LATVIJAS BANKA
EIROSISTĒMA

ISBN 978-9984-888-50-7

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WORKING PAPER
5 / 2014

INTERNATIONAL TRANSMISSION OF CREDIT SHOCKS: EVIDENCE FROM GLOBAL VECTOR AUTOREGRESSION MODEL

CONTENTS

ABBREVIATIONS

ADF – augmented Dickey–Fuller test
AL – Albania
AR – Argentina
AU – Australia
Baltic States – EE, LT, LV
BD – Bulgaria
BIS – Bank for International Settlements
BR – Brazil
BY – Belarus
CA – Canada
CESEE – Central, Eastern and Southeastern Europe
CH – Switzerland
CIS – Commonwealth of Independent States
CL – Chile
CN – China
CPI – Consumer Price Index
CZ – Czech Republic
DK – Denmark
DSGE – dynamic stochastic general equilibrium model
EA – euro area
ECB – European Central Bank
EE – Estonia
ESRB – European Systemic Risk Board
GDP – gross domestic product
GE – Georgia
GVAR – global VAR
HR – Croatia
HU – Hungary
ID – Indonesia
IN – India
IS – Iceland
JP – Japan
KR – South Korea
LT – Lithuania
LV – Latvia
MA – moving average
MX – Mexico
MY – Malaysia
NO – Norway
NZ – New Zealand
OeNB – Oesterreichische Nationalbank
PE – Peru
PH – Philippines
PL – Poland
PPP – purchasing power parity
RO – Romania
RU – Russia
SE – Sweden
SG – Singapore
SI – Slovenia
SK – Slovakia
TH – Thailand
TR – Turkey
UA – Ukraine
UK – the United Kingdom
US – United States of America
VAR – vector autoregression
VARX – vector autoregression model with exogenous variables
VEC – vector error correction model
VECX – vector error correction model with exogenous variables

ABSTRACT

In this paper, we examine international transmission of the negative credit supply shock, which originated in the euro area and the US. We use the multi-country global vector autoregression (GVAR) approach with trade and bilateral banking exposures as weights, and identify five structural shocks via sign restrictions. Special focus of this research is on CESEE – a region that shares strong financial linkages with the euro area. Our main results are as follows. First, US-specific shocks account for a significant share in explaining the deviations from growth trends in output and total credit in both the euro area and the US; second, compared to a domestic aggregate demand shock, the economic downturn caused by the credit supply shock in the US and the euro area can bring more harm in the long run, yet the international spillover of the former is stronger; third, the transmission of euro area shocks to emerging Europe is faster and more pronounced compared to US shocks; fourth, there is strong heterogeneity in responses of emerging Europe to shocks in the euro area and the US.

Keywords: credit shock, global vector autoregressions, sign restrictions

JEL codes: C32, F44, E32, O54

The views expressed in this paper are not necessarily those of the Oesterreichische Nationalbank (OeNB) and Latvijas Banka. We would like to thank Konstantīns Beņkovskis, Rūdolfs Bēms, Sandra Eickmeier, participants of an internal seminar at Latvijas Banka, and the OeNB for helpful comments. We are grateful to Kristiāna Rozīte for the assistance during the internship at Latvijas Banka. E-mail address: Ludmila.Fadejeva@bank.lv, Martin.Feldkircher@oenb.at and Thomas.Reininger@oenb.at.

1. INTRODUCTION

When the financial crisis erupted in 2008, the global economy witnessed a collapse in trade followed by a sharp contraction of real activity. In the aftermath of the crisis, financial and economic conditions were characterised by tight credit, increasing credit loss provisions and a lack of confidence among banks (Busch et al. (2010)). On the one hand, it was argued that the decrease in new lending was driven by a sharp reduction in the demand for credits. On the other hand, banks were blamed to have tightened credit standards, being overly reluctant to engage in new lending as a part of cleaning their balance sheets. From a policy perspective, the distinction between supply-driven and demand-driven shocks to lending and macroeconomic variables is important since they might call for very different responses of monetary and fiscal policy (Gambetti and Musso (2012)).

In the aftermath of the crisis, heightened interest in the real effects of negative credit shocks was reflected in the vastly growing empirical literature. One strand of the literature employs survey data. Lown and Morgan (2006) use the US Federal Reserve's credit officer opinion survey and treat credit standards as an endogenous variable in a small vector autoregression (VAR). They find that fluctuations in commercial credit standards are highly significant in predicting commercial bank credits, output and investment in the trade sector. Furthermore, the US credit standards are unaffected by an (unexpected) increase in the federal funds rate, while lending rates rise in parallel with the policy rate. More recently, Ciccarelli et al. (2010) use detailed answers from the US and unique euro area bank lending surveys to assess the effect of a monetary policy shock on output and inflation via credit supply and demand (credit channel). They come up with evidence for an operative credit channel implying that an increase in the policy rate deters the availability of credit and consequently impacts output and inflation. While the credit channel tends to amplify the real consequences of monetary policy shocks, Ciccarelli et al. (2010) have found evidence that during the recent crisis, a reduction of credit supply to firms contributed to the decline in output growth. Bassett et al. (2014) construct a unique credit supply indicator from the US, based on a credit officer opinion survey that is adjusted for macroeconomic and bank-specific factors that otherwise would affect credit demand. They discover that tightening credit supply leads to substantial decrease in output, widening in credit spreads and easing of monetary policy.

A second strand of the literature uses aggregated data and sign restrictions on the impulse response functions to identify credit supply shocks. Busch et al. (2010) focus on the recent dynamics of credits to non-financial corporations in Germany. Based on historical shock decompositions, they find that the monetary policy was basically neutral in the period of the outbreak of the global financial crisis and its immediate aftermath. With the beginning of 2008, other non-identified shocks overcompensated the detrimental effect of a negative credit supply shock on credit dynamics. Meeks (2012) investigated credit shocks in the US market for high yield corporate bonds and found that the shocks to the credit spread caused immediate and prolonged contractions in output. Furthermore, the shocks to the credit market had had an adverse effect on output in every recession in the US since 1982. Fornari and Stracca (2012) estimate a panel VAR for 21 advanced economies and assess how shocks emanating from the financial sector impact standard indicators of real activity and financial conditions. The restrictions they imposed on the impulse response functions allowed them to isolate this financial shock from aggregated demand and monetary policy shocks, but failed to attach a more structural meaning to financial shock itself. Their results show that financial shocks have a noticeable effect on key macro variables (such as output) with investment reacting most strongly, and this fact is well in line with Peek et al. (2003). Furthermore, cross-country differences seem to play only a minor role. Gambetti and Musso (2012) use a time-varying VAR framework allowing for stochastic volatility and analyse the effect of credit supply shocks on output and credit growth in three major economies – the euro area, the UK and the US. They find that credit supply shocks have a significant impact on economic activity, inflation and credit markets and that this effect is varying over time. Especially, during periods of economic slowdown, the contribution of the credit supply shock to explaining movements in output and credit growth is larger. Furthermore, the short-term impact of the credit supply shock on output and credit growth seems to have strengthened in the most recent past. Hristov et al. (2012) derive sign restrictions from DSGE models that explicitly allow for a banking sector and feature financial frictions. Based on a panel VAR, they find that credit supply shocks in the euro area countries are important determinants of growth in credits and real GDP, thereby corroborating the results of Gambetti and Musso (2012). In contrast to Fornari and Stracca (2012), however, the results provided in Hristov et al. (2012) reveal important cross-country differences within the euro area as regards the timing and the magnitude of shocks.

While the literature reviewed above differs with respect to the identification of the credit supply shock and the data employed, it shares the focus on the effect of credit supply shocks on the domestic economy. There are only few papers that bring in a global angle. Helbling et al. (2011) reveal that credit market shocks shaped the global business cycle during the latest global recession, especially if the shock emanated from the US. Eickmeier and Ng (2011) extend this further by addressing the question how shocks to lending in four major economies transmit internationally using a global macro model that links single economies by the strength of their bilateral trade and financial ties. In line with Helbling et al. (2011), Eickmeier and Ng (2011) find a pivotal role for the US in shaping economic conditions in the global economy, while the effect of credit supply shocks emanating from Japan or the euro area are comparably milder. Finally, Eickmeier and Ng (2011) observe a significant flight-to-quality effect, which is mirrored in the appreciation of the US dollar vis-à-vis other main currencies.

The goal of this paper is to investigate the international spillover of the credit supply shock which originated in the US and the euro area, controlling for demand-driven shocks using rich multi-country approach. The special focus of this research is on the impact of a euro area credit supply shock on CESEE, a region that shares strong financial linkages with the euro area.

