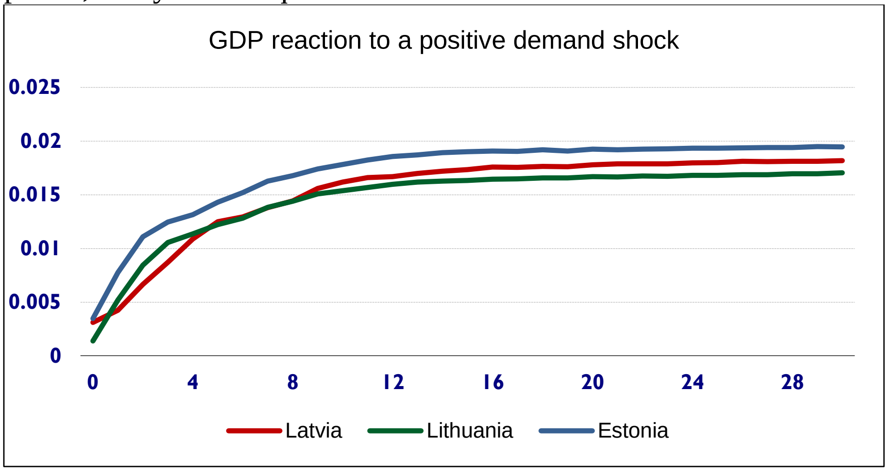
Demand-driven shock

The results we obtained for oil demand shock mostly go in line with existing research discussed in the literature review section. All countries except India in our sample experience a short-run boost in real output and face long-run inflationary pressure. Real equity prices of all countries for which data was available react positively to the shock. The results are quite expected, since we tried to model an endogenous oil shock driven by a positive change in global economic activity. Central Banks should respond with a more tightened monetary policy to combat inflation, and we see that interest rates go up in most of the cases. Latvia and Russia, however, are exceptions here. In fact, in Russia both short- and long-term interest rates react negatively to an oil demand shock. It might be because expensive oil gives significant boost to the whole economy and monetary policy therefore is loosened to catch the momentum and accelerate growth. It can further be explained by the fact that although it is officially declared by the Central Bank of Russia that its main goal is control of inflation, historically the institute was caring more about the exchange rate (UN, 2014). Norway's real output increases by a very small fraction, which is quite a surprising result, however, one should not forget that during an oil supercycle the country accumulated huge wealth and significantly diversified its economy. Apart from that, it is rather difficult to come up with good explanation of this impulse response movement. In Cashin et al. (2014) Norway is the only country in which real output drops as a result of positive demand shock.

We can see that China experiences the lowest growth in real output among all the countries. This is not surprising, since it was discussed previously that 70 percent of energy consumption basket in the country is comprised of coal (BP, 2015), way below the world's average, therefore, we can expect that oil shock does not have sizeable effect on the economy. Movement of Indian real output is quite unexpected, given that we tried to model the shock driven by global economic activity. This is even more surprising since the country has implemented a handful of policies to facilitate trade with GCC bloc.

Surprisingly, the Baltic States react on the demand shock with the highest increase in output in the short-run. This increase, in part, might be spurred by economic growth of main trading partners, especially, Russia, real output of which increases by approximately the same amount as a result of the shock. Inflation in Latvia and Lithuania increases by approximately 0.2 percentage points and more than 1 percentage point in Estonia in the long-run, which is not a significant pressure given the target level of inflation in the EU.

Figure 5. IRFs of GDP reaction to a negative supply shock. x-axis measured in percentage points, and y-axis in quarters



Source: created by the authors

Robustness of results

The decision to perform the analysis using fixed weights was based on the notion that changes in trade weights are rather gentle and these changes are usually antagonized by the comovements of the macroeconomic time series which makes foreign variables computed with fixed weights not very different from the variables computed with time-varying weights (see, for instance, Dees et al. (2007)). To assess the robustness of the results we ran the model with three-year rolling averages of trade figures. We obtained similar persistence profiles and test results that are not reported for convenience. Another robustness check that is often performed in the GVAR literature is exclusion of the global financial crisis from sample and re-estimation of the model. Unfortunately, this is not possible in our case because the time span of our dataset is relatively narrow. However, the GVAR has been found to be robust to exclusion of this time period in most of the existing research (see, for example, Eickmeier et al. (2015)).

Limitations of the research

We believe that the most significant limitation of our research is inability to measure the effects of the supply shock to the full extent, since our dataset comprises the events that had the least significant effects on the level of oil prices of all geopolitical tensions that caused supply disruptions. This is obviously because the Baltic States regained independence in the early 1990s, in the aftermath of the major political events that had the most sweeping supply-side effects on the oil market. Most of them are included in the data used in the existing literature on identification of oil supply and demand shocks.

Next limitation of the paper is inability to identify the positive supply shock using sign restrictions, since there was not a single one during the past 20 years identified in structural literature. Current OPEC oversupply has not yet left its mark in the data and therefore can only be modelled to a very limited extent. Therefore, we leave it for future research when more data is going to be available.

Another limitation is data unavailability for most of the GCC countries, which left us with annual data that we had to interpolate. Although, this is not the best method to deal with missing values, it was applied previously in the GVAR modelling (see, for instance, Smith and Galesi (2014)) and did not seem to cause any significant problems.

Finally, we did not impose any elasticity restrictions, which become trendy in the recent demand/supply shock identification literature (that was done, for instance, in Cashin et al. (2014)).

Conclusions

In the study we applied the sign restriction technique to the GVAR model comprised of 17 individual country models, covering around 70% of the global gross domestic product, to disentangle supply and demand shocks in order to assess their distinctive effects.

Our results demonstrate that the modelling of a simple oil price shock is not enough, rather the fundamental driver behind a shock to oil price is essential to correctly assess the effects on main macroeconomic aggregates of the countries. More specifically, negative oil-supply shock and positive demand shock affect oil exporters and oil importers in a different manner.

We show that oil-price driven economy of Russia suffers from a negative supply shock in the long run and therefore provides no buffer against negative direct effects that the Baltics experience. The demand shock, however, results in significant higher than average short-term gain in economic output and long-term inflationary pressure. Part of the increase in economic activity can be attributed to indirect effects stemming from relationships with the main trading partners and Russia in particular.

For further research we would suggest to put additional constraint – elasticity bound on oil, which has recently been widely employed in the research. Addition of more oil exporters and expansion of the time period of the sample might be beneficial for the performance of the model.

References

Andrews, D., & Ploberger, W. (1994). Optimal tests when a nuisance parameter is present only under the alternative. *Econometrica, 62*(6), 1383. doi:10.2307/2951753

Barro, R. (1994). The aggregate-supply/aggregate-demand model. *Eastern Economic Journal, 20*(1), 1-6.

Barsky, R., & Kilian, L. (2002). Do we really know that oil caused the great stagflation? A monetary alternative. *NBER/Macroeconomics Annual, 16*(1), 137-183. doi:10.1162/088933601320224900

Barsky, R., & Kilian, L. (2004). Oil and the macroeconomy since the 1970s. *Journal Of Economic Perspectives, 18*(4), 115-134. doi:10.1257/0895330042632708

Baumeister, C., Peersman, G., & Van Robays, I. (2010). The economic consequences of oil shocks: differences across countries and time. *RBA Annual Conference.*

Belke, A., & Dreger, C. The transmission of oil and food prices to consumer prices: evidence for the MENA countries. *SSRN Journal*. doi:10.2139/ssrn.2348563

Bernanke, B. (1983). Irreversibility, uncertainty, and cyclical investment. *The Quarterly Journal Of Economics, 98*(1), 85. doi:10.2307/1885568

Bettendorf, T. (2012). Investigating global imbalances: empirical evidence from a GVAR approach . Retrieved March 15, 2015, from ftp://ftp.repec.org/opt/ReDIF/RePEc/ukc/ukcedp/1217.pdf

Bloom, N. (2009). The impact of uncertainty shocks. *Econometrica, 77*(3), 623-685. doi:10.3982/ecta6248

BP. (2015). *Statistical review of world energy 2014 [Historical data workbook]*. Retrieved April 1, 2015, from http://www.bp.com/content/dam/bp/excel/Energy-Economics/statistical-review-2014/BP-Statistical_Review_of_world_energy_2014_workbook.xlsx

Brüggemann, R. (2002). On the small sample properties of weak exogeneity tests in cointegrated VAR models. *Humboldt Universitaet Berlin, Sonderforschungsbereich,* 373.

Campbell, J., & Perron, P. (1991). Pitfalls and opportunities: what macroeconomists should know about unit roots. *NBER Macroeconomics Annual*, *6*, 141. doi:10.2307/3585053

Cashin, P., Mohaddes, K., Raissi, M., & Raissi, M. (2014). The differential effects of oil demand and supply shocks on the global economy. *Energy Economics*, *44*, 113-134. doi:10.1016/j.eneco.2014.03.014

Cesa-Bianchi, A., Pesaran, M., Rebucci, A., & Xu, T. (2012). China's emergence in the world economy and business cycles in Latin America. *Economía*, *12*(2), 1-75. doi:10.1353/eco.2012.0001

Cheung, Y., & Lai, K. (1993). Finite-sample sizes of Johansen’s likelihood ratio tests for cointegration. *Oxford Bulletin Of Economics And Statistics*, *55*(3), 313-328. doi:10.1111/j.1468-0084.1993.mp55003003.x

Chudik, A., & Fidora, M. (2011). Using the global dimension to identify shocks with sign restrictions. *ECB Working Paper 1318*

Chudik, A., & Pesaran, M. (2014). Theory and practice of GVAR modeling. *Journal of Economic Surveys*.

Chuku, C. (2012). Linear and asymmetric impacts of oil price shocks in an oil-importing and -exporting economy: the case of Nigeria. *OPEC Energy Review*, *36*(4), 413-443. doi:10.1111/j.1753-0237.2012.00220.x

Clements, M., & Hendry, D. (1998). *Forecasting economic time series*. Cambridge: Cambridge University Press.

Cochrane, J. (1991). A critique of the application of unit root tests. *Journal Of Economic Dynamics And Control*, *15*(2), 275-284. doi:10.1016/0165-1889(91)90013-q

Davier, M., & Carstensen, C. (2007). *Multivariate and mixture distribution Rasch models*. New York: Springer.

de Souza, L. (2015). *Commodity prices and growth: A changing relationship? | VOX, CEPR’s Policy Portal*. *Voxeu.org*. Retrieved 1 March 2015, from http://www.voxeu.org/article/commodity-prices-and-growth-changing-relationship

Dees, S., Mauro, F., Pesaran, M., & Smith, L. (2007). Exploring the international linkages of the euro area: a global VAR analysis. *Journal Of Applied Econometrics*, *22*(1), 1-38. doi:10.1002/jae.932

Di Mauro, F., & Pesaran, M. (2013). *The GVAR handbook*. Oxford: Oxford University Press.

Dohner, R. S. **(**1981). Energy prices, economic activity and inflation: Survey of issues and results. *K.A. Mork (Ed.) Energy Prices, Inflation and Economic Activity. Cambridge, MA: Ballinger.*

Ebrahim, Z., Inderwildi, O., & King, D. (2014). Macroeconomic impacts of oil price volatility: mitigation and resilience. *Front. Energy*, *8*(1), 9-24. doi:10.1007/s11708-014-0303-0

Edelstein, P., & Kilian, L. (2007). The response of business fixed investment to changes in energy prices: A test of some hypotheses about the transmission of energy price shocks. *The B.E. Journal Of Macroeconomics*, *7*(1). doi:10.2202/1935-1690.1607

Eickmeier, S., & Ng, T. (2015). How do US credit supply shocks propagate internationally? A GVAR approach. *European Economic Review*, *74*, 128-145. doi:10.1016/j.euroecorev.2014.11.011

Elder, J., & Serletis, A. (2010). Oil price uncertainty. *Journal Of Money, Credit And Banking*, *42*(6), 1137-1159. doi:10.1111/j.1538-4616.2010.00323.x

Energy Information Administration. (2015). *Total Petroleum and Other Liquids 2015* [Data file]. Retrieved March 10, 2015, from http://www.eia.gov/beta/international/

European Commission. (n.d.). *Latvia*. Retrieved April 10, 2015, from http://ec.europa.eu/energy/sites/ener/files/documents/2014_countryreports_latvia.pdf

Eurostat. (2015). *Share of renewable energy in gross final energy consumption* [Data file]. Retrieved March 10, 2015, from http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=t2020_31&plugin=1

Feldkircher, M. (2014). A global macro model for emerging Europe. *Journal Of Comparative Economics*. doi:10.1016/j.jce.2014.09.002

Ferderer, J. P. (1996). Oil price volatility and the macroeconomy: a solution to the asymmetry puzzle. *Journal of Macroeconomics, 18,* 1-26. doi:10.1016/s0164-0704(96)80001-2

Filis, G., & Chatziantoniou, I. (2013). Financial and monetary policy responses to oil price shocks: evidence from oil-importing and oil-exporting countries. *Review Of Quantitative Finance And Accounting*, *42*(4), 709-729. doi:10.1007/s11156-013-0359-7

Fry, R., & Pagan, A. (2011). Sign restrictions in structural vector autoregressions: a critical review. *Journal Of Economic Literature*, *49*(4), 938-960. doi:10.1257/jel.49.4.938

Gelos, G., & Ustyugova, Y. (2012). Inflation responses to commodity price shocks – how and why do countries differ?. *IMF Working Paper 12.*

Greenspan, A. (2015, February 19). OPEC has ceded to the US its power over oil price. Financial Times. Retrieved from http://www.ft.com/cms/s/0/92ab80e4-b827-11e4-b6a5-00144feab7de.html

Gross, M. (2013). Estimating GVAR weight matrices. *ECB Working Paper 1523*

Güntner, J. (2013). How do international stock markets respond to oil demand and supply shocks?. *Macroecon. Dynam.*, *18*(08), 1657-1682. doi:10.1017/s1365100513000084

Guo, H., & Kliesen, K. (2005). Oil price volatility and U.S. macroeconomic activity. *Federal Reserve Bank of St. Louis Review, 87*(6), 669–683.

Hamilton, J. (1983). Oil and the macroeconomy since world war II. *Journal Of Political Economy*, *91*(2), 228. doi:10.1086/261140

Hamilton, J. (2009). Understanding crude oil prices. *EJ*, *30*(2). doi:10.5547/issn0195-6574-ej-vol30-no2-9

Hamilton, J. D. (2011). Historical oil shocks. *NBER Working Paper 16790*

Hansen, B. (1992). Tests for parameter instability in regressions with I(1) processes. *Journal Of Business & Economic Statistics*, *10*(3), 321-335. doi:10.1080/07350015.1992.10509908

Hansen, B. E. (1990). Lagrange multiplier tests of parameter instability in non-linear models. *Unpublished manuscript, University of Rochester, Dept. of Economics*

Harbo, I., Johansen, S., Nielsen, B., & Rahbek, A. (1998). Asymptotic inference on cointegrating rank in partial systems. *Journal Of Business & Economic Statistics, 16*(4), 388-399. doi:10.1080/07350015.1998.10524779

Hashimzade, N., & Thornton, M. *Handbook of research methods and applications in empirical macroeconomics.*

Hendry, D. F. (1996). A theory of co-breaking. *Mimeo, Nuffield College, University of Oxford.*

Henriques, I., & Sadorsky, P. (2011). The effect of oil price volatility on strategic investment. *Energy Economics, 33*(1), 79-87. doi:10.1016/j.eneco.2010.09.001

Jiménez-Rodríguez, R., & Sánchez, M. (2005). Oil price shocks and real GDP growth: empirical evidence for some OECD countries. *Applied Economics*, *37*(2), 201-228. doi:10.1080/0003684042000281561

Jo, S. (2014). The effects of oil price uncertainty on global real economic activity. *Journal Of Money, Credit And Banking*, *46*(6), 1113-1135. doi:10.1111/jmcb.12135

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal Of Economic Dynamics And Control*, *12*(2-3), 231-254. doi:10.1016/0165-1889(88)90041-3

Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in gaussian vector autoregressive models. *Econometrica*, *59*(6), 1551. doi:10.2307/2938278

Jones, D., & Paik, P. (2004). Oil price shocks and the macroeconomy: What has been learned since 1996. *EJ*, *25*(2). doi:10.5547/issn0195-6574-ej-vol25-no2-1

Kilian, L. (2008). A comparison of the effects of exogenous oil supply shocks on output and inflation in the G7 countries. *Journal Of The European Economic Association*, *6*(1), 78-121. doi:10.1162/jeea.2008.6.1.78

Kilian, L. (2009). Not all oil price shocks are alike: disentangling demand and supply shocks in the crude oil market. *American Economic Review*, *99*(3), 1053-1069. doi:10.1257/aer.99.3.1053

Kilian, L., & Murphy, D. (2013). The role of inventories and speculative trading in the global market for crude oil. *Journal Of Applied Econometrics*, *29*(3), 454-478. doi:10.1002/jae.2322

Leybourne, S., Kim, T., & Newbold, P. (2005). Examination of some more powerful modifications of the Dickey-Fuller test. *J Time Series Analysis*, *26*(3), 355-369. doi:10.1111/j.1467-9892.2004.00406.x

Lucas, R. (1976). Econometric policy evaluation: a critique. *Carnegie-Rochester Conference Series On Public Policy*, *1*, 19-46. doi:10.1016/s0167-2231(76)80003-6

Lütkepohl, H. (2005). *New introduction to multiple time series analysis*. Berlin: New York.

Lütkepohl, H., Saikkonen, P., & Trenkler, C. (2001). Maximum eigenvalue versus trace tests for the cointegrating rank of a VAR process. *Econometrics Journal*, *4*(2), 287-310. doi:10.1111/1368-423x.00068

MacKinnon, J., Haug, A., & Michelis, L. (1999). Numerical distribution functions of likelihood ratio tests for cointegration. *Journal Of Applied Econometrics*, *14*(5), 563-577. doi:10.1002/(sici)1099-1255(199909/10)14:5<563::aid-jae530>3.3.co;2-i

Nyblom, J. (1989). Testing for the constancy of parameters over time. *Journal Of The American Statistical Association*, *84*(405), 223-230. doi:10.1080/01621459.1989.10478759

Osorio, C., & Unsal, D. (2013). Inflation dynamics in Asia: causes, changes, and spillovers from China. *Journal Of Asian Economics*, *24*, 26-40. doi:10.1016/j.asieco.2012.10.007

Pantula, S. G., Gonzalez-Farias G., & Fuller W. A. (1995). A comparison of unit root test criteria. *Journal of Business & Economic Statistics, 12*(4), 449–59.

Park, H., & Fuller, W. (1995). Alternative estimators and unit root tests for the autoregressive process. *J Time Series Analysis*, *16*(4), 415-429. doi:10.1111/j.1467-9892.1995.tb00243.x

Paustian, M. (2007). Assessing sign restrictions. *The B.E. Journal Of Macroeconomics*, *7*(1). doi:10.2202/1935-1690.1543

Peersman, G., & Van Robays, I. (2012). Cross-country differences in the effects of oil shocks. *Energy Economics, 34*(5), 1532-1547.