In this paper we follow the work by Eickmeier and Ng (2011) by taking an international angle and applying the global VAR (GVAR) methodology to investigate the international transmission of credit supply shocks. The dataset contains information of 42 countries for the period from 1995 Q1 to 2013 Q4. The variable set consists of real GDP, inflation, short-term interest rate, government bond yields, total credit to households and firms, exchange rate and oil price. Foreign country variables are combined via trade and financial weights and used in individual country VECX models as explanatory weakly exogenous variables.

We contribute to the existing literature of GVAR models with credits and financial weights by extending it in several aspects. First, to our knowledge, there are no other attempts to look at the effects of an adverse credit supply shock in the euro area on output and credits in CESEE. This region is of particular interest, since a large part of the domestic banking sector in CESEE is owned by banks located in the euro area. The extent to which these parent-to-affiliate relationships exist is unique in the global economy, which renders it perfect to study the transmission and effect of a credit supply shock on the host countries' economies. Second, we use a specially compiled data set of bilateral financial weights by Backé et al. (2013) that comprises countries/regions that are potentially important sources or transmitters of credit supply shocks for the CESEE region. We also use a new data set from the BIS that provides total domestic credits to the private sector, which we have adjusted for foreign exchange rate movements for countries whose credit markets are characterised by large shares of foreign currency denominated credits. Third, we disentangle credit supply shock via sign restrictions by controlling for other four structural country-specific shocks, namely, aggregate supply, aggregate demand, credit demand and monetary policy shocks. Fourth, we are the first, to our knowledge, to provide historical decompositions of output and credit series by country and by structural shocks, thereby providing new angle to the analysis of international spillovers of region-specific shocks.

Our results show that, first, the US-specific shocks account for a significant share in explaining deviations from growth trends in output and total credit in both the euro area and the US; second, compared to a domestic aggregate demand shock, the economic downturn caused by the credit supply shock in the US and the euro area can bring more harm in the long run, yet the international spillover of the former is stronger; third, the transmission of euro area shocks to emerging Europe is faster and more pronounced compared to US shocks; fourth, there is strong heterogeneity in responses of emerging Europe to shocks in the euro area and the US.

The paper is structured as follows. Section 2 introduces our empirical framework, the GVAR model, the data and the model specification. Section 3 presents a set of sign restrictions that we employ to separate credit supply shocks from aggregate demand and supply as well as monetary policy shocks. Section 4 outlines the results, and Section 5 concludes.

2. THE GVAR MODEL

The empirical literature on GVAR models has been largely influenced by the work of Pesaran and co-authors (Pesaran et al. (2004)), Garratt et al. (2006). In a series of papers, these authors examine the effect of US macroeconomic impulses on selected foreign economies employing agnostic, structural and long-run macroeconomic relations to identify the shocks (Pesaran et al. (2004), Dees et al. (2007a, 2007b)). Recent papers have advanced the literature on GVAR modelling in terms of country coverage (Feldkircher (2013)), Bayesian estimation of the local models (Crespo Cuaresma et al. (2014), Feldkircher and Huber (2014)), identification of shocks (Eickmeier and Ng (2011)) and the specification of international linkages (Eickmeier and Ng (2011), Chudik and Fratzscher (2011), Galesi and Sgherri (2013)). For an excellent survey regarding recent applications of the GVAR framework see Chudik and Pesaran (2014).

The GVAR model is a compact representation of the world economy designed to model multilateral dependencies among economies across the globe. In principle, a GVAR model comprises *two layers* via which the model is able to capture cross-country spillovers. In the first layer, separate time series models, one per country, are estimated. In the second layer, the country models are stacked to yield a global model that is able to trace the spatial propagation of a shock as well as its time dynamics.

The first layer is composed by country-specific local VAR models, enlarged by a set of weakly exogenous and global variables (VARX model). Assuming that our global economy consists of $N+1$ countries, we estimate a VARX model of the following form for every country $i=0,\dots,N$:[1]

$$x_{it}=a_{i0}+a_{i1}t+\Phi_i x_{i,t-1}+\Lambda_{i0}x^*_{it}+\Lambda_{i1}x^*_{i,t-1}+\pi_{i0}d_t+\pi_{i1}d_{t-1}+\varepsilon_{it} \quad (1).$$

Here, x_{it} is a $k_i\times 1$ vector of endogenous variables in country i at time $t\in 1,\dots,T$, Φ_i denotes the $k_i\times k_i$ matrix of parameters associated with the lagged endogenous variables, and Λ_{ik} are the coefficient matrices of k^*_i weakly exogenous variables of dimension $k_i\times k^*_i$. Furthermore, $\varepsilon_t\colon N(0,\Sigma_i)$ is the standard vector error term, d_t denotes the vector of *strictly exogenous* variables, which are linked to the vector of exogenous variables through matrices π_{i0} and π_{i1}, and t is a deterministic trend component. If $\Lambda_{i0},\Lambda_{i1},\pi_0$ and π_1 are composed exclusively of zero elements, the specification boils down to that of a standard VAR model (with a deterministic linear trend, if $a_{i1}\neq 0$).

The weakly exogenous or *foreign* variables x^*_{it} are constructed as a weighted average of their cross-country counterparts

$$x^*_{it}:=\sum_{j\neq i}^{N}\omega_{ij}x_{jt} \quad (2)$$

where ω_{ij} denotes the weights corresponding to the pair of country i and country j. The weights ω_{ij} reflect economic and financial ties among economies, which are usually proxied using data on bilateral trade weights (see, e.g. Eickmeier and Ng (2011) for an application using a broad set of different weights). The assumption that the x^*_{it} variables are weakly exogenous at the individual level reflects the belief that most countries are small relative to the world economy.

Following Pesaran et al. (2004), the country-specific models can be rewritten as

$$A_i z_{it}=a_{i0}+a_{i1}t+B_i z_{it-1}+\pi_0 d_t+\pi_1 d_{t-1}+\varepsilon_{it} \quad (3)$$

where $A_i:=(I_{k_i}-\Lambda_{i0})$, $B_i:=(\Phi_i-\Lambda_{i1})$ and $z_{it}=(x_{it}\ \ x^*_{it})'$. By defining a suitable link matrix W_i of dimension $(k_i+k^*_i)\times k$ where $k=\sum_{i=1}^{N}k_i$, we can rewrite z_{it} as $z_{it}=W_i x_t$, with x_t (the so-called global vector) being a vector where all the endogenous variables of the countries in our sample are stacked. Substituting (3) into (1) and stacking the different local models lead to the global equation, which is given by

$$x_t=G^{-1}a_0+G^{-1}a_1t+G^{-1}Hx_{t-1}+G^{-1}\pi_0 d_t+G^{-1}\pi_1 d_{t-1}+G^{-1}\varepsilon_t$$

[1] For simplicity, we use a first-order VARX model for the exposition. The generalisation to longer lag structures is straightforward.

$$= b_0 + b_1 t + F x_{t-1} + \Gamma_0 d_t + \Gamma_1 d_{t-1} + e_t \quad (4)$$

where $G = (A_0 W_0 \cdots A_N W_W)'$, $H = (B_0 W_0 \cdots B_N W_W)'$ and a_0, a_1, π_0 and π_1 contain the corresponding stacked vectors containing the parameter vectors of the country-specific specifications. The eigenvalues of matrix F, which is of prime interest for forecasting and impulse response analysis, have to lie within the unit circle in order to ensure stability of (4).

2.1 Estimation

Following the bulk of the literature, we estimate the single country VARX models in error correction form, which allows for cointegration relationships within and between countries.

$$\Delta x_{i,t} = c_{i,0} + \alpha_i \beta_{i'} (z_{i,t-1} - \gamma_i (t-1)) + \beta_{i,0} \Delta x_{i,t}^* + \sum_{j=1}^{p_i} + \Gamma_{i,j} \Delta z_{i,t-j} + u_{i,t} \quad (5).$$

Here, α_i denotes the $k_i \times r_i$ adjustment or loading matrix, β_i is the $(k_i + k_i^*) \times r_i$ matrix of coefficients attached to the long-run equilibrium, and r_i is the cointegration rank. In case the variables contained in z_t are cointegrating, the long-run matrix $\alpha_i \beta_{i'}$ will be rank-deficient. We follow the convention made in the literature and assume that the foreign variables are "long-run forcing" for endogenous variables but not vice versa. The single country VARX models are then estimated conditional on the weakly exogenous variables contained in $x_{i,t}^*$ using reduced rank regression. This provides estimates of α_i, β_i and r_i. The remaining parameters can then be estimated by standard least squares.