Pesaran, H., & Shin, Y. (1998). Generalized impulse response analysis in linear multivariate models. *Economics Letters*, *58*(1), 17-29. doi:10.1016/s0165-1765(97)00214-0

Pesaran, M., & Shin, Y. (1996). Cointegration and speed of convergence to equilibrium. *Journal Of Econometrics*, *71*(1-2), 117-143. doi:10.1016/0304-4076(94)01697-6

Pesaran, M., Schuermann, T., & Weiner, S. (2004). Modeling regional interdependencies using a global error-correcting macroeconometric model. *Journal Of Business & Economic Statistics, 22*(2), 129-162. doi:10.1198/073500104000000019

Pierce, J., Enzler, J., Fand, D., & Gordon, R. (1974). The effects of external inflationary shocks. *Brookings Papers On Economic Activity, 1974*(1), 13. doi:10.2307/2534072

Plante, M., & Traum, N. Time-varying oil price volatility and macroeconomic aggregates. *SSRN Journal*. doi:10.2139/ssrn.2005312

Ploberger, W., & Kramer, W. (1992). The CUSUM test with OLS residuals. *Econometrica, 60*(2**),** 271. doi:10.2307/2951597

Quandt, R. (1960). Tests of the hypothesis that a linear regression system obeys two separate regimes. *Journal Of The American Statistical Association*, *55*(290), 324-330. doi:10.1080/01621459.1960.10482067

Rasche, R., & Tatom, J. (1981). Energy price shocks, aggregate supply and monetary policy: The theory and the international evidence. *Carnegie-Rochester Conference Series On Public Policy, 14,* 9-93. doi:10.1016/0167-2231(81)90002-6

Rasmussen, T., & Roitman, A. (2011). Oil shocks in a global perspective: Are they really that bad?. *IMF Working Papers*, *11*(194), 1. doi:10.5089/9781462305254.001

Rentschler, J. (2013). Oil price volatility, economic growth and the hedging role of renewable energy. *World Bank Policy Research Working Paper 6603*. Washington DC: The World Bank

Rubio-Ramirez, J., Waggoner, D., & Zha, T. (2010). Structural vector autoregressions: theory of identification and algorithms for inference. *Review Of Economic Studies*, *77*(2), 665-696. doi:10.1111/j.1467-937x.2009.00578.x

Schneider, M. (2004). The impact of oil price changes on growth and inflation. *Monetary Policy and the Economy*, *2*, 27-36.

Smith, L. V., & Galesi, A. (2011). GVAR Toolbox 1.1. Retrieved December 1, 2014, from www.cfap.jbs.cam.ac.uk/research/gvartoolbox

Stock, J., & Watson, M. (1996). Evidence on structural instability in macroeconomic time series relations. *Journal Of Business & Economic Statistics*, *14*(1), 11-30. doi:10.1080/07350015.1996.10524626

Susris. (2015). *GCC Summit: A Show of Unity – Arab News Editorial SUSRIS*. Retrieved March 26, 2015, from http://susris.com/2014/12/12/gcc-summit-a-show-of-unity-arab-news-editorial/

Tang, W., Wu, L., & Zhang, Z. (2010). Oil price shocks and their short- and long-term effects on the Chinese economy. *Energy Economics*, *32*, S3-S14. doi:10.1016/j.eneco.2010.01.002

The Atlas of Economic Complexity. (2015). *Export/Import Statistics* [Data file]. Retrieved March 10, 2015, from http://atlas.cid.harvard.edu/explore/tree_map/export/nor/all/show/2003/

Thepeninsulaqatar. (2015). *GCC customs union fully operational*. Retrieved March 25, 2015, from http://thepeninsulaqatar.com/news/middle-east/314466/gcc-customs-union-fully-operational

United Nations. (2014, February). *Shifting monetary policy priorities in the Russian Federation.* Retrieved March 10, 2014, from http://www.un.org/en/development/desa/policy/wesp/wesp_wh/wesp_wh45.pdf

White, H. (1980). A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica*, *48*(4), 817-838. doi:10.2307/1912934

Data Appendix 1

Data sources

Data series		Countries	Source
GDP	Quarterly GDP Index	AUSTRIA, BELGIUM, CHINA, DENMARK, ESTONIA, FINLAND, FRANCE, GERMANY, GREECE, INDIA, IRELAND, ITALY, JAPAN, LATVIA, LITHUANIA, NETHERLANDS, NORWAY, POLAND, PORTUGAL, QATAR, RUSSIAN FEDERATION, SPAIN, SWEDEN, UNITED KINGDOM, UNITED STATES	IMF IFS
	Annual GDP Index	BAHRAIN, KUWAIT, OMAN, SAUDI ARABIA, UNITED ARAB EMIRATES	
CPI	CPI Quarterly	AUSTRIA, BAHRAIN, BELGIUM, DENMARK, ESTONIA, FINLAND, FRANCE, GERMANY, GREECE, INDIA,IRELAND, ITALY, JAPAN, KUWAIT, LATVIA, LITHUANIA, NETHERLANDS, NORWAY, OMAN, POLAND, PORTUGAL, QATAR, RUSSIAN FEDERATION, SAUDI ARABIA, SPAIN, SWEDEN, UNITED KINGDOM, UNITED STATES	IMF IFS
	CPI Quarterly	CHINA	OECD
	CPI Annual	UNITED ARAB EMIRATES	UAE NATIONAL BUREAU OF STATISTICS
EQUITY INDEX	MSCI STANDARD	AUSTRIA, BELGIUM, CHINA, DENMARK, FINLAND, FRANCE, GERMANY, GREECE, INDIA, IRELAND, ITALY, JAPAN, NETHERLANDS, NORWAY, POLAND, PORTUGAL, SPAIN, SWEDEN, UK, USA	MSCI
SHORT-TERM RATES	MONEY MARKET RATE	DENMARK , FINLAND, GERMANY, KUWAIT, LATVIA, LITHUANIA, POLAND, RUSSIAN FEDERATION	IMF IFS

	DEPOSIT RATE	BAHRAIN, CHINA, ESTONIA, NETHERLANDS, OMAN	
	GOVERNMENT SECURITIES, TREASURY BILLS	AUSTRIA, BELGIUM, FRANCE, GREECE, IRELAND, ITALY, JAPAN, PORTUGAL, SPAIN, SWEDEN, UNITED KINGDOM, UNITED STATES	
LONG-TERM RATES	GOVERNMENT SECURITIES, GOVERNMNET BONDS	AUSTRIA, BELGIUM, DENMARK, ESTONIA, FINLAND, FRANCE, GERMANY, GREECE, INDIA, IRELAND, ITALY, JAPAN, NETHERLANDS, NORWAY, PORTUGAL, RUSSIAN FEDERATION, SPAIN, SWEDEN, UK, USA	IMF IFS
OIL PRICE	BRENT SPOT PRICE PER BARREL	-	US ENERGY INFORMATION ADMINISTRATION
OIL QUANTITY	QUARTERLY AVERAGE PRODUCTION OF OIL PER DAY	-	INTERNATIONAL ENERGY STATISTICS

Source: created by the authors

Data Appendix 2

Unit Root Tests for the domestic variables at the 5% Significance Level

Domestic Variables	*Statistic*	*Critical Value*	*CHINA*	*DENMARK*	*ESTONIA*	*EURO*	*GCC*	*INDIA*	*JAPAN*	*LATVIA*	*LITHUANIA*	*NORWAY*	*POLAND*	*RUSSIA*	*SWEDEN*	*UK*	*USA*
y (with trend)	ADF	-3.5	-1.6	-2.2	-2.0	-2.6	-2.9	-1.7	-2.8	-2.1	-2.2	-2.2	-2.9	-1.5	-2.0	-1.7	-1.9
y (with trend)	WS	-3.2	-1.9	-2.3	-1.6	-2.2	-1.3	-1.4	-2.9	-2.4	-2.3	-2.2	-3.0	-1.2	-2.1	-0.8	-1.8
y (no trend)	ADF	-2.9	-0.5	-1.8	-2.1	-1.8	0.3	-0.2	-1.8	-1.5	-1.9	-1.2	-0.3	-2.0	-1.2	-2.0	-1.0
y (no trend)	WS	-2.6	0.9	-1.1	0.4	0.0	-0.3	1.1	-0.9	-0.8	-0.2	1.3	0.4	1.0	0.6	1.3	1.1
Dy	ADF	-2.9	-2.3	-3.6	-3.1	-3.4	-2.0	-3.7	-4.6	-2.0	-3.6	-8.5	-2.5	-3.9	-4.0	-3.8	-3.4
Dy	WS	-2.6	-2.6	-3.8	-3.4	-3.3	-2.1	-3.9	-4.8	-2.3	-3.7	-8.7	-2.6	-4.1	-4.2	-3.7	-2.9
DDy	ADF	-2.9	-9.6	-10.8	-7.9	-5.9	-5.6	-6.8	-5.8	-5.6	-8.9	-6.7	-11.0	-7.4	-8.7	-5.0	-4.8
DDy	WS	-2.6	-10.0	-10.9	-8.2	-6.1	-5.6	-6.4	-6.2	-5.9	-9.1	-7.0	-10.8	-7.6	-9.0	-5.1	-4.9
dp (with trend)	ADF	-3.5	-4.5	-4.5	-5.9	-4.8	-2.5	-4.3	-4.1	-2.6	-2.6	-5.7	-4.0	-5.8	-4.0	-5.3	-5.2
dp (with trend)	WS	-3.2	-4.9	-4.7	-6.3	-5.1	-2.8	-4.4	-4.5	-2.8	-2.8	-5.9	-2.9	-4.0	-4.2	-5.5	-5.5
dp (no trend)	ADF	-2.9	-3.9	-4.5	-6.0	-4.5	-2.0	-1.4	-3.9	-2.6	-2.7	-5.7	-4.3	-1.8	-4.0	-4.1	-5.1
dp (no trend)	WS	-2.6	-4.1	-4.5	-6.4	-4.9	-2.0	-1.1	-4.2	-2.8	-2.7	-5.9	-2.6	-0.1	-4.2	-4.2	-5.3
Ddp	ADF	-2.9	-5.6	-8.0	-6.9	-5.1	-4.8	-7.9	-8.7	-5.4	-4.8	-9.6	-4.2	-6.8	-7.8	-7.3	-6.2
Ddp	WS	-2.6	-5.8	-8.2	-7.3	-5.4	-5.0	-8.2	-9.0	-5.5	-5.1	-9.9	-4.5	-5.9	-8.0	-7.8	-6.7
DDdp	ADF	-2.9	-10.2	-6.4	-6.2	-13.7	-9.8	-8.1	-13.3	-6.6	-7.4	-6.4	-6.8	-6.6	-6.3	-7.5	-8.3
DDdp	WS	-2.6	-10.6	-6.6	-6.6	-14.1	-10.0	-8.3	-13.7	-6.9	-7.8	-6.6	-6.0	-6.9	-6.5	-8.5	-8.8
eq (with trend)	ADF	-3.5	-2.7	-2.7		-2.5		-2.1	-2.1			-2.2	-2.9		-3.6	-2.4	-2.1
eq (with trend)	WS	-3.2	-2.3	-2.9		-2.7		-2.2	-2.4			-2.5	-2.8		-3.0	-2.4	-2.1
eq (no trend)	ADF	-2.9	-1.2	-1.7		-2.1		-1.0	-2.2			-1.9	-2.6		-3.0	-2.5	-2.4
eq (no trend)	WS	-2.6	-1.6	-1.6		-2.1		-1.3	-2.3			-1.9	-2.7		-2.9	-2.0	-2.0
Deq	ADF	-2.9	-3.8	-4.8		-4.4		-3.6	-5.0			-5.1	-3.2		-4.4	-4.4	-4.4
Deq	WS	-2.6	-4.0	-4.9		-4.6		-3.9	-5.1			-5.3	-3.5		-3.8	-4.7	-4.6
DDeq	ADF	-2.9	-10.4	-8.5		-6.3		-7.3	-7.1			-6.3	-6.3		-5.8	-6.2	-6.4
DDeq	WS	-2.6	-10.5	-8.7		-6.6		-6.8	-7.4			-6.7	-6.5		-6.0	-6.6	-6.8
st (with trend)	ADF	-3.5	-3.2	-2.8	-2.1	-3.5	-3.2		-2.5	-2.6	-2.2		-3.0	-2.9	-3.8	-2.4	-3.9
st (with trend)	WS	-3.2	-3.5	-2.7	-2.4	-3.9	-3.2		-2.8	-2.9	-2.4		-3.0	-2.4	-4.0	-2.5	-4.1
st (no trend)	ADF	-2.9	-2.2	-1.5	-1.8	-2.4	-2.7		-2.6	-1.9	-1.3		-2.4	-3.2	-2.2	-1.4	-3.3
st (no trend)	WS	-2.6	-2.4	-1.8	-2.0	-2.4	-1.9		-2.8	-2.0	-0.8		-1.4	-2.1	-2.4	-1.4	-3.0
Dst	ADF	-2.9	-4.4	-4.1	-3.8	-3.9	-4.5		-3.5	-6.7	-5.0		-3.8	-7.2	-4.5	-4.6	-3.0
Dst	WS	-2.6	-4.6	-4.2	-4.2	-3.9	-4.6		-3.5	-6.9	-4.5		-3.7	-7.2	-4.5	-4.5	-3.0
DDst	ADF	-2.9	-8.2	-5.8	-5.0	-7.0	-7.1		-11.3	-6.6	-6.4		-6.8	-6.2	-7.7	-8.5	-7.6
DDst	WS	-2.6	-8.5	-4.8	-5.4	-6.8	-7.5		-11.7	-7.1	-6.7		-6.6	-5.7	-8.0	-8.7	-7.9
lt (with trend)	ADF	-3.5		-2.8	-1.6	-2.7		-2.1	-2.3			-2.5		-4.6	-3.5	-2.6	-2.8
lt (with trend)	WS	-3.2		-2.7	-1.5	-2.9		-1.0	-2.6			-2.4		-1.2	-3.4	-2.6	-3.1
lt (no trend)	ADF	-2.9		-1.1	-1.5	-2.0		-2.5	-1.8			-1.1		-5.0	-1.4	-1.4	-2.0
lt (no trend)	WS	-2.6		-1.3	-0.2	-2.1		-0.8	-1.8			-1.3		-0.1	-1.5	-1.4	-1.2
Dlt	ADF	-2.9		-6.0	-4.6	-4.5		-5.1	-6.0			-5.6		-7.3	-6.3	-5.9	-4.2
Dlt	WS	-2.6		-5.4	-4.4	-3.3		-5.3	-6.1			-5.6		-1.6	-5.8	-5.9	-3.9
DDlt	ADF	-2.9		-6.8	-7.4	-6.5		-6.6	-8.9			-7.5		-4.5	-7.1	-7.1	-6.4
DDlt	WS	-2.6		-6.5	-7.5	-5.8		-6.8	-9.1			-7.8		-5.2	-6.2	-6.9	-6.5

Unit Root Tests for the domestic variables at the 5% Significance Level

Unit Root Tests for the foreign variables at the 5% Significance Level

Foreign Variables	Statistic	Critical	CHINA	DENMARK	ESTONIA	EURO	GCC	INDIA	JAPAN	LATVIA	LITHUANIA	NORWAY	POLAND	RUSSIA	SWEDEN	UK	USA
ys (with trend)	ADF	-3.45	-2.54	-2.03	-1.47	-1.94	-1.79	-2.14	-1.37	-1.78	-1.85	-2.49	-2.39	-2.16	-1.87	-2.35	-1.63
ys (with trend)	WS	-3.24	-2.50	-1.80	-1.64	-2.03	-2.07	-2.40	-1.73	-1.70	-1.69	-2.23	-2.14	-2.16	-1.61	-2.23	-1.94
ys (no trend)	ADF	-2.89	-0.97	-1.42	-1.27	-0.94	-0.76	-0.57	-0.77	-1.65	-1.23	-1.27	-1.57	-1.03	-1.55	-1.16	-0.94
ys (no trend)	WS	-2.55	0.85	0.84	0.46	0.78	0.92	0.35	0.68	0.41	0.59	0.58	0.69	0.77	0.80	0.71	0.79
Dys	ADF	-2.89	-3.69	-3.18	-3.34	-3.58	-3.59	-2.86	-3.52	-3.24	-2.93	-3.34	-3.55	-3.28	-3.25	-3.46	-3.69
Dys	WS	-2.55	-3.71	-3.06	-3.34	-3.60	-3.51	-3.10	-3.73	-3.46	-3.14	-3.23	-3.55	-3.30	-3.21	-3.38	-3.86
DDy	ADF	-2.89	-5.56	-5.93	-4.61	-6.32	-6.64	-6.10	-6.74	-6.96	-4.86	-5.12	-5.85	-5.76	-6.31	-5.87	-7.19
DDy	WS	-2.55	-5.81	-6.18	-4.93	-6.57	-6.74	-6.31	-7.04	-7.18	-5.04	-5.35	-6.09	-6.00	-6.56	-6.11	-7.46
dps (with trend)	ADF	-3.45	-4.89	-4.49	-4.00	-4.48	-5.76	-3.09	-3.68	-3.38	-4.25	-4.56	-4.76	-4.40	-4.71	-4.75	-3.66
dps (with trend)	WS	-3.24	-5.10	-4.83	-4.33	-4.55	-5.99	-3.33	-3.91	-3.54	-3.90	-4.91	-5.11	-4.74	-5.04	-5.10	-3.89
dps (no trend)	ADF	-2.89	-4.91	-4.48	-3.75	-4.52	-4.53	-3.03	-3.59	-3.27	-3.42	-4.63	-3.86	-4.42	-4.56	-4.73	-3.48
dps (no trend)	WS	-2.55	-5.11	-4.81	-3.99	-4.52	-4.55	-3.20	-3.79	-3.29	-2.38	-4.96	-4.02	-4.73	-4.82	-5.07	-3.63
Ddps	ADF	-2.89	-6.47	-5.44	-6.58	-5.38	-6.27	-5.13	-5.49	-5.15	-5.06	-5.35	-5.03	-5.08	-5.74	-5.26	-5.68
Ddps	WS	-2.55	-6.86	-5.92	-6.83	-5.93	-6.58	-5.35	-5.71	-5.70	-5.58	-5.77	-5.59	-5.51	-6.27	-5.75	-5.90
DDdp	ADF	-2.89	-7.28	-6.07	-11.45	-6.93	-8.69	-6.18	-6.36	-5.86	-5.71	-6.58	-5.57	-6.44	-5.90	-6.36	-6.37
DDdp	WS	-2.55	-7.69	-6.38	-11.74	-7.42	-9.19	-6.55	-6.84	-6.38	-6.10	-6.95	-5.79	-6.81	-6.20	-6.70	-6.76
eqs (with trend)	ADF	-3.45	-2.44	-2.50	-2.85	-2.66	-2.60	-2.61	-2.82	-2.50	-2.49	-2.50	-2.47	-2.50	-2.48	-2.49	-2.56
eqs (with trend)	WS	-3.24	-2.66	-2.74	-2.85	-2.57	-2.67	-2.54	-2.40	-2.74	-2.73	-2.72	-2.73	-2.65	-2.72	-2.72	-2.49
eqs (no trend)	ADF	-2.89	-2.53	-2.55	-3.07	-2.34	-2.37	-2.63	-2.21	-2.53	-2.49	-2.55	-2.35	-2.58	-2.53	-2.52	-2.37
eqs (no trend)	WS	-2.55	-2.51	-2.68	-2.82	-2.49	-2.59	-2.56	-2.28	-2.68	-2.60	-2.61	-2.40	-2.61	-2.70	-2.59	-2.48
Deqs	ADF	-2.89	-4.57	-4.40	-4.40	-4.57	-4.79	-4.68	-4.91	-4.45	-4.45	-4.36	-4.41	-4.55	-4.51	-4.50	-4.80
Deqs	WS	-2.55	-4.75	-4.58	-4.56	-4.80	-4.99	-4.91	-5.15	-4.65	-4.65	-4.54	-4.59	-4.76	-4.71	-4.69	-5.03
DDeq	ADF	-2.89	-6.37	-7.57	-6.02	-7.96	-8.25	-8.17	-8.82	-6.08	-6.11	-7.39	-7.50	-7.82	-7.68	-7.67	-8.51
DDeq	WS	-2.55	-6.68	-7.72	-6.33	-8.25	-8.55	-8.46	-9.08	-6.39	-6.43	-7.58	-7.65	-8.07	-7.90	-7.87	-8.80
sts (with trend)	ADF	-3.45	-3.97	-3.91	-3.77	-4.22	-3.02	-4.23	-4.68	-3.05	-2.16	-3.59	-3.99	-3.94	-4.26	-4.07	-3.50
sts (with trend)	WS	-3.24	-4.10	-4.19	-4.13	-4.35	-3.27	-4.24	-4.64	-3.38	-2.38	-3.87	-4.29	-4.22	-4.53	-4.32	-3.77
sts (no trend)	ADF	-2.89	-3.16	-2.14	-2.01	-3.12	-2.62	-2.86	-3.91	-2.11	-2.05	-1.93	-2.43	-2.58	-1.99	-2.10	-2.95
sts (no trend)	WS	-2.55	-2.88	-2.13	-2.04	-2.43	-2.54	-2.16	-3.60	-1.83	-1.06	-1.93	-2.47	-2.56	-1.88	-1.79	-2.99
Dsts	ADF	-2.89	-3.27	-2.97	-2.54	-2.86	-3.06	-2.85	-2.77	-3.14	-6.31	-3.10	-2.57	-3.53	-3.55	-3.63	-2.78
Dsts	WS	-2.55	-2.72	-2.87	-2.68	-2.59	-2.96	-2.69	-2.55	-3.37	-6.25	-2.99	-2.51	-3.63	-3.53	-3.62	-2.80
DDst	ADF	-2.89	-8.82	-6.83	-10.07	-3.57	-6.80	-6.61	-8.20	-7.86	-8.19	-6.93	-10.77	-5.70	-7.93	-7.03	-6.97
DDst	WS	-2.55	-9.02	-7.06	-9.65	-3.12	-7.07	-6.86	-8.44	-7.69	-8.27	-7.18	-11.08	-5.79	-8.20	-7.14	-7.23
lts (with trend)	ADF	-3.45	-5.80	-2.51	-3.86	-4.25	-2.69	-3.55	-6.48	-3.59	-4.10	-3.01	-3.66	-2.75	-3.68	-2.62	-4.51
lts (with trend)	WS	-3.24	-0.76	-2.32	-0.90	-0.97	-2.03	-1.56	-0.71	-0.85	-1.10	-2.93	-0.95	-3.00	-1.43	-1.99	-1.08
lts (no trend)	ADF	-2.89	-5.91	-1.88	-3.66	-3.72	-2.86	-3.28	-3.82	-3.94	-4.51	-1.57	-3.60	-1.76	-3.71	-2.38	-4.79
lts (no trend)	WS	-2.55	1.12	-0.04	0.88	0.70	-0.90	0.78	0.86	0.73	0.24	-0.13	0.79	-1.50	0.68	0.02	0.84
Dlts	ADF	-2.89	-3.77	-7.04	-4.93	-5.13	-3.70	-4.12	-3.81	-4.52	-5.86	-7.05	-4.67	-4.83	-4.12	-6.85	-3.83
Dlts	WS	-2.55	-3.68	-6.50	-4.05	-3.59	-3.86	-4.36	-3.62	-1.78	-1.71	-6.54	-4.02	-3.70	-4.38	-6.32	-3.97
DDlt	ADF	-2.89	-6.45	-6.24	-7.34	-7.35	-6.66	-5.97	-6.56	-4.35	-4.22	-6.15	-7.30	-6.75	-5.93	-6.27	-10.19
DDlt	WS	-2.55	-5.86	-5.85	-6.60	-6.61	-6.96	-5.78	-5.76	-5.38	-5.27	-5.79	-6.57	-6.19	-5.87	-5.88	-9.33