We have tested each variable for the presence of a unit root by means of an augmented Dickey–Fuller test. Output, price inflation and interest rates are mostly integrated of order 1, which ensures the appropriateness of the econometric framework pursued in this study. The ADF-test results for the total credit, on the other hand, show that it is mostly integrated of order 2. From the theoretical perspective this might cause an estimation problem. When looking closely at credit series, one can notice a clear change in the growth rate of total credit after the financial crisis. Importantly, the ratio between the output and credit growth has changed a lot. It is mostly stable or slightly decreasing from 2009 compared to the persistent growth during the whole analysed period before the crisis. Undoubtedly, this influences the long-term cointegration relation in individual country models, which is clearly depicted by the break in the long-term cointegration relations. We propose to fix the above described problem by introducing a constant dummy in the long-term equations of selected country models from 2009 Q1 (see Table A2). The structural break dummy accounts for a break in the output-credit growth tendency and helps stabilise the model[2]. The cointegration rank is tested by means of a trace statistics provided in Smith and Galesi (2011). The test identifies 2–3 relationships that determine the long-run behavior of the economy for most of the countries. The number of cointegrations in the country models was further reduced by examining the country-specific persistence profiles of the long-run relationships. The final model specification is presented in Table A1.

[2] We did robustness check by excluding the structural dummy from the model. In general, model is still stable, the impulse responses of total credits, however, are largely explosive.

2.2 Data and Model Specification

The data set in this paper contains quarterly observations for 41 countries and one regional aggregate, i.e. the euro area (EA)[3]. Table 1 presents the country coverage of the sample herein, which includes the emerging economies, advanced economies and most important oil producers and consumers across the globe.

Table 1
Country coverage

Emerging Asia (9)	CN, ID, IN, KR, MY, PH, SG, TH, TR
CESEE (12)	AL, BG, CZ, EE, HR, HU, LT, LV, PL, RO, SI, SK
CIS (4)	BY, GE, RU, UA
Emerging Latin America (5)	AR, BR, CL, MX, PE
Rest of the world (12)	AU, CA, CH, DK, EA, IS, JP, NO, NZ, SE, UK, US

Note. Abbreviations refer to the two-digit ISO country code.

There are 42 economies in the sample with 76 quarterly observations by country spanning the period from 1995 Q1 to 2013 Q4. The *domestic* variables that are used in the analysis comprise data on real activity, changes in prices, real exchange rates, short-term interest rates and government bond yields (Dees et al. (2007a; 2007b), Pesaran et al. (2004; 2009; 2007)). We follow the bulk of the literature in including oil prices as a *global* control variable.

The variables used in the model are briefly described in Table 2. Most of the data are available with wide country coverage, with the exception of government bond yields. Since local capital markets in emerging economies (in particular in Eastern Europe) are still developing, data on interest rates are hardly available for these countries. For those countries for which data at the beginning of the sample period were missing, we use an expectation maximisation algorithm to impute the values.[4]

[3] The country composition, on which the data on the euro area is based, changes with time. While historical time series are based on data of the 10 original euro area countries, the most recent data are based on 17 countries. The results of the analysis remain qualitatively unchanged, if we use a consistent set of 14 euro area member states throughout the sample period instead of the rolling country composition for the data on the euro area, as the relative economic size of these three countries is quite small.

[4] A more detailed account of the imputation method and data sources is provided in Feldkircher (2013).

Table 2
Data description

Variable	Description	Min	Mean	Max	Coverage (%)
y	Real GDP, average of 2005 = 100, seasonally adjusted, in logarithms	3.675	4.545	5.400	100
Δp	Consumer price inflation, seasonally adjusted, in logarithms	–0.213	0.018	1.215	100
e	Nominal exchange rate vis-à-vis the US dollar, deflated by national price levels (CPI)	–5.699	–2.404	5.459	100
i_S	Typically 3-month-market rates, per annum	–0.001	0.092	4.331	97.6
i_L	Typically government bond yields, rates per annum	0.006	0.054	0.638	40.5
dc	Credit volume, average of 2005 = 100, in logarithms	–2.575	4.495	7.786	97.6
EA_{lr}	Composite lending rate for the euro area, weights based on volumes of credit outstanding	0.028	0.053	0.098	–
US_{lr}	Composite lending rate for the US, weights based on volumes of credit outstanding	0.032	0.060	0.095	–
$poil$	Price of oil, seasonally adjusted, in logarithms	2.395	3.710	4.753	–
Trade flows	Bilateral data on exports and imports of goods and services, annual data	–	–	–	–
Banking exposure	Bilateral outstanding assets and liabilities of banking offices located in BIS reporting countries and Russia, annual data	–	–	–	–

Notes. Summary statistics pooled over countries and time. The coverage refers to the cross-country availability per country, in %. The share of foreign currency denominated credits in total credits for CZ, HU, PL, SI, SK, BG, RO, EE, LT, LV, HR, AL , RU, UA and TR is calculated at constant exchange rates as at end-June 2013.

In the early literature on GVARs, weakly exogenous variables have been exclusively constructed based on bilateral trade flows (Pesaran et al. (2004; 2009), Dees et al. (2007b)). More recent contributions suggest using trade flows to calculate foreign variables related to the real side of the economy (e.g. output and inflation) and financial flows for variables related to the financial side of the economy (e.g. interest rates, credit volumes). We follow Eickmeier and Ng (2011), Feldkircher and Huber (2014) and choose weights based on bilateral trade and bilateral banking sector exposure to calculate the weakly exogenous variables given in equation (4). For that purpose we use a new data set from the BIS that provides for total domestic credits to the private sector adjusted for foreign exchange rate movements for the countries whose credit markets are characterised by large shares of foreign-currency-denominated credit.

In line with the literature, the oil price is determined within the US country model. We distinguish big oil importer/exporter countries (US, CN, RU, BR, MX, IN, CA and NO) by including an oil variable into the long-run cointegration equation of these countries. Since the observed data span is rather short, untreated outliers can have a serious impact on the overall stability and results of the model. We therefore introduce a set of dummy variables in the country-specific specifications to control for outliers. These account for the fact that some countries witnessed extraordinarily high interest rates at the beginning of the sample period (which returned steadily to "normal" levels) and that some economies (Russia or Argentina, for instance) were exposed to one-off crisis events. We identify the largest deviations from "normal" times per country and use interaction terms to take care of unusually large historical observations. Exact specification of country models is provided in Appendix (Table A2).

3. IDENTIFICATION OF EURO AREA CREDIT SUPPLY SHOCK

Applied literature using GVAR models for counterfactual analysis relies strongly on the concept of generalised impulse response functions to trace the dispersion of shocks to macroeconomic variables across countries. While these studies successfully trace the propagation of shocks across countries, they fail to attach any economic interpretation to the origins of the shock. In this study, we follow Eickmeier and Ng (2011) and go beyond the rather agnostic approach by identifying the negative credit supply shock via restrictions that are imposed on the signs of the impulse response functions directly.

More specifically, we follow equation (1) and identify shocks locally in the US and the euro area country models. Suppose that the US model is indexed by $i = 0$:

$$x_{0,t} = \psi_{0,1} x_{0,t-1} + \Lambda_{0,0} x^*_{0,t} + \Lambda_{0,1} x^*_{0,t-1} + \varepsilon_{0,t} \qquad (6).$$

Without loss of generality, we omit the deterministic part of the given model. To back out the structural form of the model, we premultiply equation (6) by Q_0:

$$Q_0 x_{0,t} = Q_0 \psi_{0,1} x_{0,t-1} + Q_0 \Lambda_{0,0} x^*_{0,t} + Q_0 \Lambda_{0,1} x^*_{0,t-1} + Q_0 \varepsilon_{0,t} \qquad (7)$$

where $Q_0 = R_0 P_0^{-1\prime}$. Structural errors are now given by $v_{0,t} = Q_0 \varepsilon_{0,t}$, with R_0 being a $k_i \times k_i$ matrix chosen by the researcher, and $P_0^{-1\prime}$ denoting a lower Cholesky factor of $\Sigma_{\varepsilon,0}$. The variance-covariance structure of $\varepsilon_{0,t}$ is given by $\Sigma_0 = P_0^{-1\prime} P_0^{-1}$. In the present application, we find R_0 by relying on sign restrictions, i.e. we search for an orthonormal $k_0 \times k_0$ rotation matrix R_0 that satisfies $R_0 R_{0\prime} = I_{k_0}$. Given R_0, we can use the following decomposition of the structural variance-covariance matrix:

$$\Sigma_v = R_0 P_0^{-1\prime} P_0^{-1} R_{0\prime} = Q_0 Q_{0\prime} \qquad (8).$$

To obtain a candidate rotation matrix, we draw R_0 using the algorithm outlined in Rubio-Ramírez et al. (2010). We then proceed by constructing a $k \times k$ matrix Q where the first k_0 rows and columns correspond to R_0.

Formally, Q looks like

$$Q = \begin{pmatrix} Q_0 & 0 & \cdots & 0 \\ 0 & I_{k_1} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & I_{k_N} \end{pmatrix} \quad (9).$$

Premultiplication of GVAR with Q leads to

$$Qx_t = Qb_0 + Qb_1 t + QFx_{t-1} + Qe_t \quad (10).$$

Equation (10) can be used to obtain structural impulse response functions. In case responses fulfil the set of sign restrictions, we keep the candidate rotation matrix. We proceed sampling rotation matrices until we have 50 matrices that fulfil the restrictions. Finally, we select between the successful rotation matrices as outlined in Fry and Pagan (2011).

It should be noted that we rely on structural generalised impulse responses advocated by Dees et al. (2007a; 2007b) that take the historical correlation among cross-country residuals into account. We furthermore rely on a block diagonal structure of Σ_e as proposed by Eickmeier and Ng (2011). To check whether the inclusion of contemporaneous foreign variable in the model helps capture the most of the cross-country correlation, we check the average pairwise correlation for the first differences of variables and the residual terms of individual country models. Maximum average correlation between the first differences of variables is 0.3 and between residuals 0.04; therefore, the block diagonal structure of error variance-covariance matrix is permissible. Technically we implement the sign restrictions as in Rubio-Ramírez et al. (2010) with respect to the proposal of candidate rotation matrices and follow Eickmeier and Ng (2011) in the implementation of these restrictions in the GVAR context.

We propose the following restrictions to separate credit supply disturbances from other macroeconomic shocks. These are based on modified restrictions proposed by Hristov et al. (2012) and Eickmeier and Ng (2011).

Table 3
Sign restrictions

Shock	y	Δp	i_s	Lending rate	dc	Lending rate – i_s
Monetary policy	$\downarrow$	$\downarrow$	$\uparrow$	–	$\downarrow$	$\downarrow$
Aggregate supply	$\downarrow, \Delta y > \Delta dc$	$\uparrow$	–	–	$\underline{\downarrow}$	–
Aggregate demand	$\downarrow, \Delta y > \Delta dc$	$\downarrow$	$\downarrow$	$\downarrow$	$\underline{\downarrow}$	–
Credit demand	$\underline{\downarrow}$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow, \Delta dc > \Delta y$	–
Credit supply	$\underline{\downarrow}$	–	–	$\uparrow$	$\downarrow, \Delta dc > \Delta y$	$\uparrow$

Notes. The restrictions are imposed as $\geq / \leq$. In general, restrictions are imposed on impact and on the first quarter. Underlined arrows reflect an exception to this: the restriction is imposed on the first quarter only.

We distinguish five different types of structural shocks affecting the euro area and the US: 1) aggregate supply shock, 2) monetary policy shock, 3) aggregate demand shock, 4) credit demand shock and 5) credit supply shock. Separating these additional shocks as opposed to leaving them as residuals to the analysis should help pinning down the credit supply shock more clearly, as the increase in the number of restrictions enhances identification of the shock of interest (Paustian (2007)).

Each shock is characterised by a different pattern of restrictions (signs) or non-restrictions on the impact on endogenous variables, namely output, prices, money market rate, credit rate, lending margin (i.e. spread between credit rate and money market rate) and credit volume. These signs are established *a priori* on theoretical grounds, making reference to recent literature on structural VARs and DSGE models (Hristov et al. (2012), Fratzscher et al. (2009), Canova and Paustian (2011), Gambetti and Musso (2012), Eickmeier and Ng (2011)). In defining these shocks, we follow the principle that they have to distinguish themselves from each other by at least one restriction in order to be mutually exclusive, which is clearly a requirement of the sign restriction approach (Fry and Pagan (2011)).

Restrictions are imposed on impact and on the first quarter only. We do not rely on additional longer lag restrictions for defining shocks and discriminating between them. Any restriction on any lag for a specific type of shock would not necessarily help distinguish sufficiently between different types of shocks that have the same restriction on impact in common (Fry and Pagan (2011)).

Further, we briefly summarise the features of different types of structural shocks, assuming an adverse, i.e. contractionary, shock. The aggregate supply shock is characterised by a decline in output and the opposite movement in prices (Hristov et al. (2012)). Several authors suggest that the central bank would react by hiking key nominal interest rates (Fratzscher et al. (2009), Canova and Paustian (2011), Hristov et al. (2012) with reference to DSGE model). We refrain from doing it, taking into account the varying historical experience and the leeway of central banks to react alternatively by the communication channel to keep inflation expectations firmly anchored. Correspondingly, we do not put a restriction on the credit rate or the lending margin. With respect to credit volumes, we assume a negative impact on both the credit volume and corporate bond volume in parallel to the adverse impact on output and costs (prices) similar to Gambetti and Musso (2012). Moreover, both Eickmeier and Ng (2011) and Hristov et al. (2012) suggest such a parallel movement of output and credits, albeit the latter do not incorporate it as an explicit restriction.

Monetary policy shock consists of an increase in the money market rate, transmitted to the credit rate, albeit imperfectly, so that the lending margin decreases. In parallel, output and prices as well as the credit volume are restricted to decline.

Aggregate demand shock consists of a decrease in output and prices, while the money market rate decreases. We acknowledge that for a small and open economy where foreign demand is a particularly large component of total final demand, an asymmetric aggregate demand shock could have such a strong depreciating effect on the currency that prices may not decrease and the central bank may be reluctant to cut key policy rates, thus preventing money market rates from decreasing. However, it should be noted that the five shocks defined herein relate to the euro area and the US, and not to CESEE countries directly. Speaking about the credit rate, on the one hand, there are good reasons to argue in favour of a decrease in it, as deterioration of investment opportunities will weaken credit demand (and issuance of corporate debt securities), and policy rate reductions may be transmitted at least partly. Taking into account possible sluggishness of the shock, we leave the immediate reaction of total credit unrestricted.

A decrease in new lending volumes can be driven by the reluctance of banks to lend as well as a reduced demand for credit. Hristov et al. (2012) and Gambetti and

Musso (2012) do not differentiate aggregate demand from the credit demand shock, assuming that the former allocates both effects. However, as shown in the work based on the bank-level data for Chile by Calani et al. (2010), differentiation between credit demand and credit supply can give you an important insight into the behaviour of economic agents during the "credit shrinkage" episodes. For example, rising unemployment and expected lower income may lead to postponing consumption, housing purchases and investment, hence also reducing the demand for credit. On the other hand, unavailability of alternative sources of funding or self-insurance against a potential future lack of liquidity by agents may expand the demand for banking credits in the short run (Calani et al. (2010)). Credit demand and aggregate demand can also work in the opposite directions during the times of relatively weak demand when mortgage is viewed as safe investment, or during the period of plummeted housing prices and recovering aggregate demand.

We distinguish credit demand shock from aggregate demand shock by restricting the relative effect of shock on real output and total credit on impact. In case of a credit demand shock, it is assumed that total credit shrinks faster than real output, and the opposite is true for aggregate demand shock. In this paper we leave the immediate effect on output from credit demand shock unrestricted.

Finally, credit supply shock consists of an increase in credit rate and a simultaneous increase in lending margin (Eickmeier and Ng (2011), while we leave it unrestricted irrespective of the money market rate increasing less than the credit rate or even decreasing. Correspondingly, we put no restriction on the reaction of prices. We find support for this cautious approach by the mixed evidence from VAR models with sign restrictions and from DSGE models with financial frictions with respect to the sign restriction on short-term interest rate and prices (Hristov et al. (2012), Eickmeier and Ng (2011)). Both output and credit volume are restricted to decrease. Moreover, we assume that output declines less than credit volume, at least on impact, following Eickmeier and Ng (2011). The above table summarises the sign restrictions for identifying five main types of shocks.

Comparing the different types of shocks, it is clear that the aggregate supply shock distinguishes itself from the monetary policy shock and the demand shock by the restrictions on inflation and from the credit supply shock by the relative response of real output and total credit on impact. The monetary policy shock distinguishes itself from the aggregate demand and credit demand shock by the restrictions on the money market rate and from the credit supply shock by the restrictions on the lending margin. Aggregate demand and credit demand shocks are distinguished by relative effect of shock on real output and total credit. Thus, these five types of shocks conform to the principle of mutual exclusivity.