Data Appendix 3

Individual model specifications

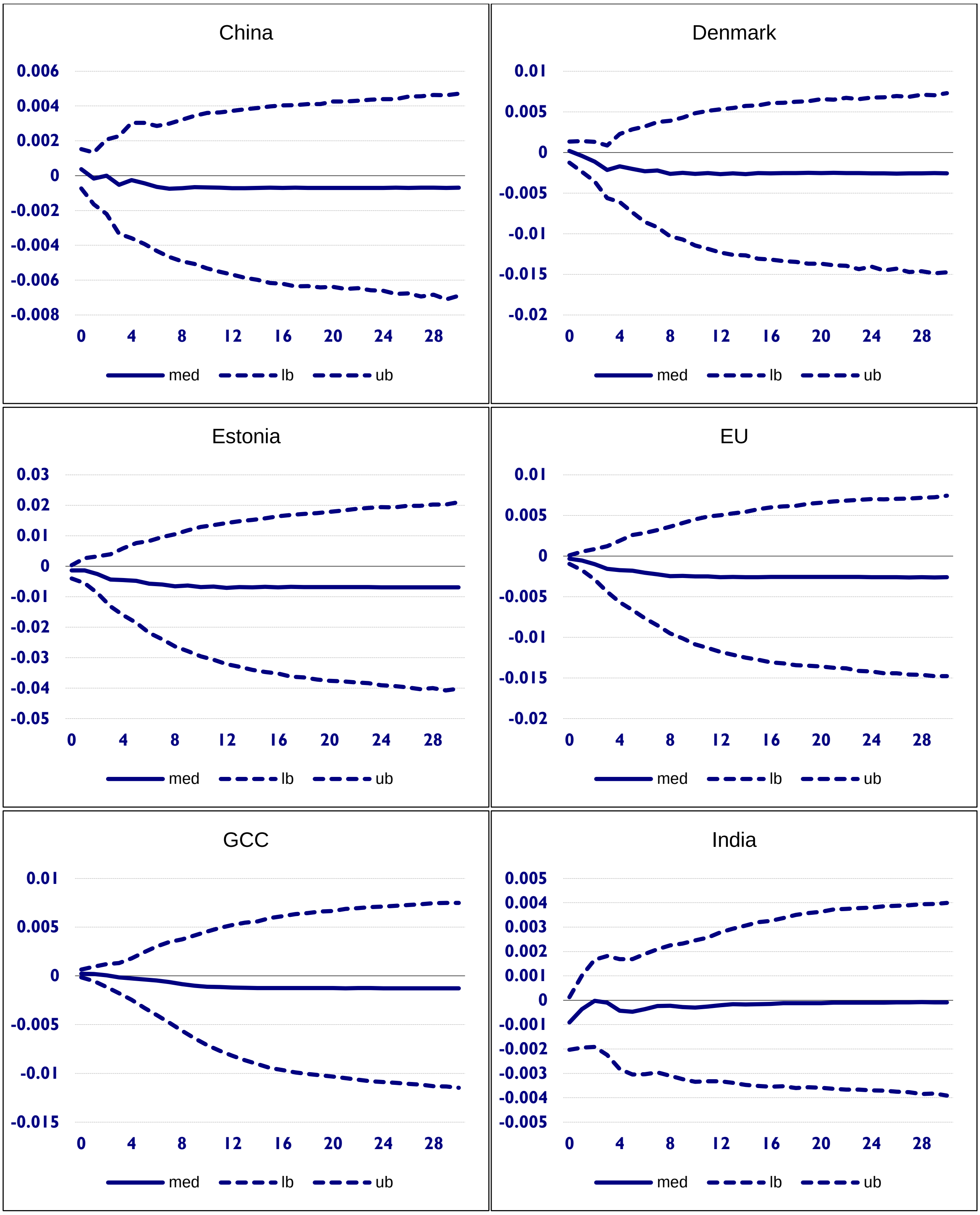
Models	*Domestic variables*						*Foreign variables*				
CHINA	y	dp	eq	st			y*	dp*	eq*	st*	lt*
DENMARK	y	dp	eq	st	lt		y*	dp*	eq*	st*	lt*
ESTONIA	y	dp		st	lt		y*	dp*	eq*	st*	lt*
EURO	y	dp	eq	st	lt		y*	dp*	eq*	st*	lt*
GCC	y	dp		st		Oil quantity	y*	dp*	eq*	st*	lt*
INDIA	y	dp	eq		lt		y*	dp*	eq*	st*	lt*
JAPAN	y	dp	eq	st	lt		y*	dp*	eq*	st*	lt*
LATVIA	y	dp		st			y*	dp*	eq*	st*	lt*
LITHUANIA	y	dp		st			y*	dp*	eq*	st*	lt*
NORWAY	y	dp	eq		lt		y*	dp*	eq*	st*	lt*
POLAND	y	dp	eq	st			y*	dp*	eq*	st*	lt*
RUSSIA	y	dp		st	lt		y*	dp*	eq*	st*	lt*
SWEDEN	y	dp	eq	st	lt		y*	dp*	eq*	st*	lt*
UK	y	dp	eq	st	lt		y*	dp*	eq*	st*	lt*
USA	y	dp	eq	st	lt	Oil price	y*	dp*			

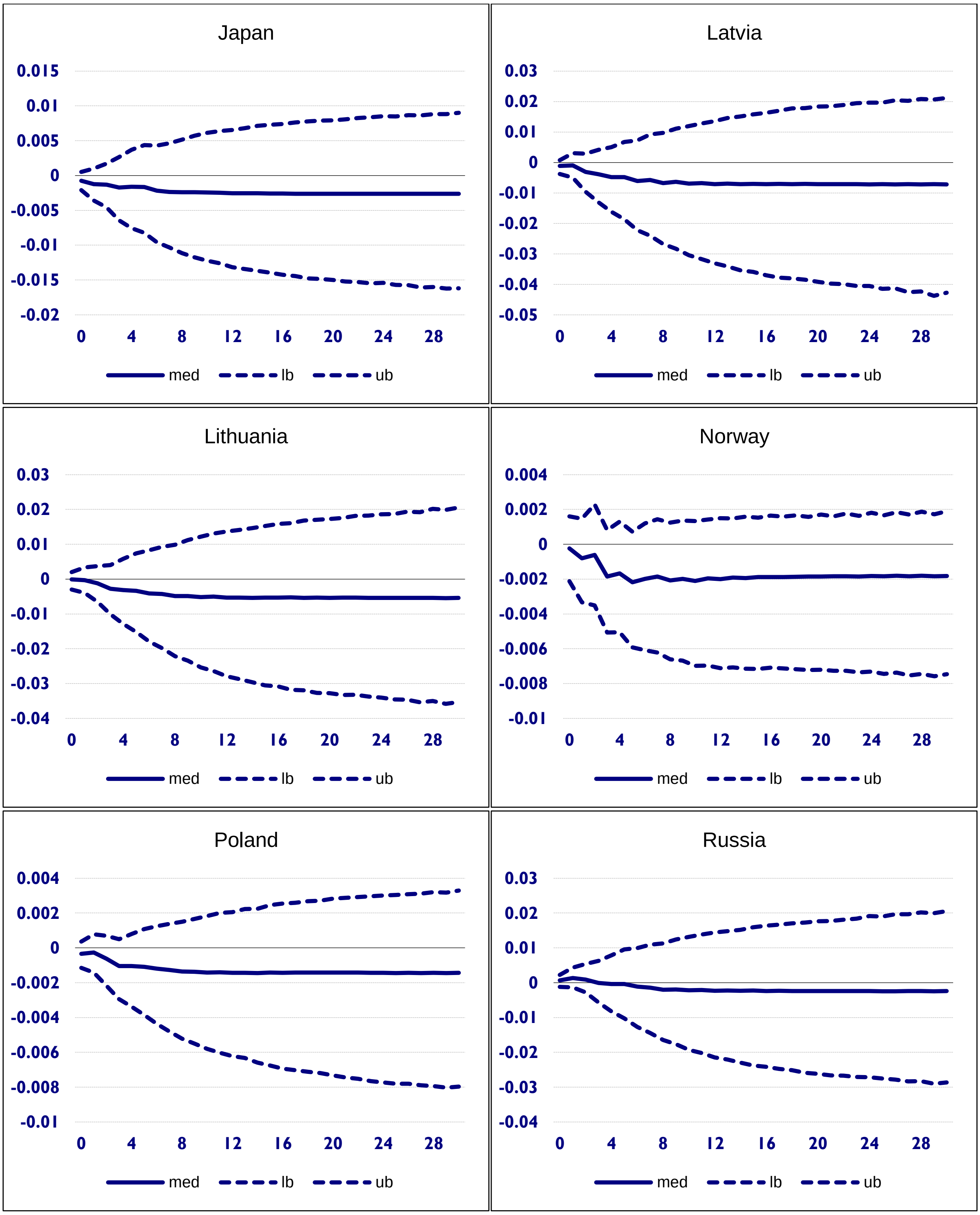
Source: created by the authors

Data Appendix 4

Impulse response functions to a negative supply shock with 5000 bootstrap replications. X-axis is measured in percentage points, and y-axis depicts number of quarters. Abbreviations med, lb, and ub deciphered as median, lower bound, and upper bound respectively.

Real GDP


China
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
0 4 8 12 16 20 24 28
med lb ub
Denmark
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
0 4 8 12 16 20 24 28
med lb ub
Estonia
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
0 4 8 12 16 20 24 28
med lb ub
EU
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
0 4 8 12 16 20 24 28
med lb ub
GCC
0.01
0.005
0
-0.005
-0.01
-0.015
0 4 8 12 16 20 24 28
med lb ub
India
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
0 4 8 12 16 20 24 28
med lb ub


Japan
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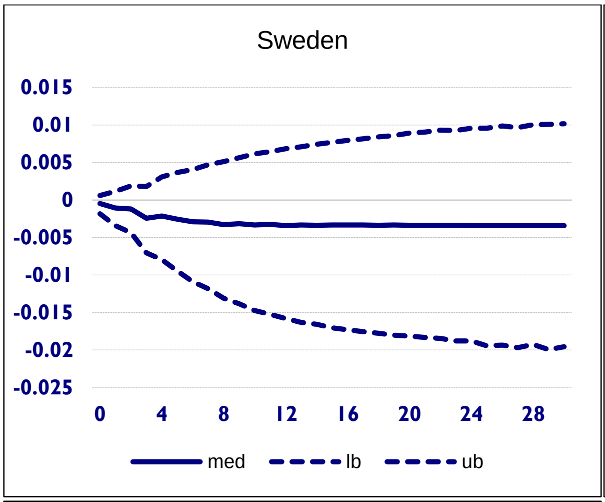
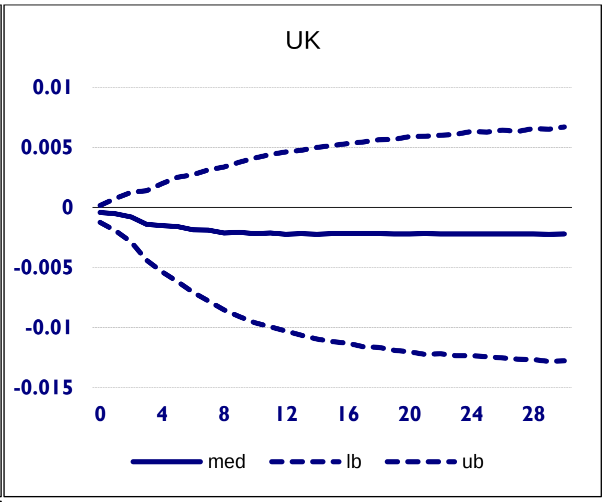
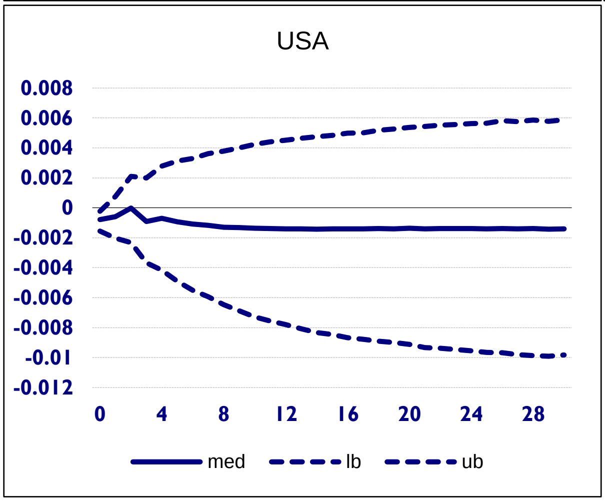
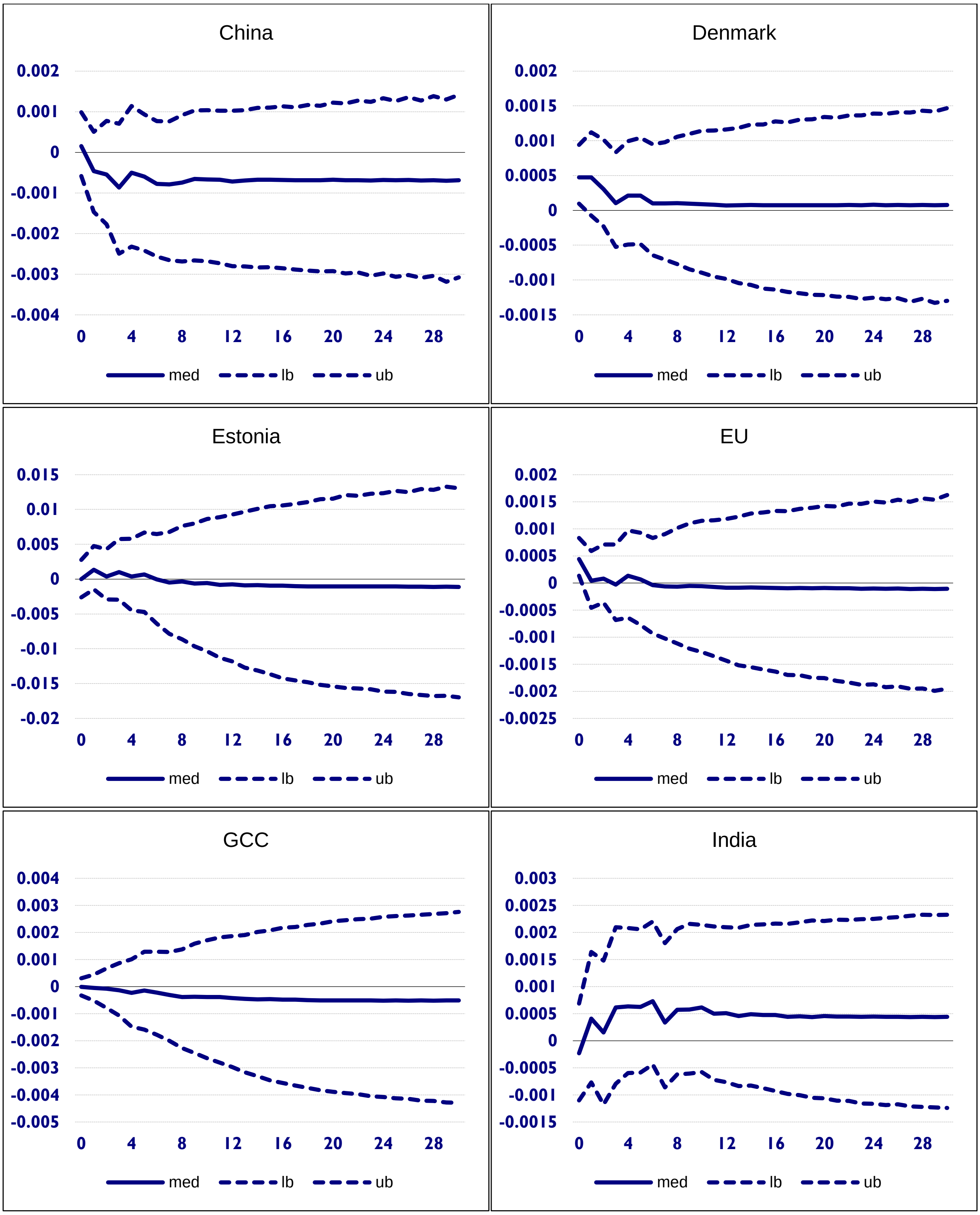
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
0
4
8
12
16
20
24
28
med
lb
ub
Latvia
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
Lithuania
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
Norway
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
Poland
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
Russia
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04