4. EMPIRICAL RESULTS

In this Section, we summarise the results of the euro area credit supply shocks using structural impulse response functions and historical variance decomposition. To set the obtained results into perspective, we carry out the same exercise for an adverse credit supply shock that emanates from the US economy.

4.1 Historical Decomposition of Total Credit Series. Cross-Country Perspective

Traditionally, the interaction between variables in VAR-type models is studied through the analysis of impulse responses to shocks in the model. The historical decomposition of the time series is presented less often. However, in the case of such big multi-country model as the GVAR, we believe it is useful to check the contribution of country-specific shocks to explaining the development of time series in the other countries. For example, it was argued (e.g. in Helbling et al. (2011), Eickmeier and Ng (2011) and Feldkircher and Huber (2014b)) that the effects of US-specific shocks propagate strongly into other regions. Therefore, one would expect that the episodes of strong US economic adjustments should be detected in the historical decomposition of another country's variables.

Any stationary VAR model can be presented in the moving average (MA) form; therefore, time series can be recreated from the estimated matrix of coefficients and error terms. We follow Luetkepohl (2011) in decomposing the GVAR series, applying the method proposed by Burbidge and Harrison (1985).

The j-th variable can be presented as cumulated sum of impulse responses to K shocks at time t cumulated over time starting from point $i = 1$:

$$x_{jt} = \sum_{i=1}^{\infty} (\phi_{j1,i} e_{1,t-i} + \ldots + \phi_{jK,i} e_{K,t-i}) \tag{11}$$

where $\phi_{jk,i}$ is the (j,k) element of MA matrix Φ_i obtained recursively from the estimated coefficient matrix F from equation (4):

$$\Phi_i = \sum_{j=1}^{i} (\Phi_{i-j} F_j); i = 1,2, \ldots \tag{12}$$

where $\Phi_0 = I$ of size K.

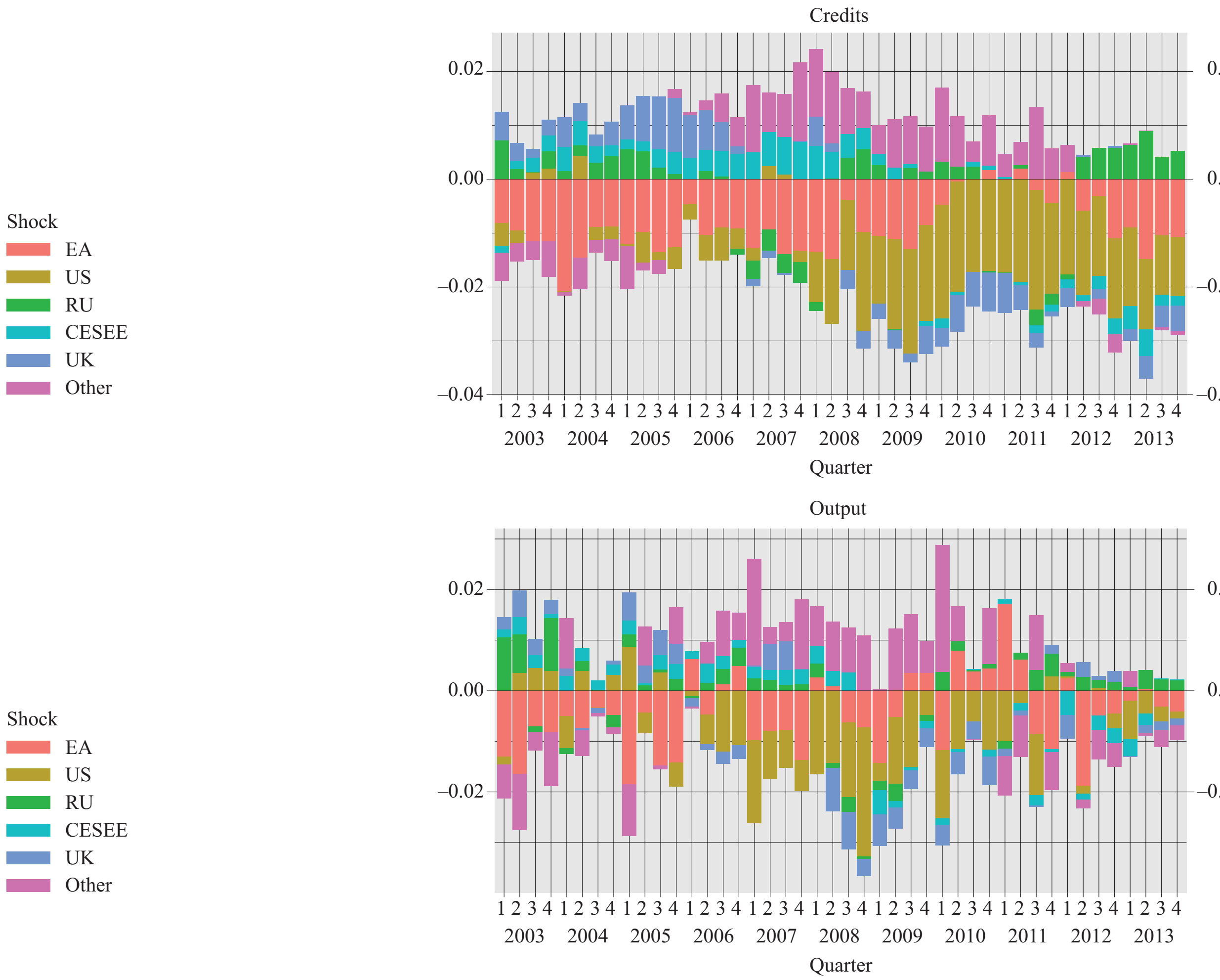
As shown by Luetkepohl (2011), since researchers possess only limited information about the time series, one can choose any starting point $x_0 = x_{t=0}$ for decomposition and apply the above formula to evaluate the contribution of k-th shock to the j-th component of K variables over the time span i:

$$x_{jt}^{(k)} = \sum_{i=0}^{t-1} (\phi_{jk,i} e_{k,t-i} + \ldots + f_j^t x_0) \tag{13}$$

where f_j is j-th row of the estimated coefficient matrix. If the process is stationary, the effect of the initial level becomes negligible with time, and the obtained series present shock historical decomposition.

In this Subsection, we look at the historical decomposition of total credit and real output series in the euro area and US over the period from 2003 to 2013 (year 2000 was used as the starting point of the procedure described in equation (4)). Historical decomposition graphs present deviations from trend growth of the credit and output series (in quarter-on-quarter terms) explained by shocks. Shocks can be grouped differently, and we present results based on the origin of shock (country/region[5]) and its economic interpretation (structural shocks) for the country of interest.

Figure 1
Historical decomposition by country of shock's origin: euro area



Figures 1 and 2 present the contribution of shocks summed up per country/region. The deviations from trend growth in credits and output in the euro area before the financial crisis, which followed the collapse of the Lehman Brothers, are, to a large extent, explained by shocks to euro area variables themselves (see Figure 1). The negative effect can be explained by slower output growth than could be predicted from the long-term fundamentals. During the crisis period, however, a large part of negative deviations can be accounted for by shocks to US variables. This holds true until 2012 when both output and credits in the euro area experienced a second wave of the crisis. Prior to the financial crisis, positive deviations are to a large extent explained by shocks to variables from the CESEE states. With the beginning of the crisis, this effect starts to peter out, which in turn tallies with the general CESEE

[5] Note that by construction (see VARX) each country model includes a foreign variable block; therefore, the degree of error term/shock correlation across countries is low. Therefore, historical decomposition gives us an opportunity to evaluate the importance of country-specific shocks on the development of country-specific variables.

experience with the crisis, which started to unfold and spill over to CESEE only after the collapse of the Lehman Brothers in the fourth quarter of 2008.

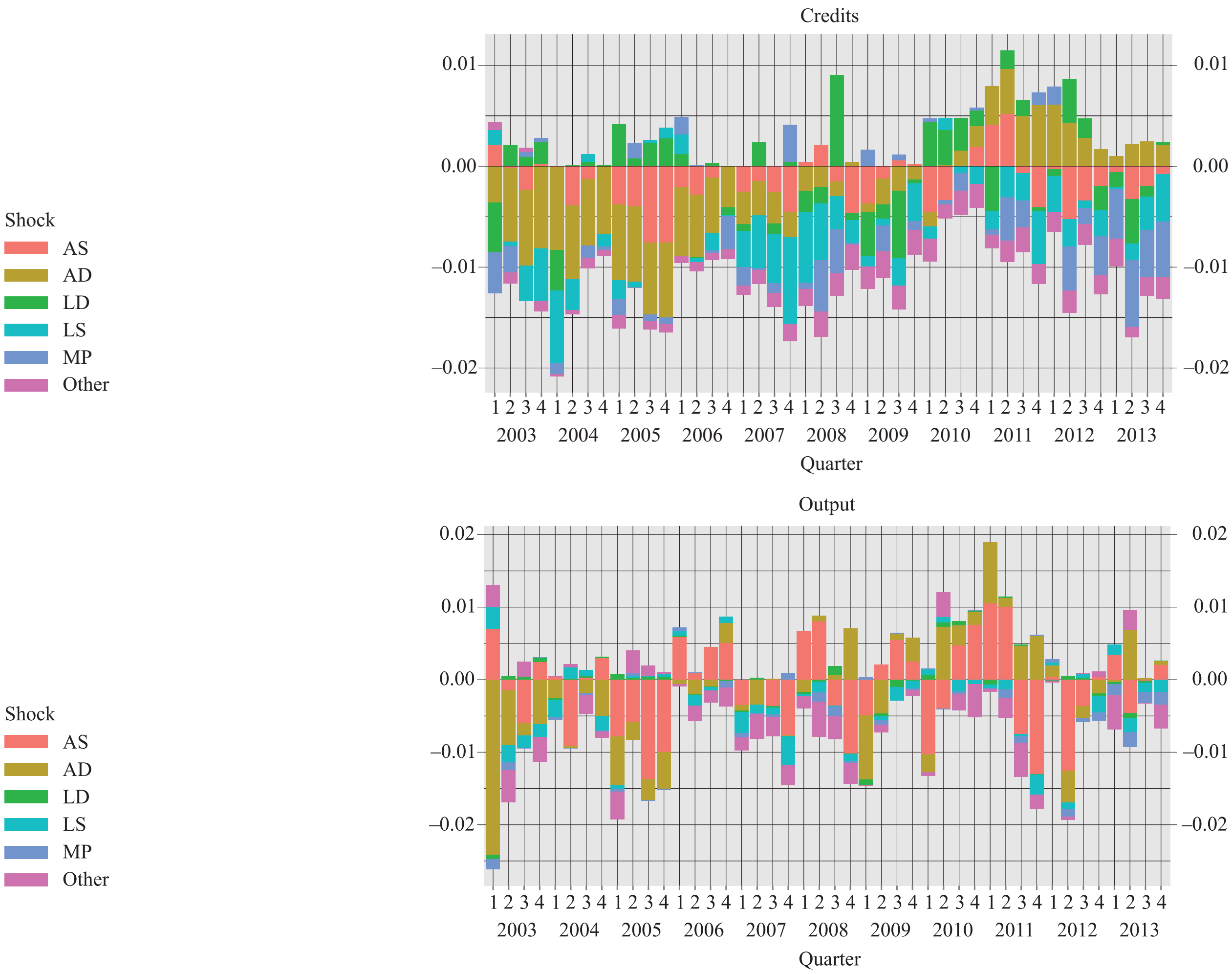
Turning to regional factors explaining the deviations from the trend growth in the US credits and output (see Figure 2), a pattern similar to the euro area credit series is observed: movements in output in the US are mainly driven by shocks to US variables, with only a modest role assigned to euro area shocks. From 2011 onwards, shocks to US domestic variables seem to hold up the growth, while shocks to euro area variables contribute negatively.

Figure 2
Historical decomposition by country of shock's origin: US

A closer analysis of country-specific shocks can be performed by applying the orthogonal rotation matrix R to the country-specific part of shocks (see equation (10)). Matrix R is country model-specific, thus we provide economic interpretation only of the euro area shock part presented in Figure 1 and the US contribution part presented in Figure 2.

Figure 3

Economic interpretation of euro area shock part in historical decomposition of euro area credits and output

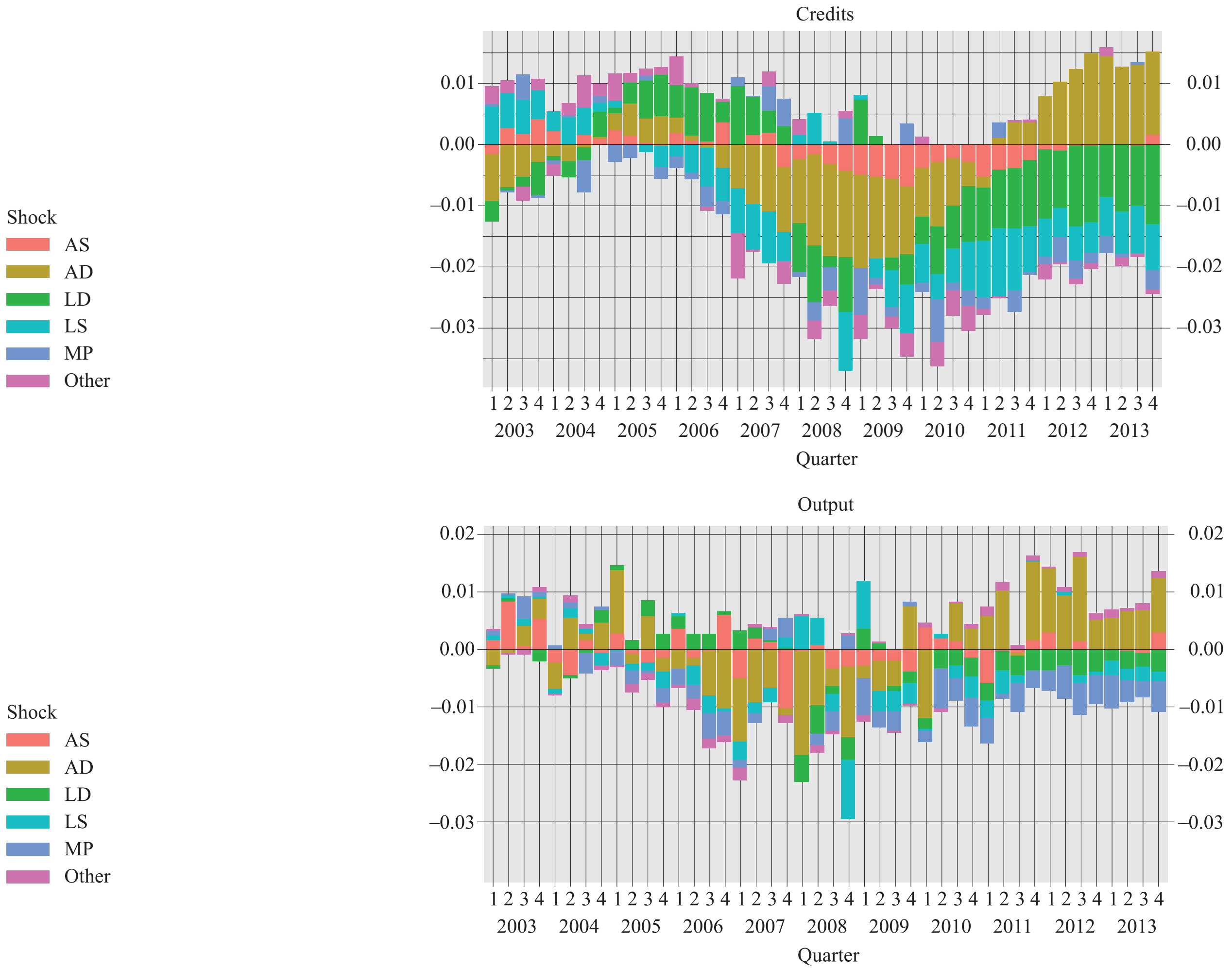


Note. Aggregate supply shock – AS, aggregate demand shock – AD, credit demand shock – LD, credit supply shock – LS, monetary policy shock – MP.

Figure 3 presents the contribution of euro area-specific structural shocks defined by the sign restrictions to the deviations from trend credit growth (note that it is only the euro area shock part). Aggregate demand and aggregate supply shocks explain a large part of the evolution of credit and output growth in the euro area. In the midst of the global financial crisis, credit supply shocks accounted for a significant share of contained credit growth in the euro area. In 2009, it was further enforced by a decline in credit demand. By contrast, credit supply shocks played only a minor role in shaping the dynamics of output directly. Since 2010, aggregate demand and credit supply shocks have mainly compensated each other. A lower zero bound effect, by restricting the central bank instrument availability, can partly explain negative contributions to credit and output growth in the euro area as depicted by monetary policy shock.