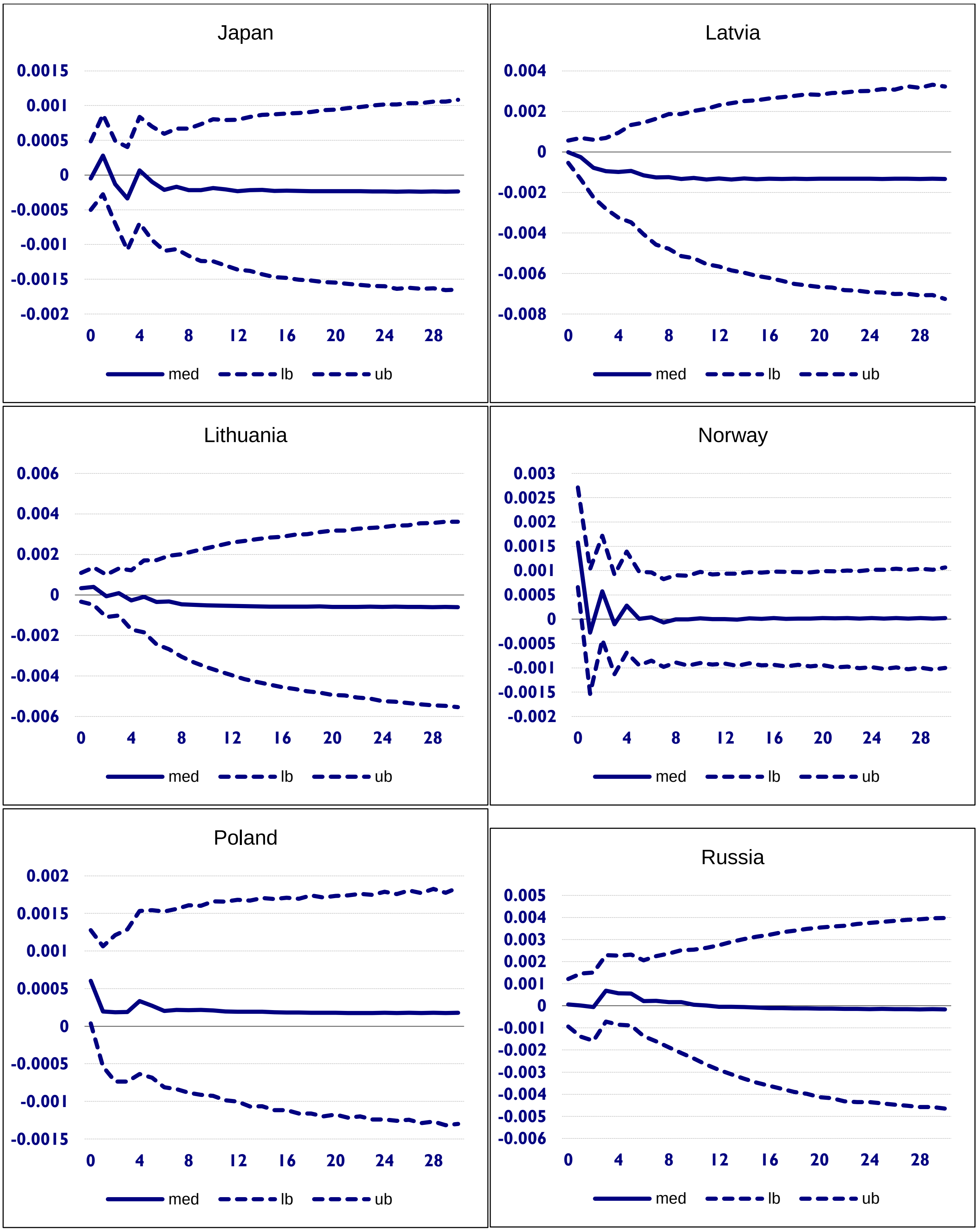




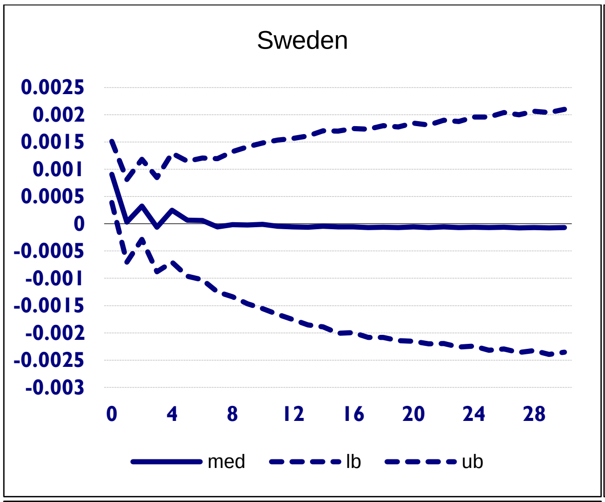


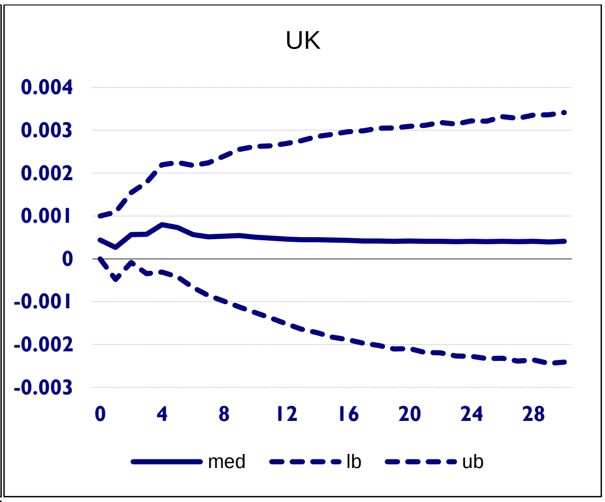
The rate of inflation

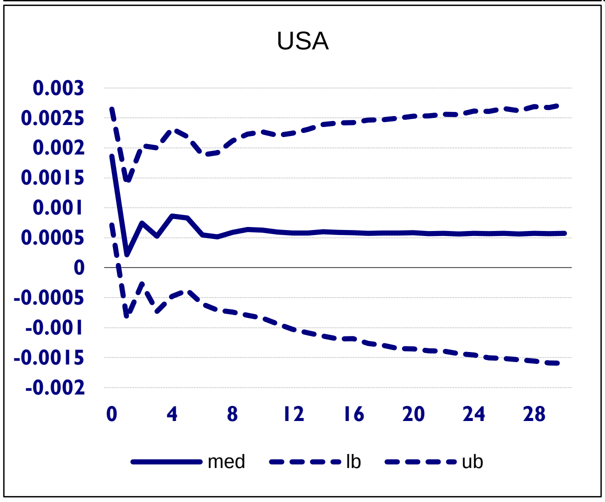

China
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
0 4 8 12 16 20 24 28
med lb ub
Denmark
0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
0 4 8 12 16 20 24 28
med lb ub
Estonia
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
0 4 8 12 16 20 24 28
med lb ub
EU
0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
-0.0025
0 4 8 12 16 20 24 28
med lb ub
GCC
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
0 4 8 12 16 20 24 28
med lb ub
India
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
0 4 8 12 16 20 24 28
med lb ub



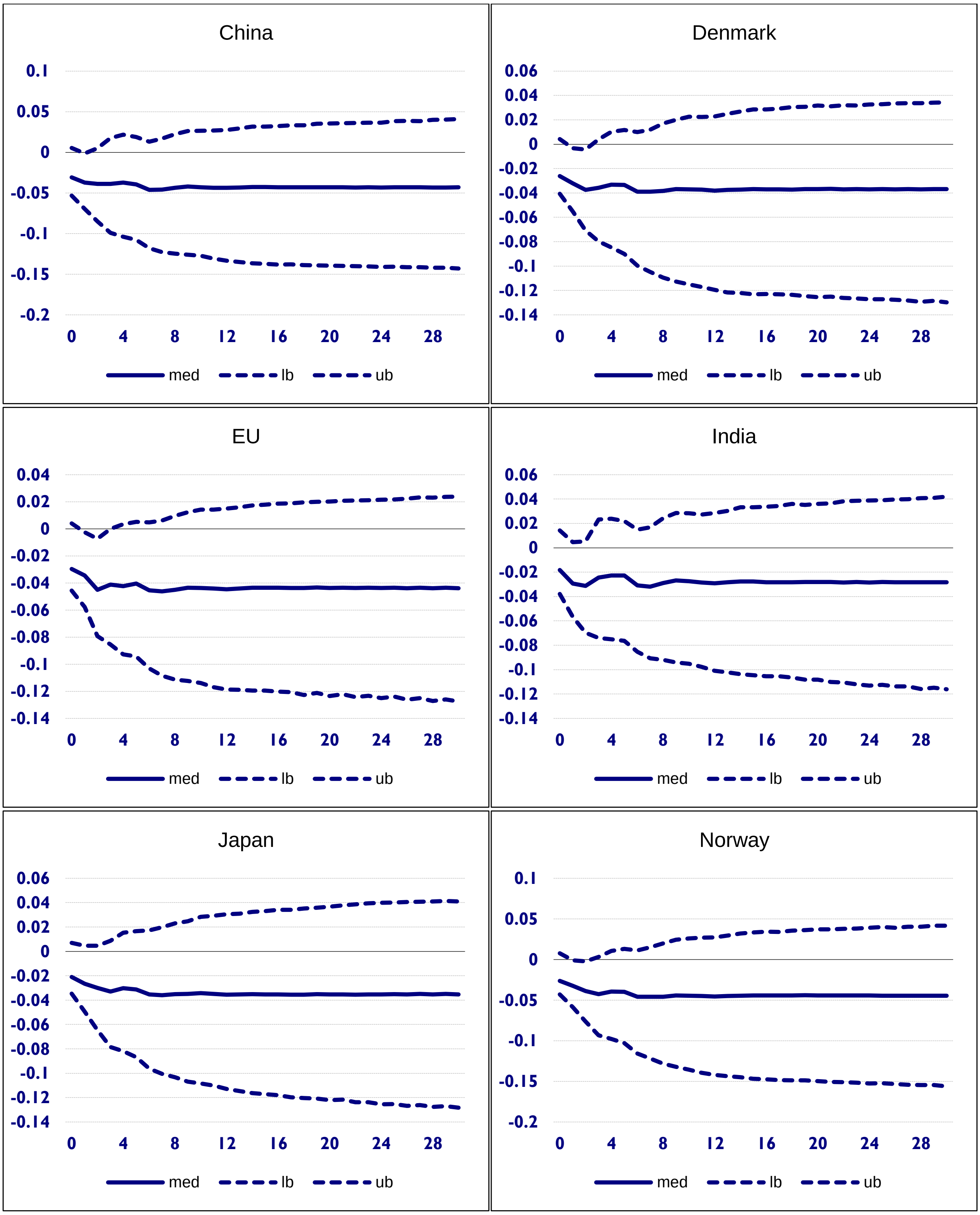
Japan
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
0 4 8 12 16 20 24 28
med lb ub
Latvia
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
0 4 8 12 16 20 24 28
med lb ub
Lithuania
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
0 4 8 12 16 20 24 28
med lb ub
Norway
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
0 4 8 12 16 20 24 28
med lb ub
Poland
0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
0 4 8 12 16 20 24 28
med lb ub
Russia
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
0 4 8 12 16 20 24 28
med lb ub