We provide the same analysis for the US economy in Figure 4. Cheap mortgage credits, systematic misevaluation of assets, and soaring household leverage put the US banking sector under severe stress. Before the global financial crisis, which originated in the US household sector around mid-2007, the US credit growth was fuelled both by positive shocks to credit supply and credit demand. The upper panel of Figure 4 shows that from mid-2007 onwards, credit supply shocks and aggregated demand disturbances accounted for negative deviations from the trend growth in credits. Credit demand shocks contributed negatively to credit and output growth from the end of 2008 till the end of the presented sample period. Throughout 2010, aggregate demand shocks played a vital role in shaping the recovery of both credit and output growth, with the effect being more pronounced for output. On the other hand, the contributions of credit demand and credit supply shocks remain negative until the end of the sample period.

Figure 4
Economic interpretation of US shock part in historical decomposition of US credits and output



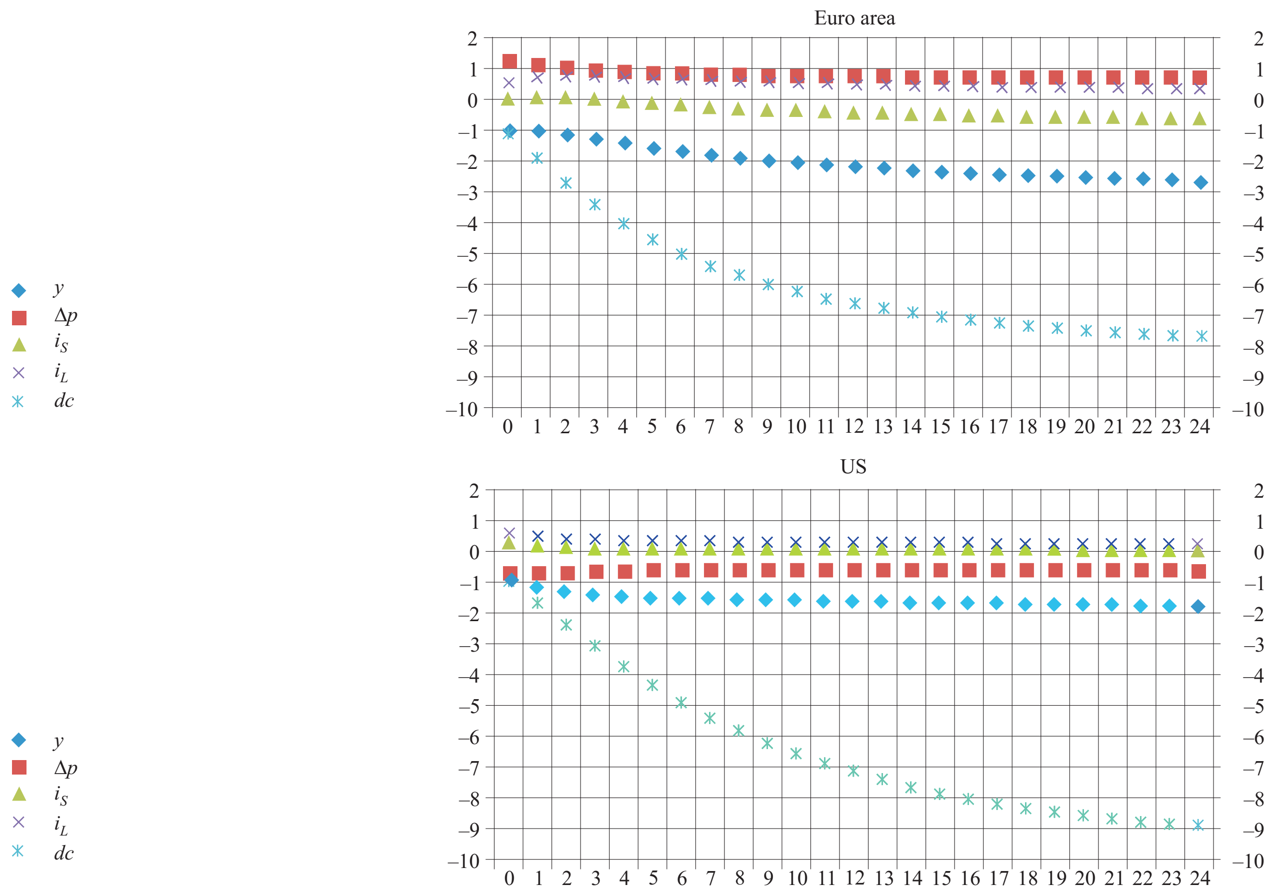
Note. Aggregate supply shock – AS, aggregate demand shock – AD, credit demand shock – LD, credit supply shock – LS, monetary policy shock – MP.

Summarising, US-specific shocks account for a significant share in explaining deviations from growth trends in both euro area and US variables. Euro area-specific shocks explain a large part of credit and output developments in the euro area, with less pronounced effects for the US. A credit supply shock, coupled with a negative shock to credit demand, is the main driver behind negative credit developments in both the euro area and the US. Aggregate demand shocks, in turn, explain the biggest share of output growth developments. It seems that in 2012 and 2013, shocks to credit supply and demand are mostly negative in both the euro area and the US propagating into a sluggish output development.

4.2 Domestic Effects of Adverse Credit Supply Shock and Aggregate Demand Shock

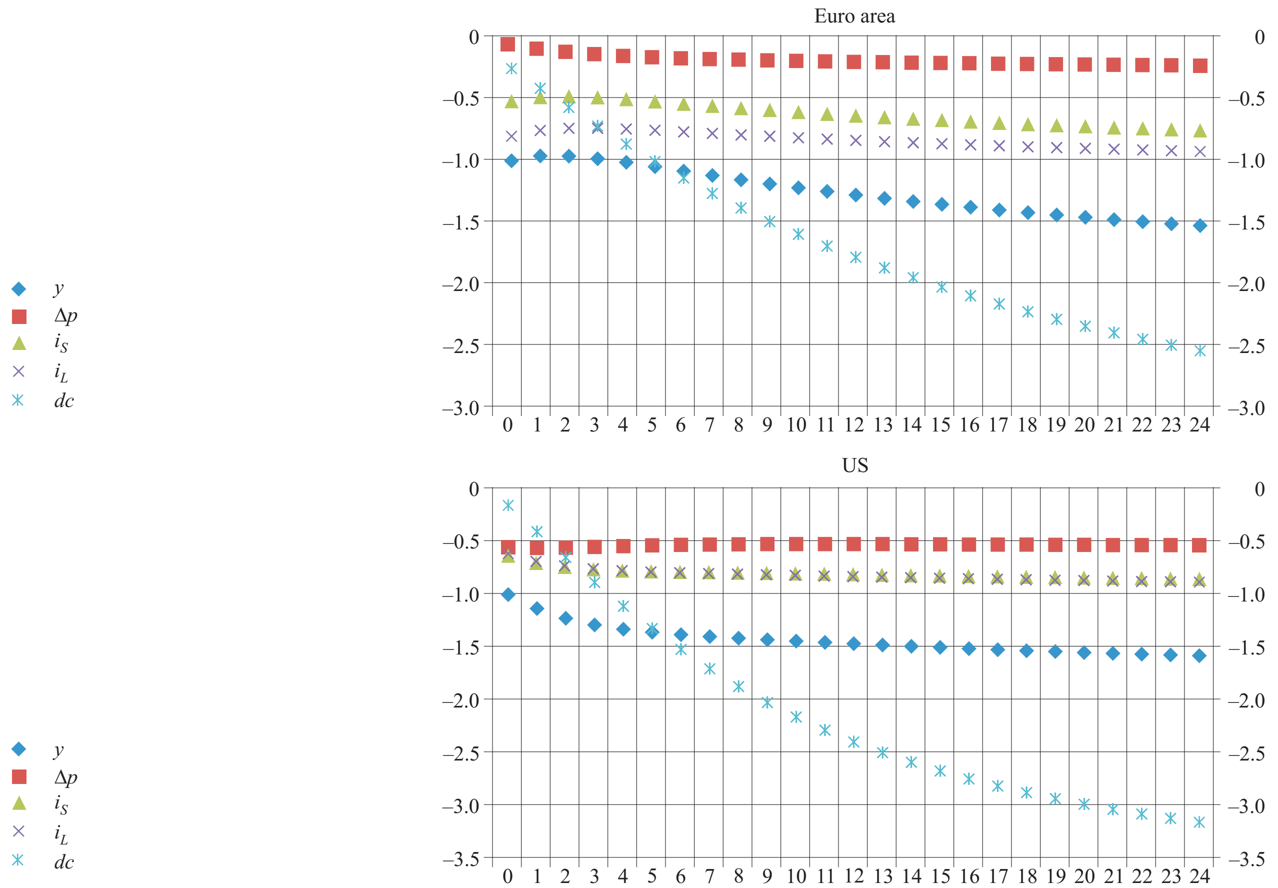
In this Subsection, we present the impulse response analysis of structural shocks defined according to sign restrictions provided in Table 3. Figure 5 presents cumulated structural impulse responses to credit supply shock in the euro area and the US. The impulse response of output is normalised to 1% on impact to facilitate the comparison of the results. As the credit supply shock hits, economy's lending rate increases and the spread between the lending and monetary policy rates widens. Credits and output contract gradually, while the other variables adjust quickly to the new equilibrium. Money market rate reaction to the credit supply shock was left unrestricted (see Table 3), which explains the opposite sign in the responses of inflation, i.e. a slight initial decline in the short-term rate in the euro area and a marginal temporary increase in the US. In the long run, the decrease in credits is about four times larger compared to the decrease in output in both the euro area and the US. The persistent drop in output and credit volumes is in line with findings of related studies (e.g. Busch et al. (2010)). The relative size adjustment is also close to the results of previous studies (e.g. Eickmeier and Ng (2011)).