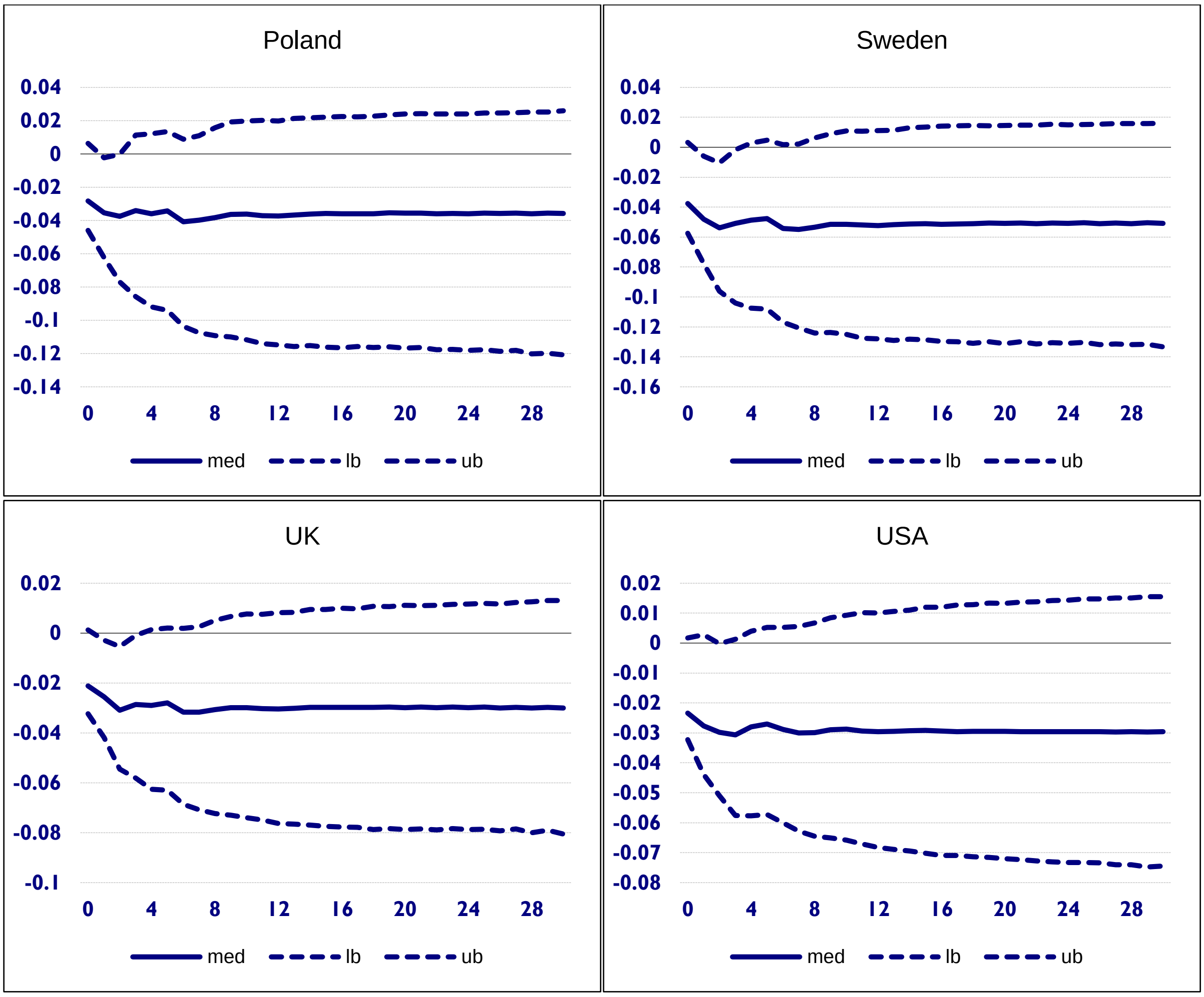




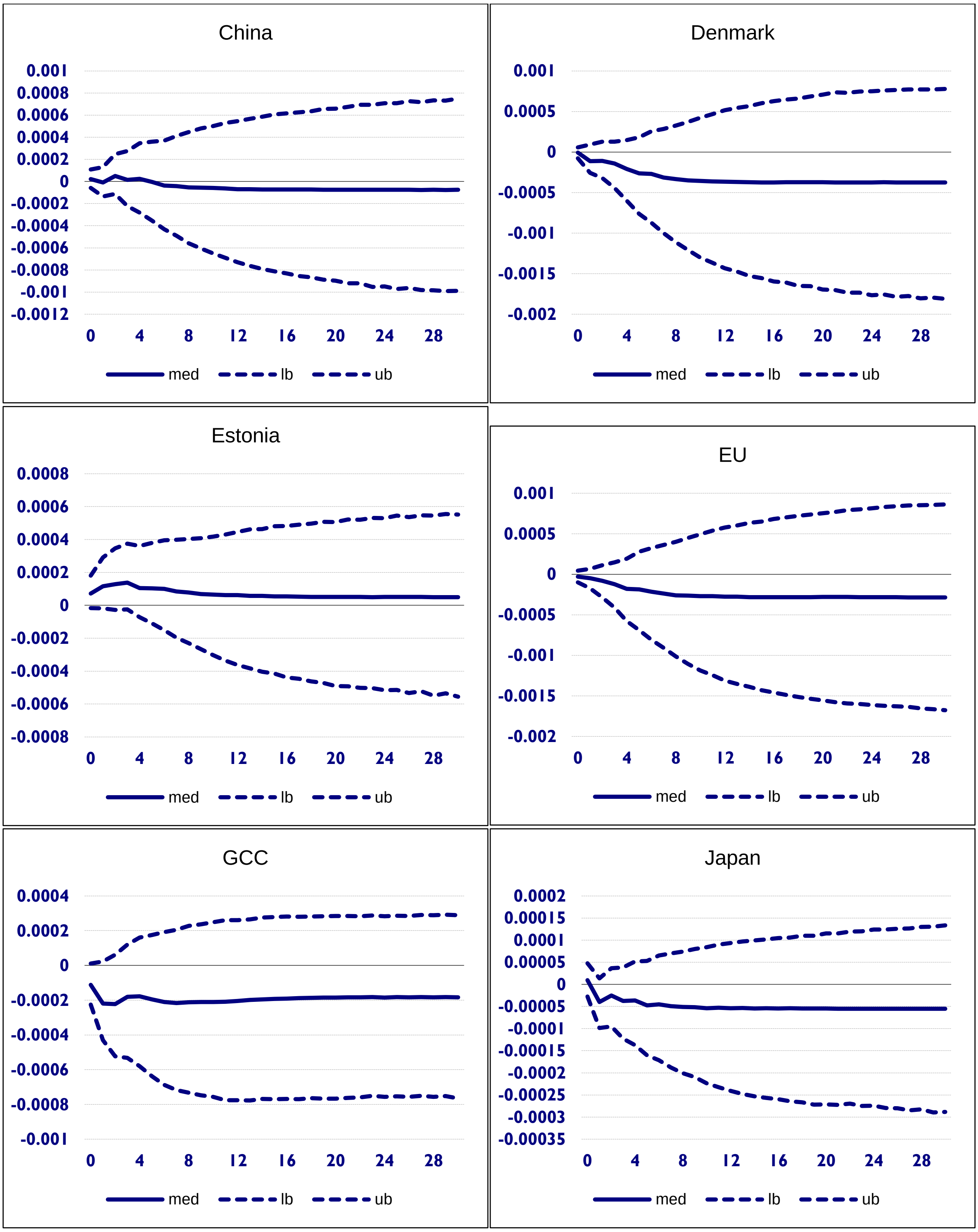


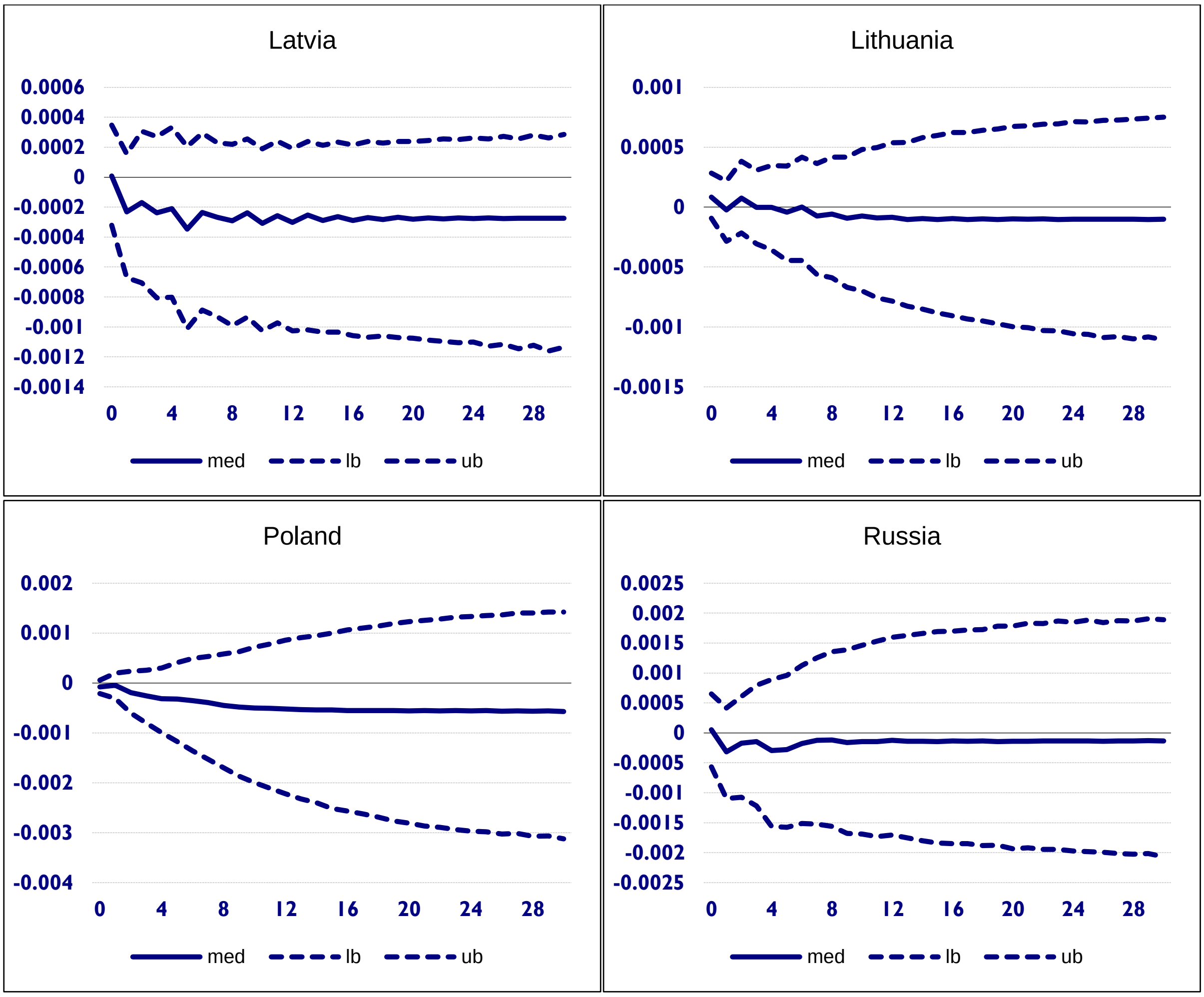
Equity index

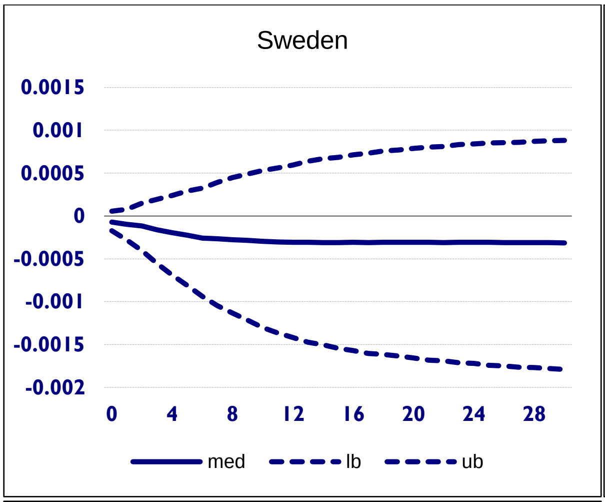

China
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
0 4 8 12 16 20 24 28
med lb ub
Denmark
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
0 4 8 12 16 20 24 28
med lb ub
EU
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
0 4 8 12 16 20 24 28
med lb ub
India
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
0 4 8 12 16 20 24 28
med lb ub
Japan
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
0 4 8 12 16 20 24 28
med lb ub
Norway
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
0 4 8 12 16 20 24 28
med lb ub

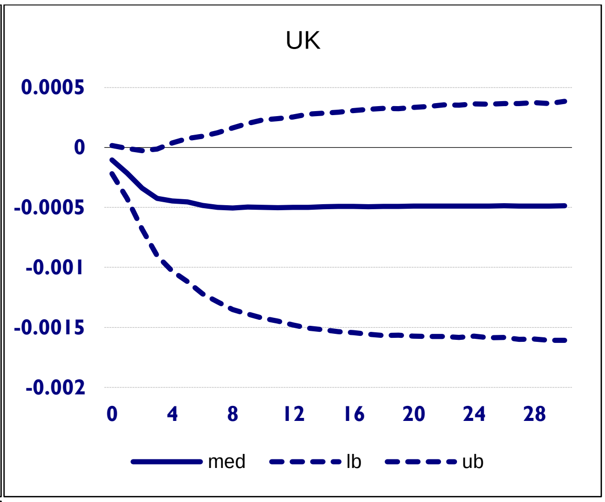


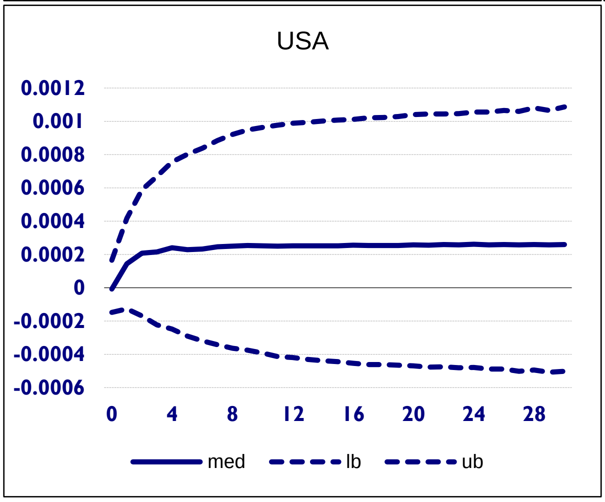
Short-term interest rate


China
0.001
0.0008
0.0006
0.0004
0.0002
0
-0.0002
-0.0004
-0.0006
-0.0008
-0.001
-0.0012
0 4 8 12 16 20 24 28
med lb ub
Denmark
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
0 4 8 12 16 20 24 28
med lb ub
Estonia
0.0008
0.0006
0.0004
0.0002
0
-0.0002
-0.0004
-0.0006
-0.0008
0 4 8 12 16 20 24 28
med lb ub
EU
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
0 4 8 12 16 20 24 28
med lb ub
GCC
0.0004
0.0002
0
-0.0002
-0.0004
-0.0006
-0.0008
-0.001
0 4 8 12 16 20 24 28
med lb ub
Japan
0.0002
0.00015
0.0001
0.00005
0
-0.00005
-0.0001
-0.00015
-0.0002
-0.00025
-0.0003
-0.00035
0 4 8 12 16 20 24 28
med lb ub

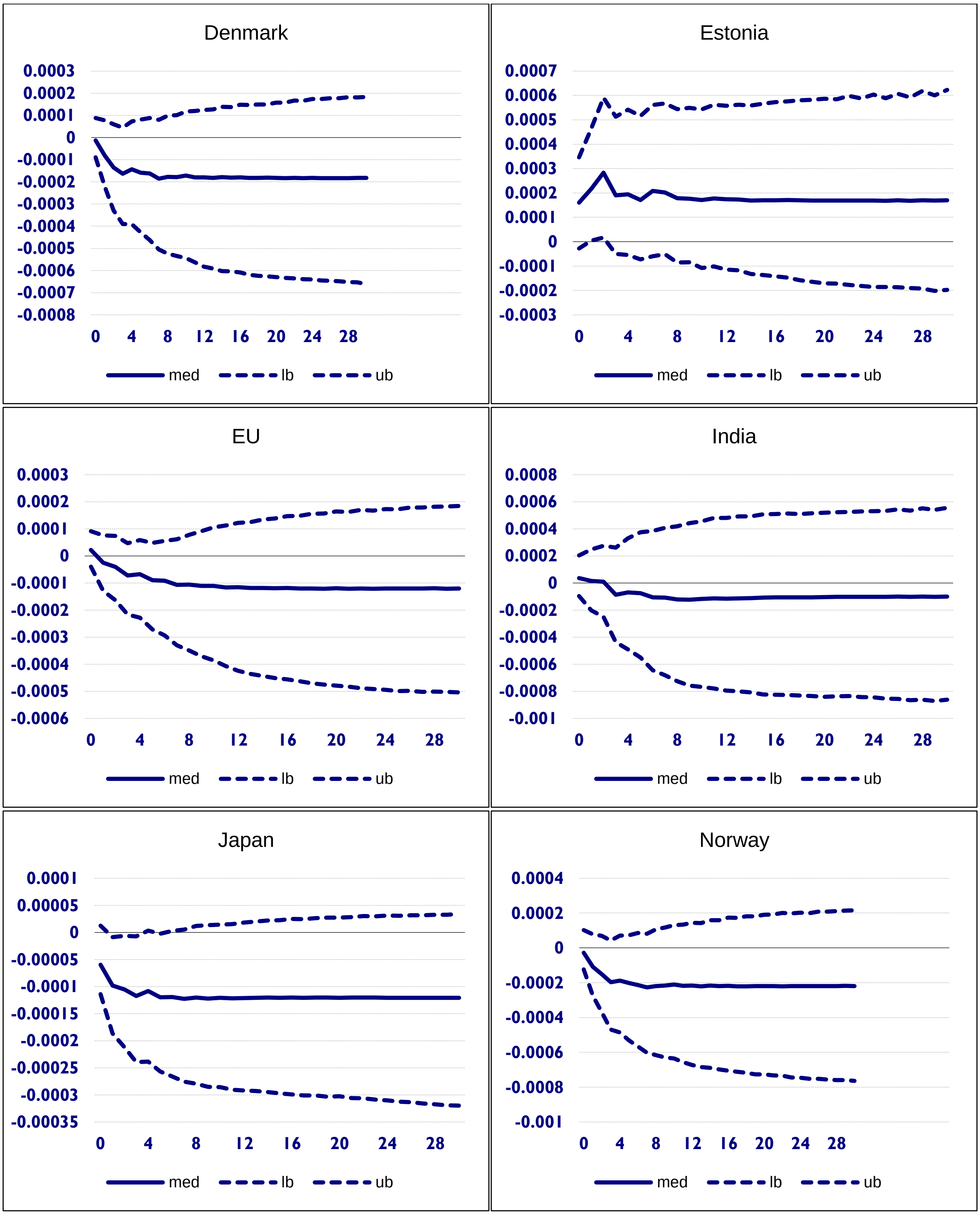

Latvia
0.0006
0.0004
0.0002
0
-0.0002
-0.0004
-0.0006
-0.0008
-0.001
-0.0012
-0.0014
0 4 8 12 16 20 24 28
med lb ub
Lithuania
0.001
0.0005
0
-0.0005
-0.001
-0.0015
0 4 8 12 16 20 24 28
med lb ub
Poland
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
0 4 8 12 16 20 24 28
med lb ub
Russia
0.0025
0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
-0.0025
0 4 8 12 16 20 24 28
med lb ub

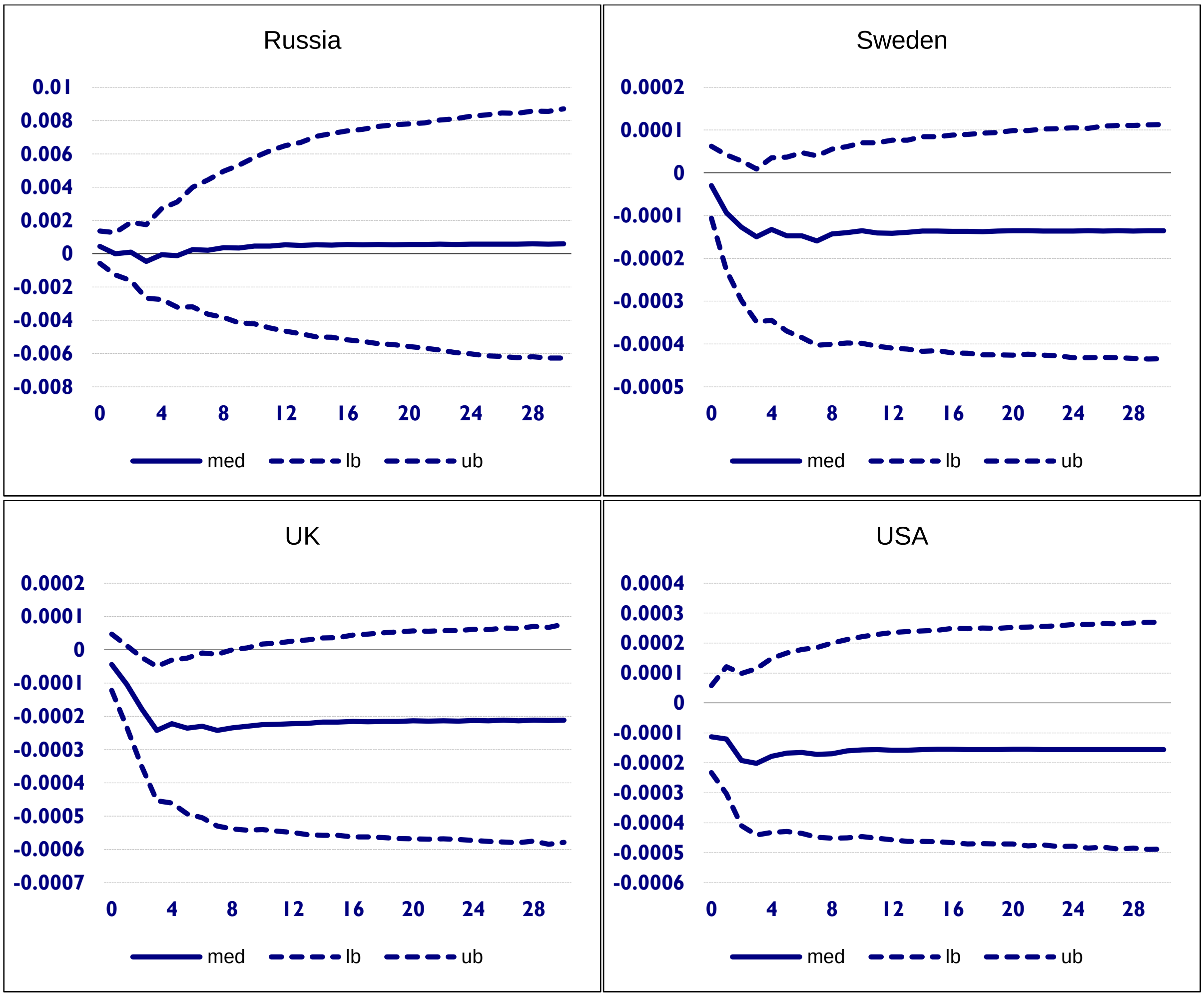






Long-term interest rate

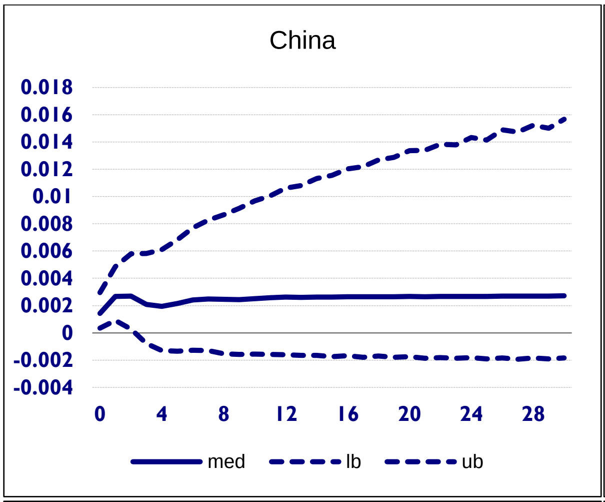

Denmark
0.0003
0.0002
0.0001
0
-0.0001
-0.0002
-0.0003
-0.0004
-0.0005
-0.0006
-0.0007
-0.0008
0 4 8 12 16 20 24 28
med lb ub
Estonia
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
-0.0001
-0.0002
-0.0003
0 4 8 12 16 20 24 28
med lb ub
EU
0.0003
0.0002
0.0001
0
-0.0001
-0.0002
-0.0003
-0.0004
-0.0005
-0.0006
0 4 8 12 16 20 24 28
med lb ub
India
0.0008
0.0006
0.0004
0.0002
0
-0.0002
-0.0004
-0.0006
-0.0008
-0.001
0 4 8 12 16 20 24 28
med lb ub
Japan
0.0001
0.00005
0
-0.00005
-0.0001
-0.00015
-0.0002
-0.00025
-0.0003
-0.00035
0 4 8 12 16 20 24 28
med lb ub
Norway
0.0004
0.0002
0
-0.0002
-0.0004
-0.0006
-0.0008
-0.001
0 4 8 12 16 20 24 28
med lb ub

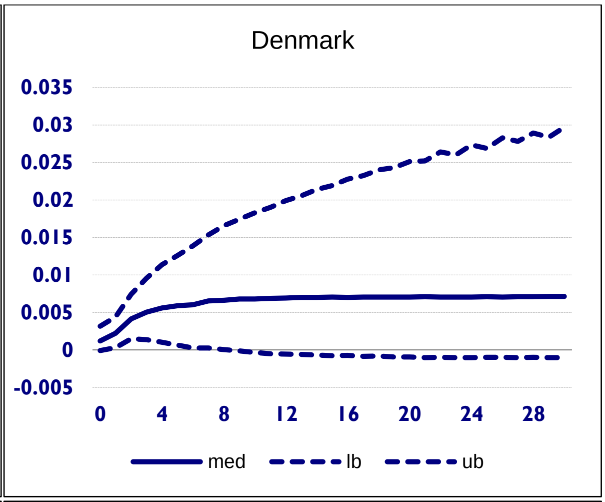


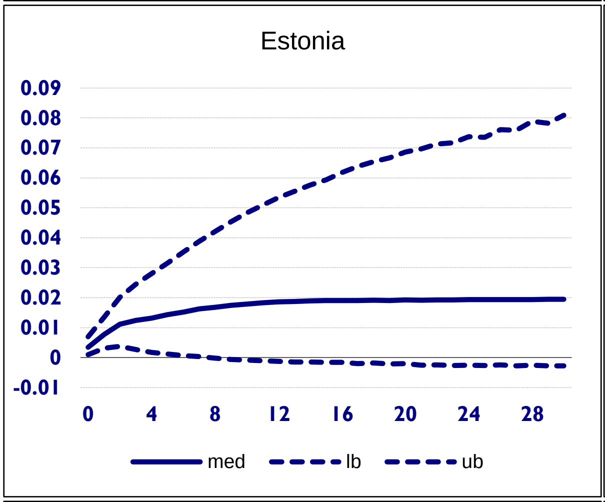
Data Appendix 5

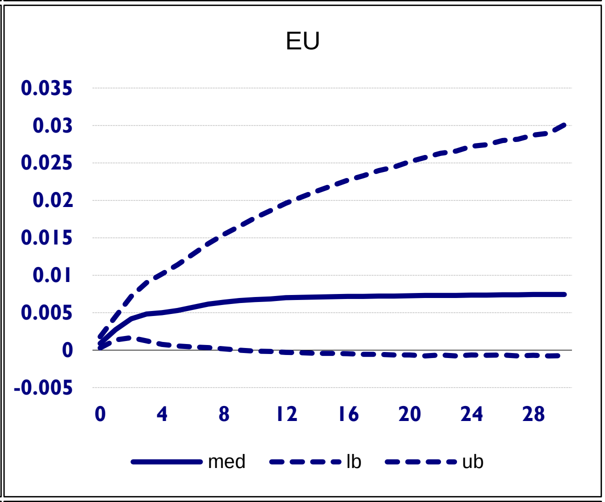
Impulse response functions to a positive demand shock with 5000 bootstrap replications. X-axis is measured in percentage points, number of quarters are depicted on y-axis. Abbreviations med, lb, and ub deciphered as median, lower bound, and upper bound respectively.

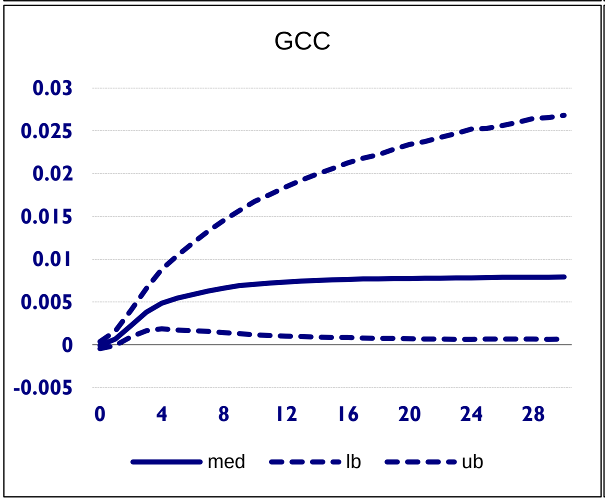
Real GDP

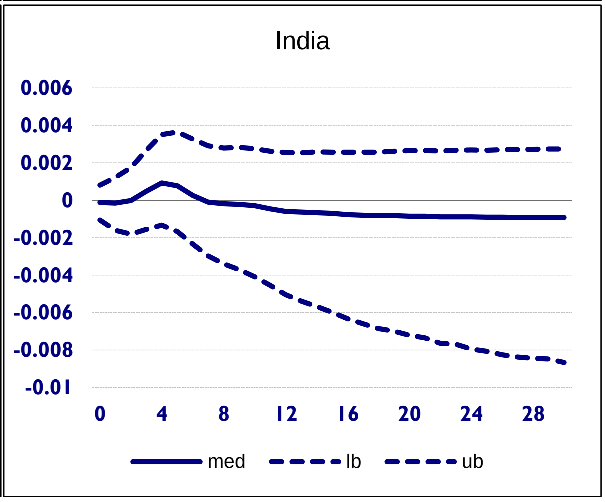

China
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
0 4 8 12 16 20 24 28
med lb ub

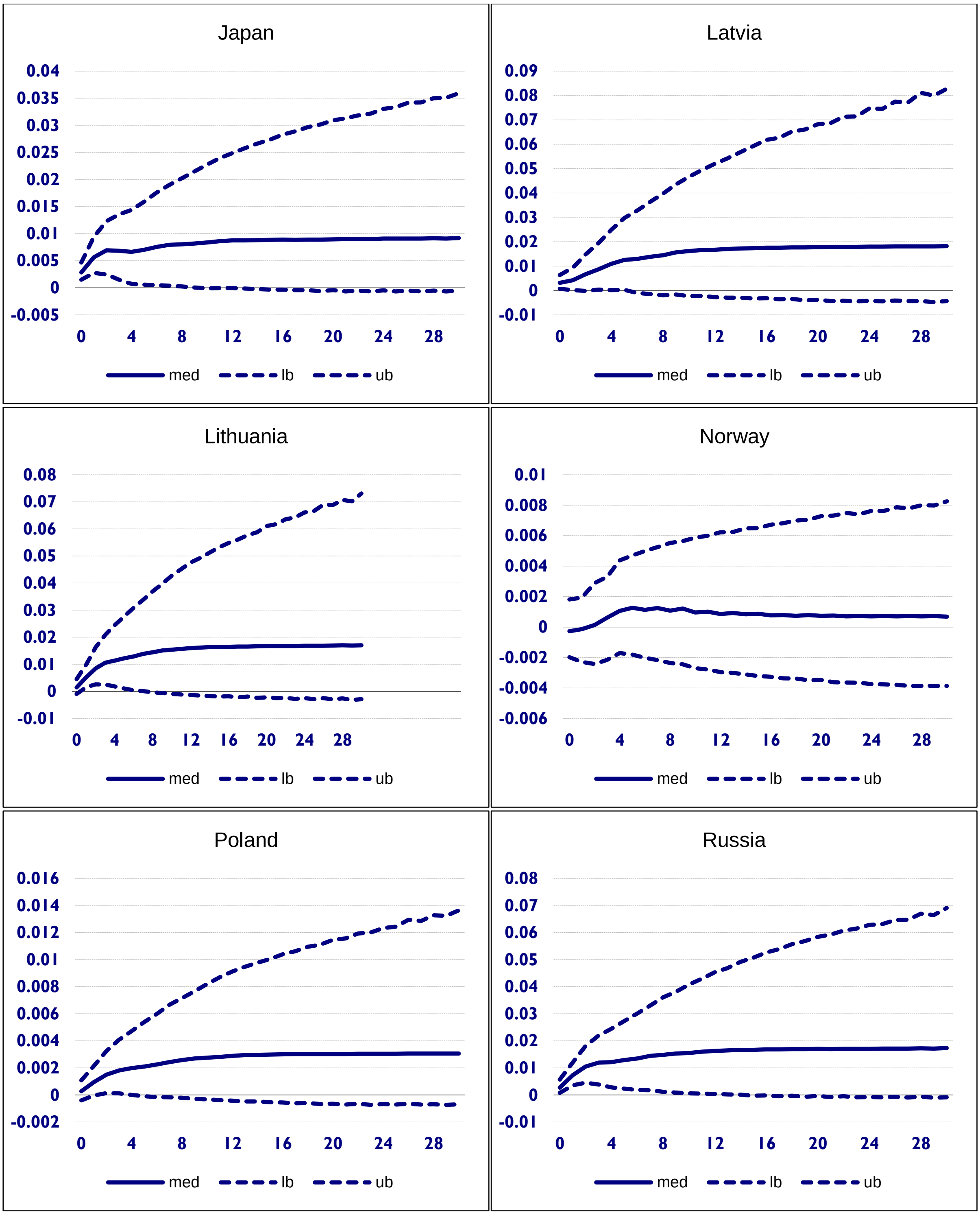

Denmark
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
0 4 8 12 16 20 24 28
med lb ub

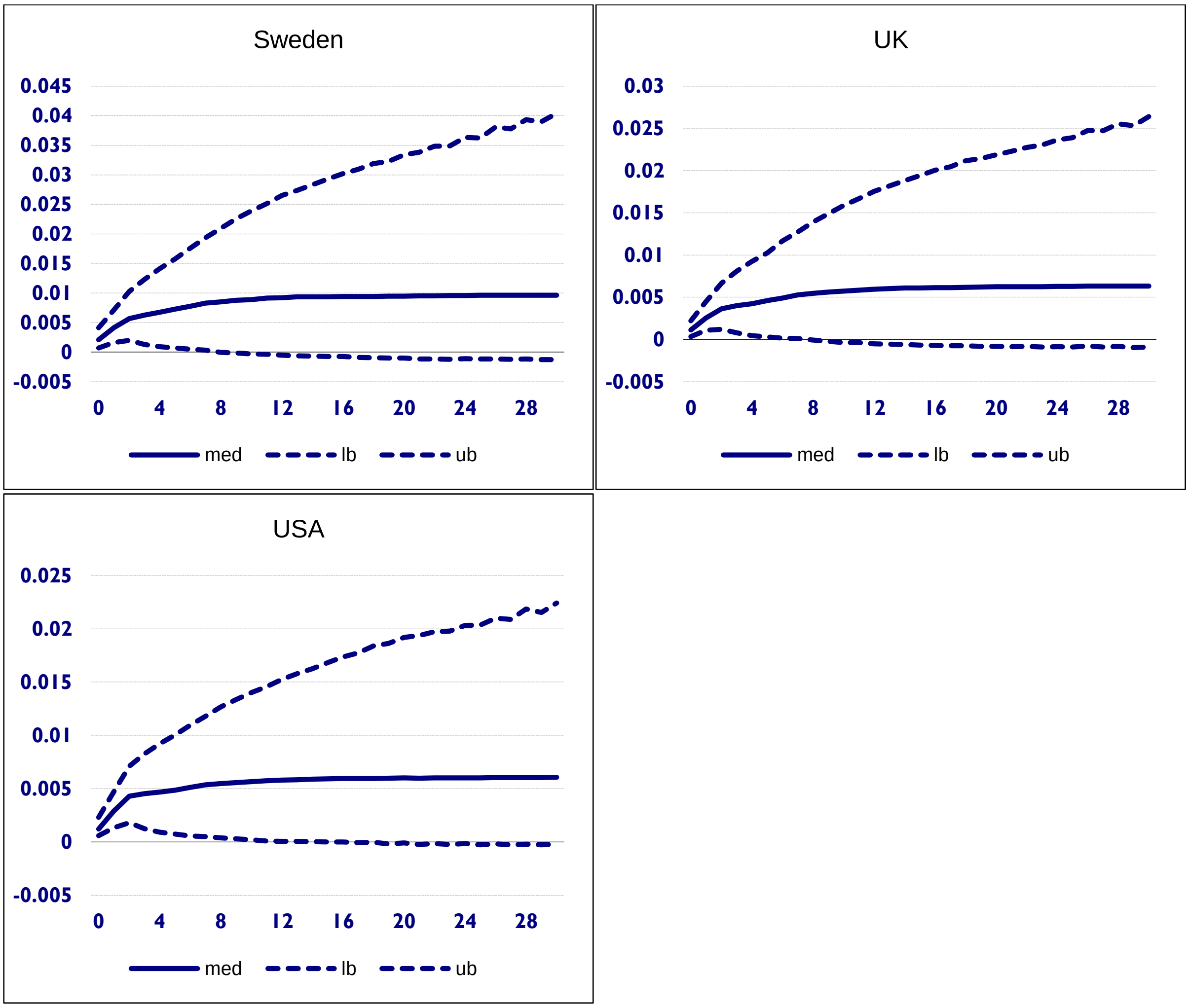

Estonia
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
0 4 8 12 16 20 24 28
med lb ub


EU
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
0 4 8 12 16 20 24 28
med lb ub

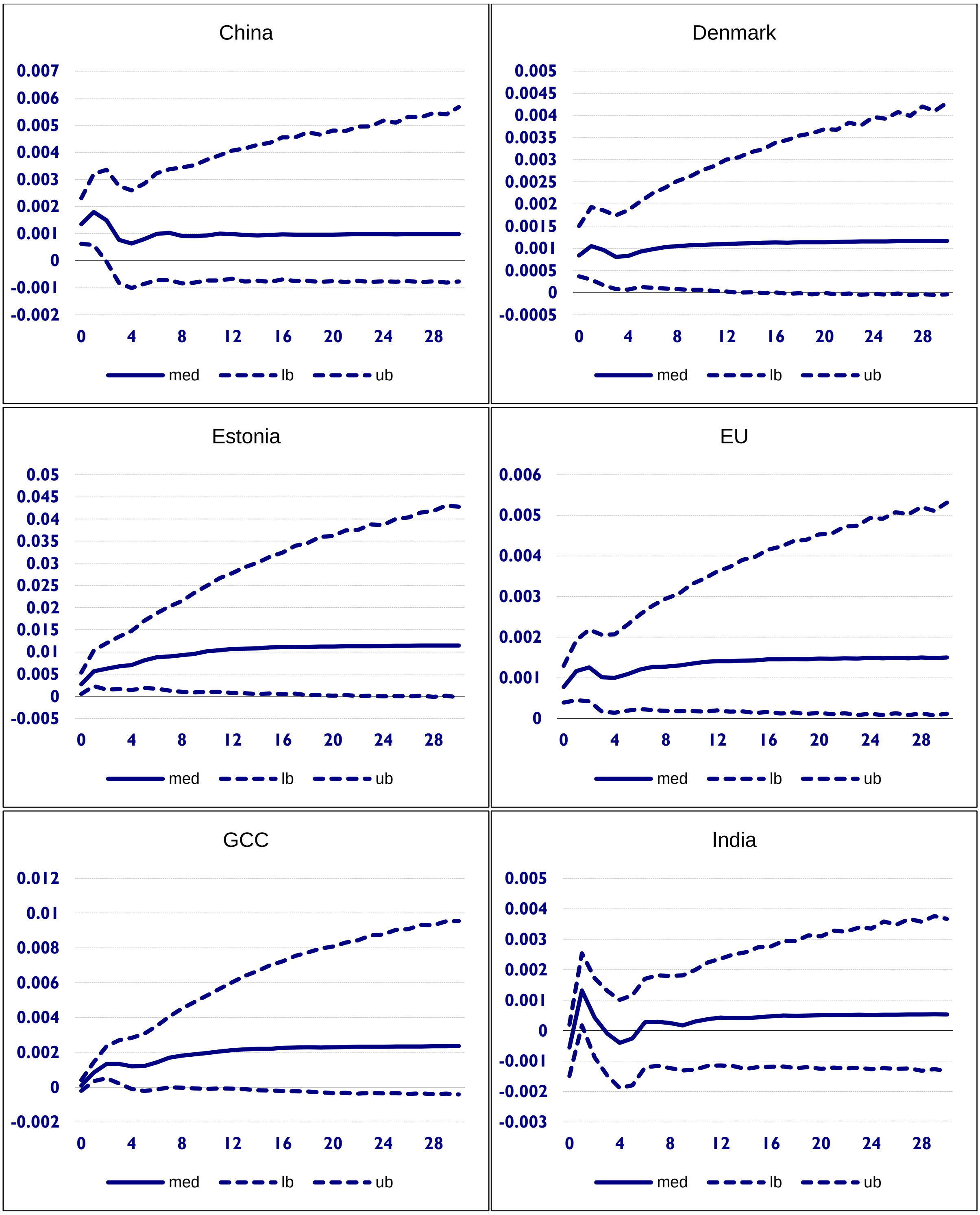

GCC
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
0 4 8 12 16 20 24 28
med lb ub

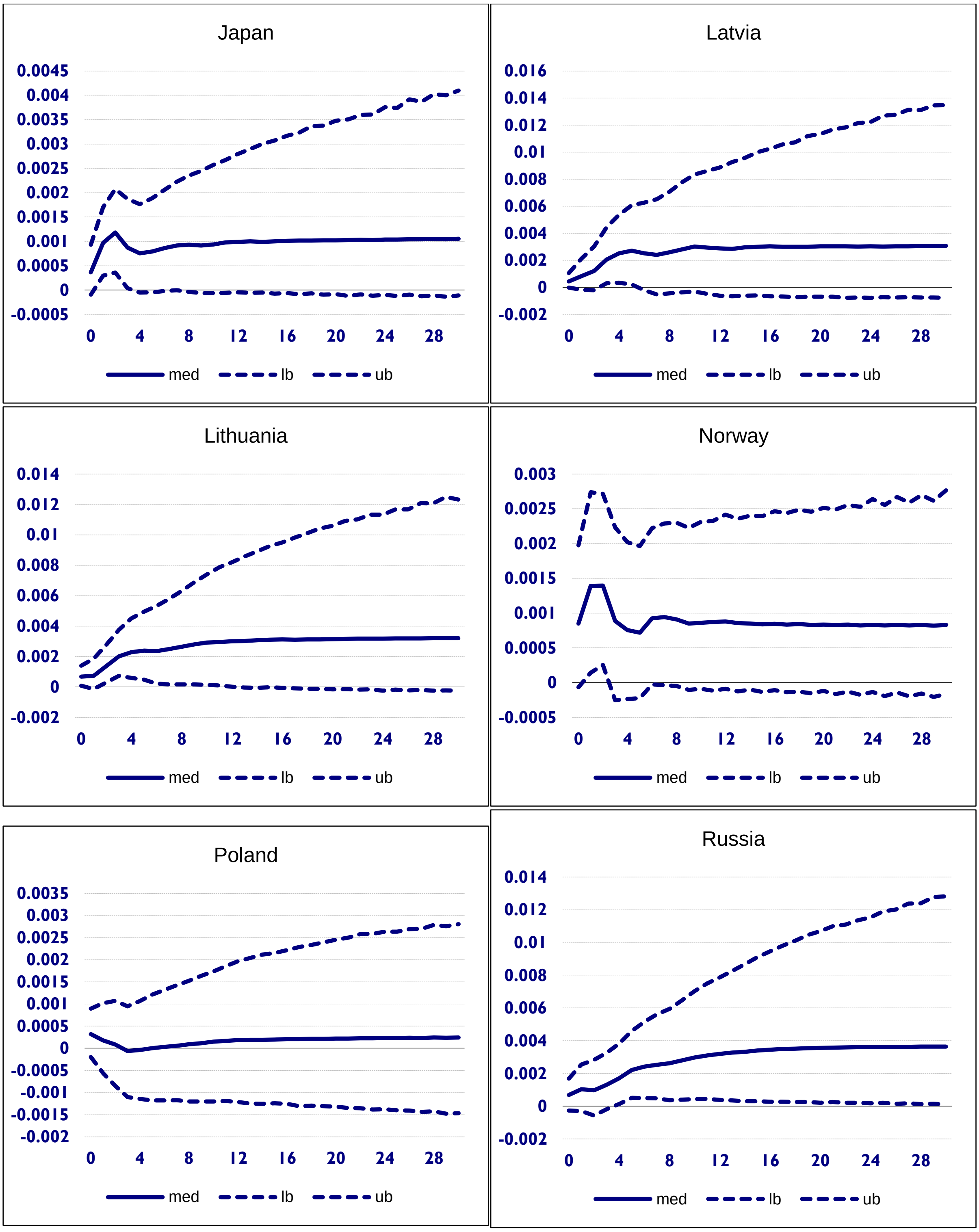

India
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
0 4 8 12 16 20 24 28
med lb ub

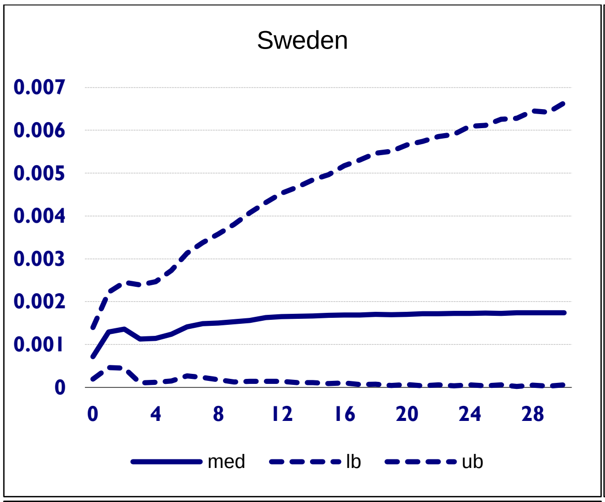

Japan
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
0 4 8 12 16 20 24 28
med lb ub
Latvia
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
0 4 8 12 16 20 24 28
med lb ub
Lithuania
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
0 4 8 12 16 20 24 28
med lb ub
Norway
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
0 4 8 12 16 20 24 28
med lb ub
Poland
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
0 4 8 12 16 20 24 28
med lb ub
Russia
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
0 4 8 12 16 20 24 28
med lb ub

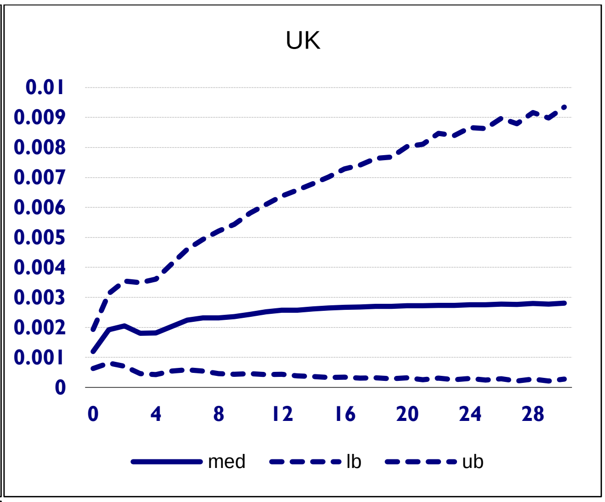


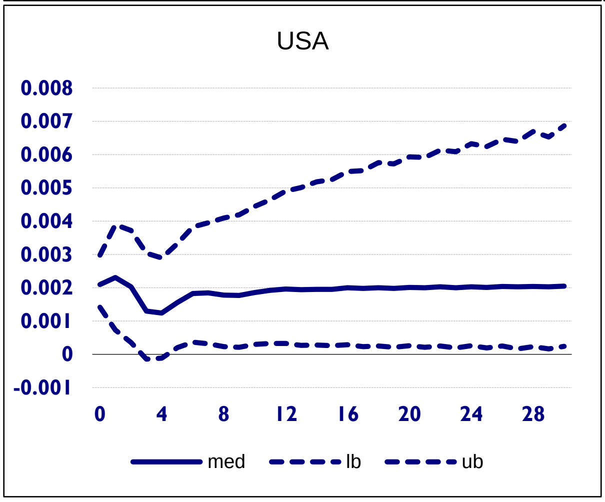
The rate of inflation


China
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
0 4 8 12 16 20 24 28
med lb ub
Denmark
0.005
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
-0.0005
0 4 8 12 16 20 24 28
med lb ub
Estonia
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
0 4 8 12 16 20 24 28
med lb ub
EU
0.006
0.005
0.004
0.003
0.002
0.001
0
0 4 8 12 16 20 24 28
med lb ub
GCC
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
0 4 8 12 16 20 24 28
med lb ub
India
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
0 4 8 12 16 20 24 28
med lb ub

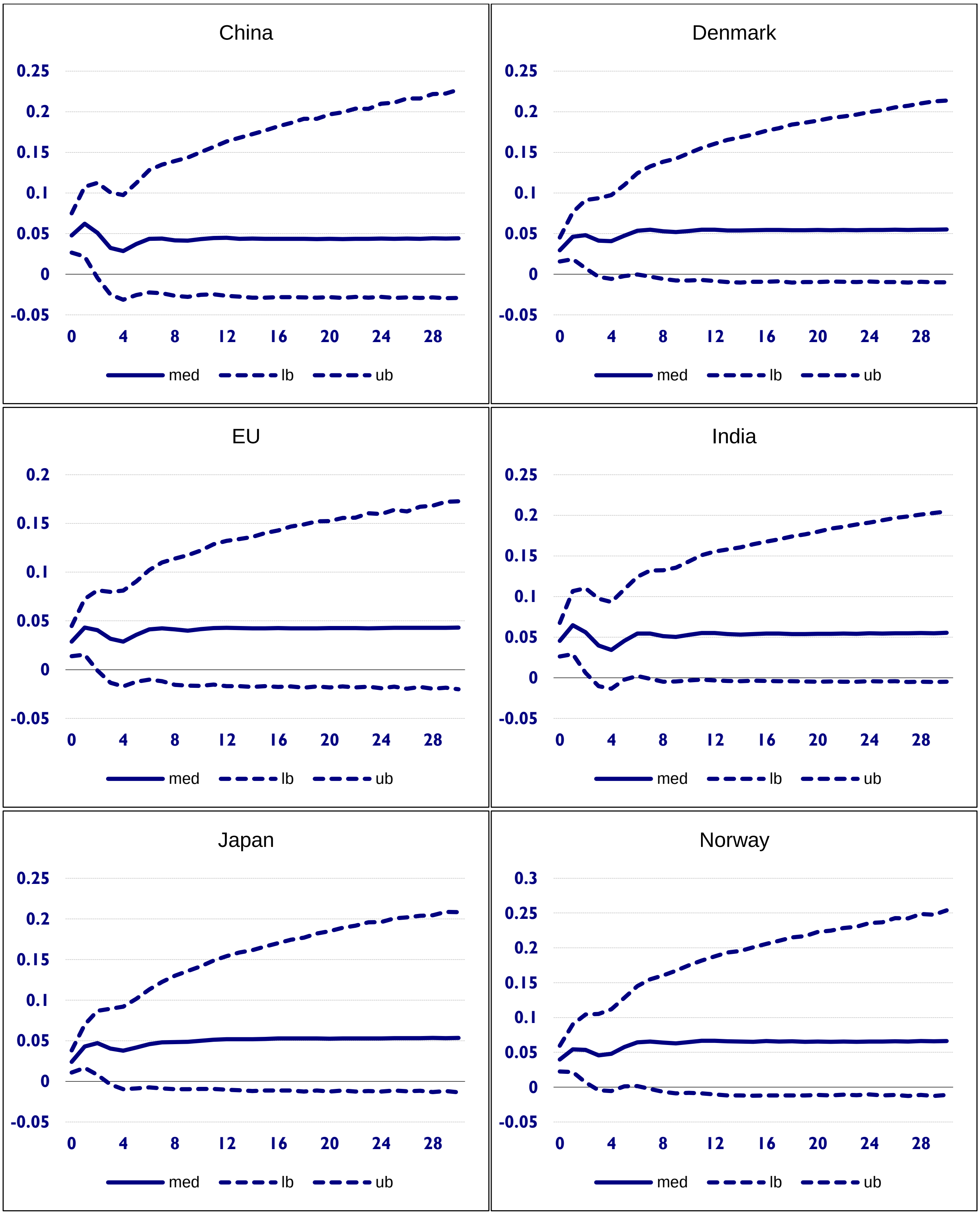

Japan
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
-0.0005
0 4 8 12 16 20 24 28
med lb ub
Latvia
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
0 4 8 12 16 20 24 28
med lb ub
Lithuania
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
0 4 8 12 16 20 24 28
med lb ub
Norway
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
-0.0005
0 4 8 12 16 20 24 28
med lb ub
Poland
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
0 4 8 12 16 20 24 28
med lb ub
Russia
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
0 4 8 12 16 20 24 28
med lb ub

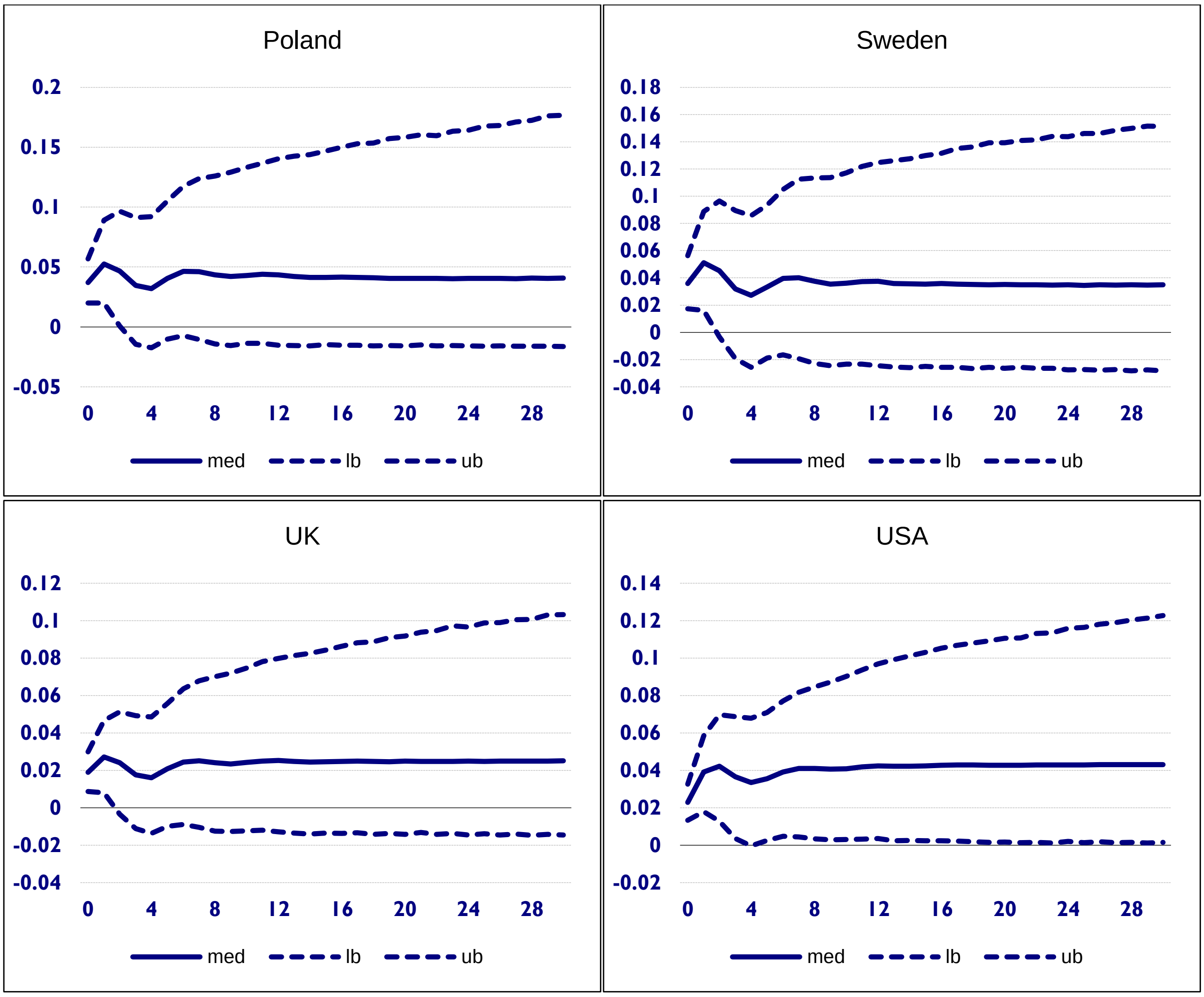




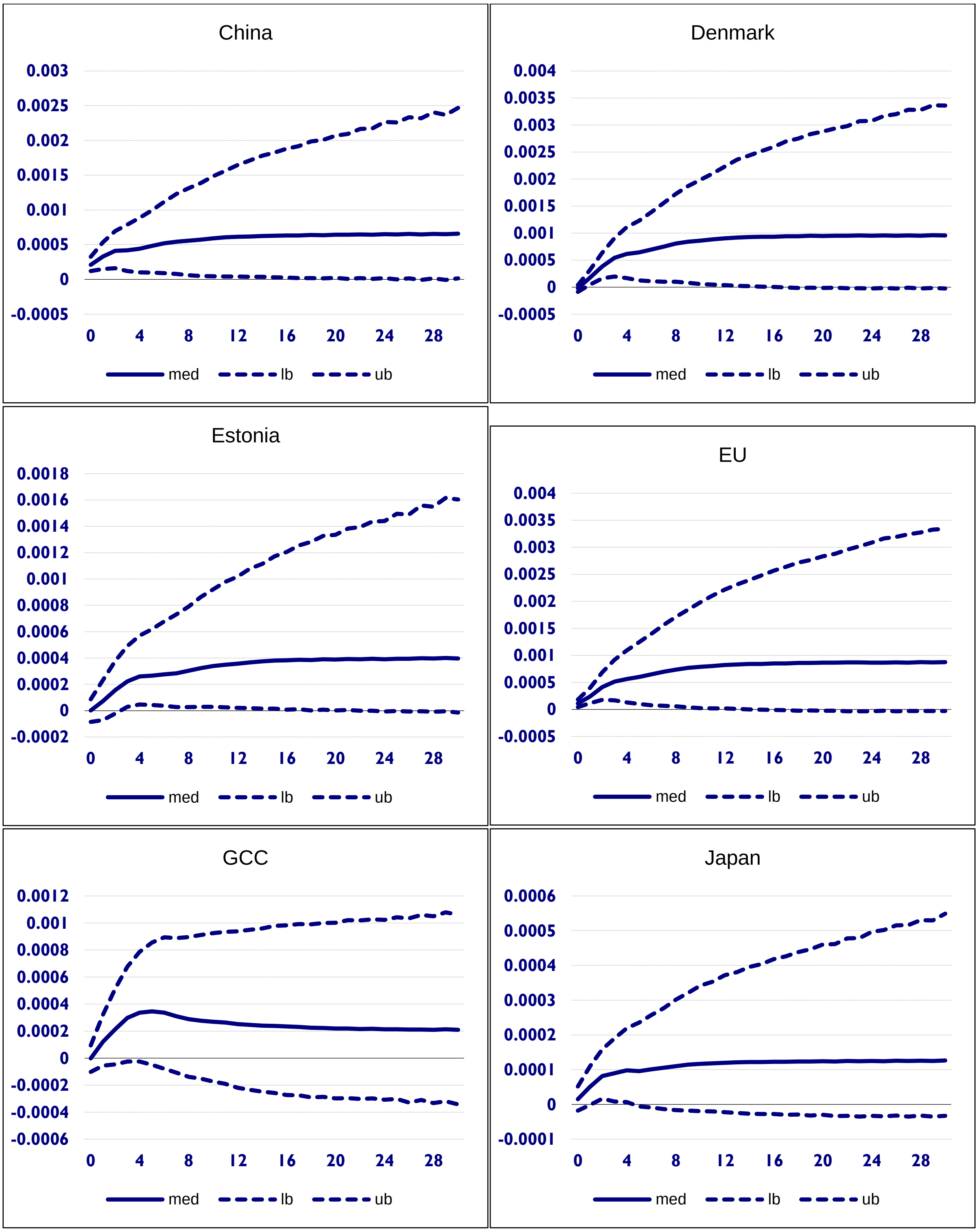


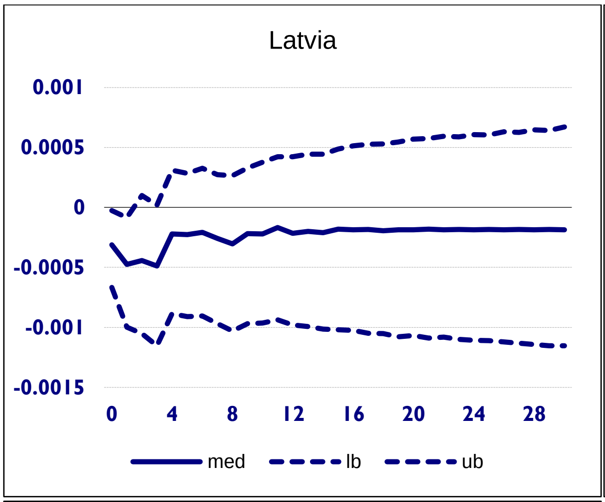
Equity index

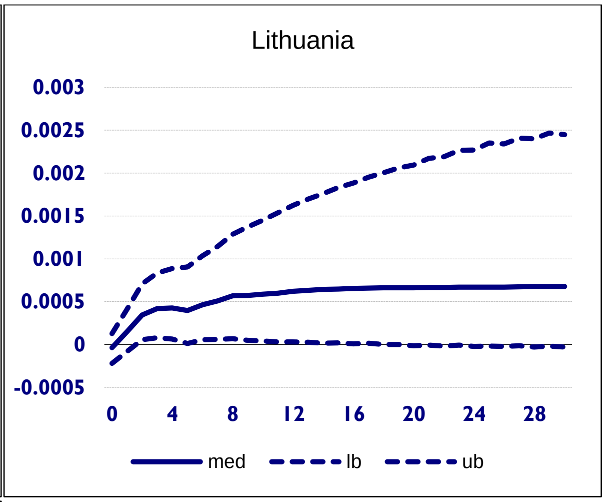

China
0.25
0.2
0.15
0.1
0.05
0
-0.05
0 4 8 12 16 20 24 28
med lb ub
Denmark
0.25
0.2
0.15
0.1
0.05
0
-0.05
0 4 8 12 16 20 24 28
med lb ub
EU
0.2
0.15
0.1
0.05
0
-0.05
0 4 8 12 16 20 24 28
med lb ub
India
0.25
0.2
0.15
0.1
0.05
0
-0.05
0 4 8 12 16 20 24 28
med lb ub
Japan
0.25
0.2
0.15
0.1
0.05
0
-0.05
0 4 8 12 16 20 24 28
med lb ub
Norway
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
0 4 8 12 16 20 24 28
med lb ub

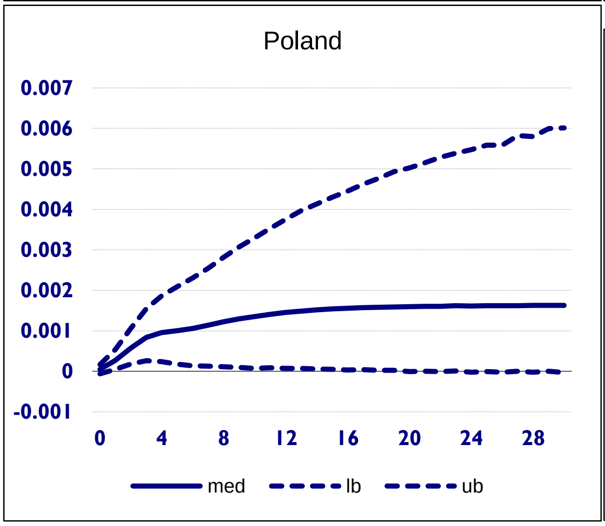


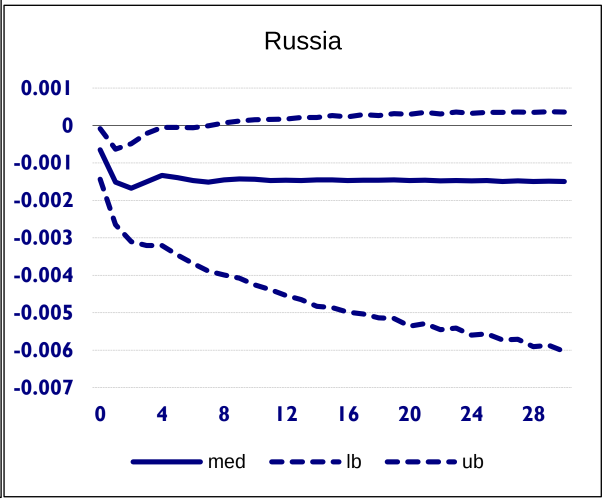
Short-term interest rate

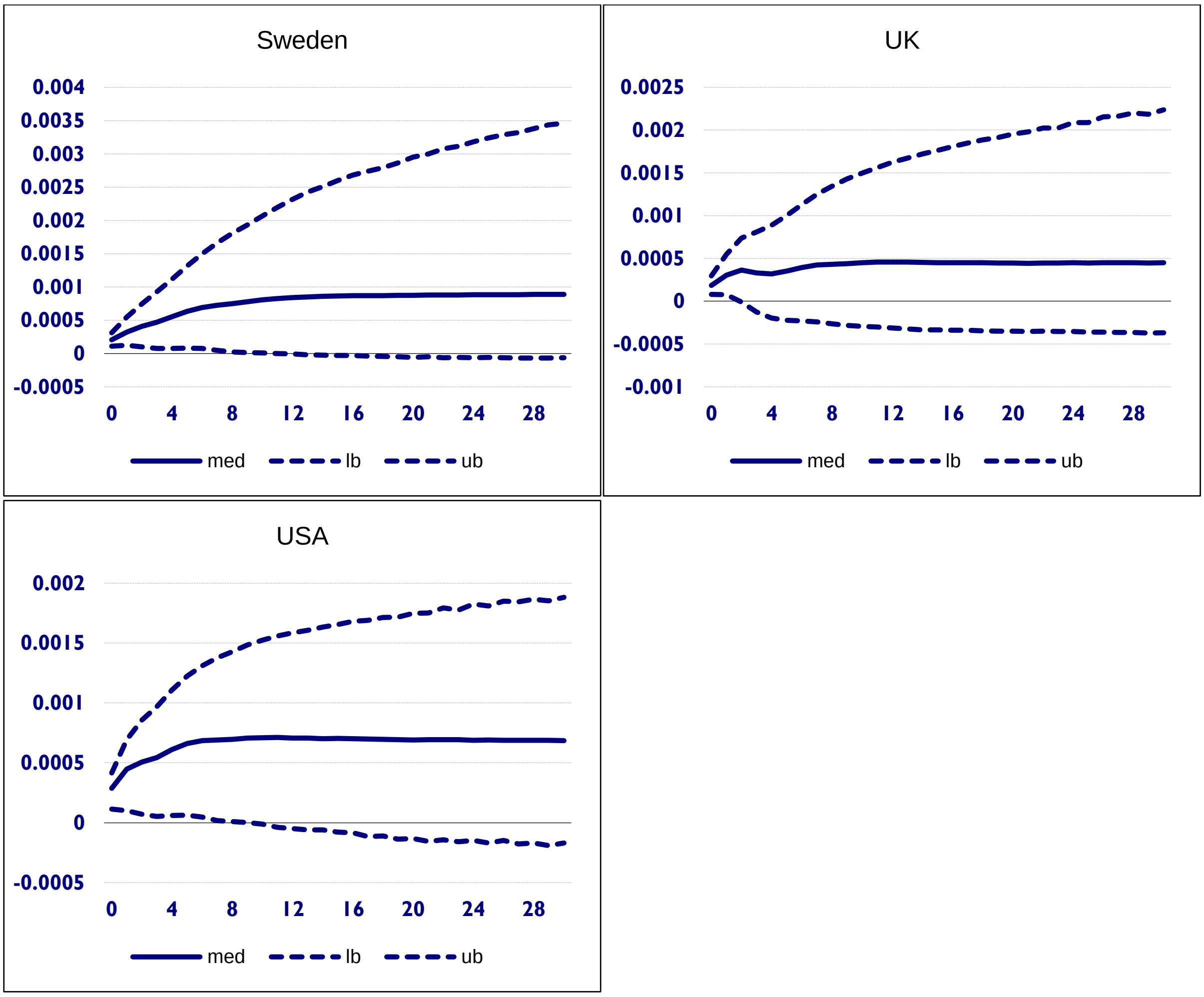

China
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
-0.0005
0 4 8 12 16 20 24 28
med lb ub
Denmark
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
-0.0005
0 4 8 12 16 20 24 28
med lb ub
Estonia
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
-0.0002
0 4 8 12 16 20 24 28
med lb ub
EU
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
-0.0005
0 4 8 12 16 20 24 28
med lb ub
GCC
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
-0.0002
-0.0004
-0.0006
0 4 8 12 16 20 24 28
med lb ub
Japan
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
-0.0001
0 4 8 12 16 20 24 28
med lb ub


Latvia
0.001
0.0005
0
-0.0005
-0.001
-0.0015
0 4 8 12 16 20 24 28
med lb ub

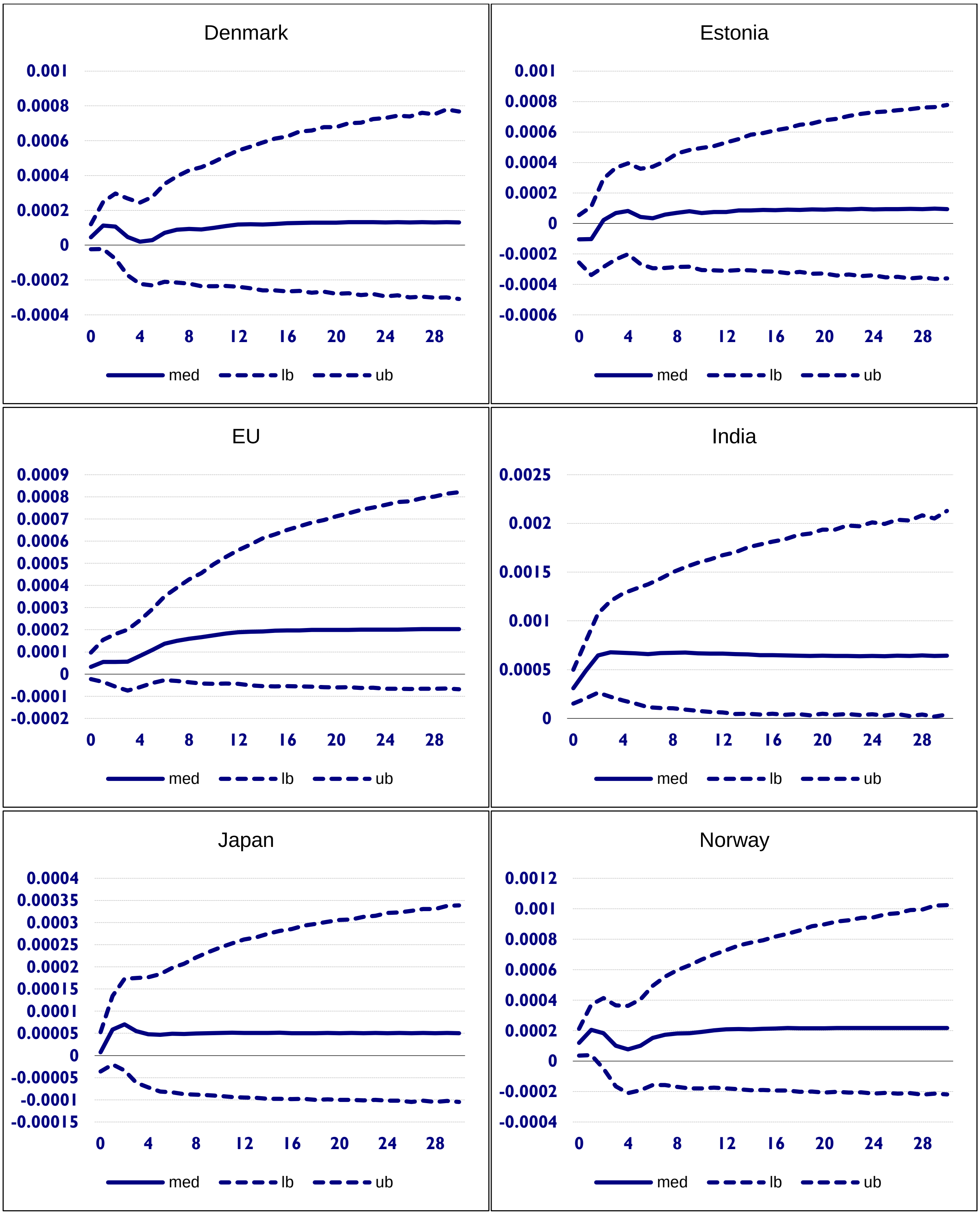

Lithuania
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
-0.0005
0 4 8 12 16 20 24 28
med lb ub


Poland
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
-0.001
0 4 8 12 16 20 24 28
med lb ub


Russia
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
0 4 8 12 16 20 24 28
med lb ub



Long-term interest rate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0.0008
0.0006
0.0004
0.0002
0
-0.0002
-0.0004
0 4 8 12 16 20 24 28
med lb ub
Estonia
0.001
0.0008
0.0006
0.0004
0.0002
0
-0.0002
-0.0004
-0.0006
0 4 8 12 16 20 24 28
med lb ub
EU
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
-0.0001
-0.0002
0 4 8 12 16 20 24 28
med lb ub
India
0.0025
0.002
0.0015
0.001
0.0005
0
0 4 8 12 16 20 24 28
med lb ub
Japan
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
-0.00005
-0.0001
-0.00015
0 4 8 12 16 20 24 28
med lb ub
Norway
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0.001
0.0008
0.0006
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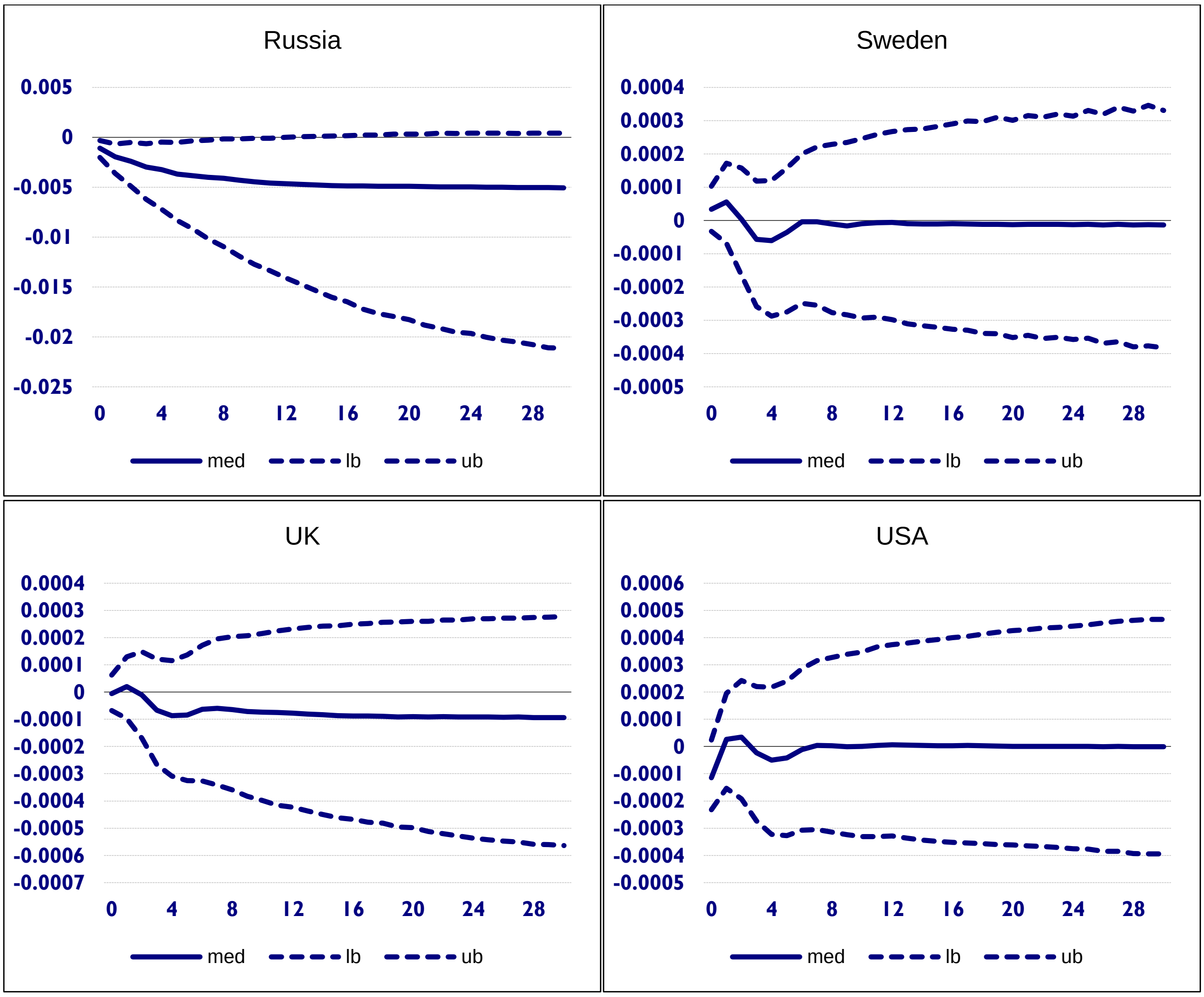
0.0002
0
-0.0002
-0.0004
0 4 8 12 16 20 24 28
med lb ub



Technical Appendix 1

Weak exogeneity test

As discussed previously, foreign variables ($\mathbf{x}_{it}^{*}$) are treated as long-run forcing (are not affected by domestic variables in the long run). It implies that foreign variables have an effect on endogenous variables, but are not affected by them in the long run. By convention, it also follows that the foreign variables should not be explained by the error correction terms. Weak exogeneity test was introduced by Johansen (1991) and is carefully described in Harbo et al. (1998). We test both foreign and global variables that are treated as weakly exogenous. For every component ℓ of $\mathbf{x}_{it}^{*}$ we construct the following regression:

$$\Delta x^*_{it,\ell} = \alpha_{i\ell} + \sum_{j=1}^{r_i} \gamma_{ij,\ell}\widehat{ECM}_{ij,t-1} + \sum_{s=1}^{p_i^*} \phi'_{is,\ell}\Delta \mathbf{x}_{i,t-s} + \sum_{s=1}^{q_i^*} \psi'_{is,\ell}\Delta\tilde{\mathbf{x}}^*_{i,t-s} + \epsilon_{it,\ell},$$

where $\widehat{ECM}_{ij,t-1}, j = 1,2,\dots,r_i$ are error correction terms, and p_i^* and q_i^* denote lag orders of domestic and foreign variables. Lag length is selected using AIC and differ from the one used in estimation of individual $VARX^*$ models. We then test for joint significance of error correction terms using F-statistics to see whether $\gamma_{ij,\ell} = 0,\ j = 1,2,\dots,r_i$ or not.

Technical Appendix 2

Structural stability test

We use three categories of tests to check if parameters are stable over time: 1) tests for time-varying coefficients; 2) tests rested on cumulative forecast errors; 3) Wald-type tests for a single break at a priori unknown point in time. Null hypothesis for all the tests is the constancy of equation parameters over time. In mathematical terms, consider ℓ^{th} equation of the error correction model of country i:

$$y_{\ell t} = \boldsymbol{\theta}'_{\ell t}\boldsymbol{z}_t + e_{\ell t} \qquad (A.1)$$

You can see that the coefficients $\boldsymbol{\theta}_{\ell t} = (\mu_{\ell t}, \gamma_{j\ell t}, \varphi'_{n\ell t}, \boldsymbol{\vartheta}'_{s\ell t})$ are now allowed to be time-varying unlike it is in serial correlation test. Then the following null hypothesis is tested: $\boldsymbol{\theta}_{\ell t} = \boldsymbol{\theta}_{\ell}$. The difference lies in alternative hypotheses that differ across the tests.

More specifically, we employ Nyblom's test for stability of parameters (Nyblom, 1989), maximal OLS cumulative sum statistic and its mean square variant (Ploberger & Kramer, 1992), and Wald test and its variations (mean Wald (MW), exponential Wald (EW)) that looks for a structural change at an unidentified point in time. Critical values for these tests are calculated from bootstrap samples of the constructed GVAR model. Now each category is described in more detail (full description and performance assessment using Monte Carlo simulations can be found in Stock and Watson (1996)):

Tests for time-varying parameters

Nyblom (1989) was first to describe the test for randomly time-varying parameters. The alternative hypothesis is that parameters follow random walk: $\theta_{\ell t} = \theta_{\ell,t-1} + \eta_{\ell t}$. Nyblom's statistic to test for parameter stability is given by

$$L_\ell = T^{-2} \sum_{t=1}^{T} S'_{\ell t} \hat{V}_\ell^{-1} S_{\ell t}$$

where $S_{\ell t} = \sum_{s=1}^{t} z_s e_{\ell s}$, where $\{e_{\ell s}\}$ are the estimated residuals from (A.1), and $\hat{V}_\ell = (T^{-1} \sum_{t=1}^{T} z_t z_t')\hat{\sigma}_\ell^2$, where $\hat{\sigma}_\ell^2 = T^{-1} \sum_{t=1}^{T} e_{\ell t}$. Hansen (1990) has derived the heteroskedasticity-robust statistic by replacing $\hat{V}$ with $\widetilde{V} = T^{-1} \sum_{t=1}^{T} e_{\ell t}^2 z_t z_t'$.

Tests based on cumulative forecast errors

We use the maximal OLS CUSUM statistic developed by Ploberger and Krämer (1992). Let $\zeta_T(\delta) = \hat{\sigma}_\ell^{-1} T^{-1/2} \sum_{s=1}^{[T\delta]} e_{\ell s}$, where $[\cdot]$ is the greatest lower integer function. The PK maximal CUSUM statistic looks as

$$PK_{sup} = \sup_{\delta \in [0,1]} \left| \zeta_{\ell T}(\delta) \right|$$

The mean square variation of the statistic looks as follows:

$$PK_{msq} = \int_0^1 \zeta_T(\delta)^2 \, d\delta$$

Wald test and its variations

The alternative hypothesis in the third category of tests is that parameter has a single break at a time fraction δ throughout the sample. The date of break is treated as unknown a priori, therefore the sequences $F_T(t/T)$ for $t = t_0, \dots, t_1$ are computed to hereafter get functionals of these sequences. We take three different functionals to ensure robustness of the results. The Quandt (1960) likelihood ratio statistic in Wald form can be expressed as

$$QLR = \sup_{\delta \in (\delta_0, \delta_1)} F_{\ell T}(\delta)$$

The mean Wald statistic (Andrews and Ploberger (1994); Hansen (1992)) is given by

$$MW = \int_{\delta_0}^{\delta_1} F_{\ell T}(\delta) \, d\delta$$

The Andrews-Ploberger (1994) average exponential Wald statistic looks as follows

$$EW = \ln\left\{\int_{\delta_0}^{\delta_1} \exp\left(\frac{1}{2}F_{\ell t}(\delta)\right) d\delta\right\}$$

The symmetric trimming parameter (δ) is set to 0.15. Heteroskedasticity-robust estimates are obtained by using White's (1980) heteroskedasticity-consistent estimator to compute $F_{\ell T}(\delta)$.