Figure 5
Euro area and US responses to adverse credit supply shock (percentage changes)



Since the effects of the global financial crisis are perceived as a mixture of negative aggregate demand and credit supply shocks, we present impulse responses to domestic aggregate demand shocks in the euro area and the US in Figure 6. The results are provided in the same fashion as before, with the response of output on impact normalised to 1%. All variables respond gradually to the shock. More specifically, output, inflation, interest rates and credits decrease, with the latter showing the most pronounced reaction. It should be noted that one of the identifying assumptions to separate aggregate demand from credit supply was the initially stronger response of output compared to credits. The data, however, show that cumulated decline in credits surpasses corresponding decline in output after 5 quarters in both the euro area and the US. This probably depicts changes in borrowing behaviour of firms and households due to a demand shock, when a drop in the economic activity does not affect borrowing immediately but adjusts it gradually over time. The relative size of decline in credits compared to output is less pronounced than in the case of credit supply shock, and in the long run it is on average twice the size of decline in output. The adjustment in price level is higher in the US, which is in line with lower price stickiness in the US compared to the euro area.

Figure 6
Euro area and US responses to adverse aggregate demand shock (percentage changes)

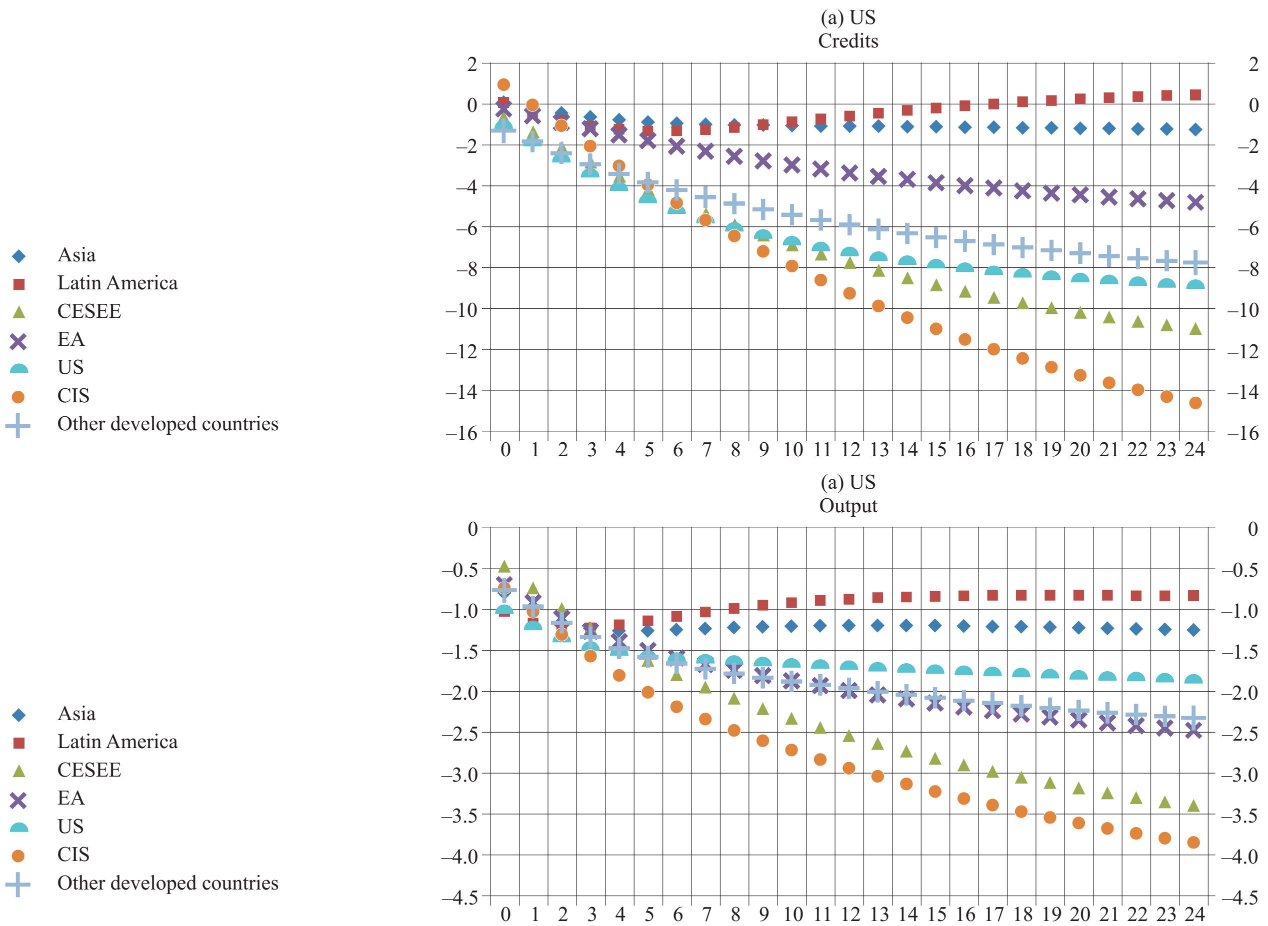


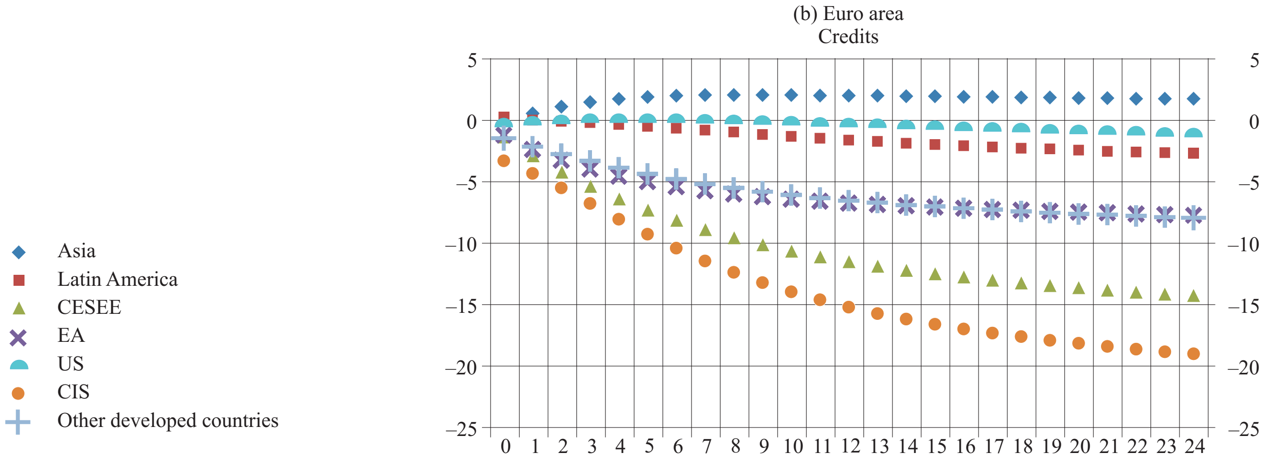
4.3 International Effects of Adverse Credit Supply Shock and Aggregate Demand Shock

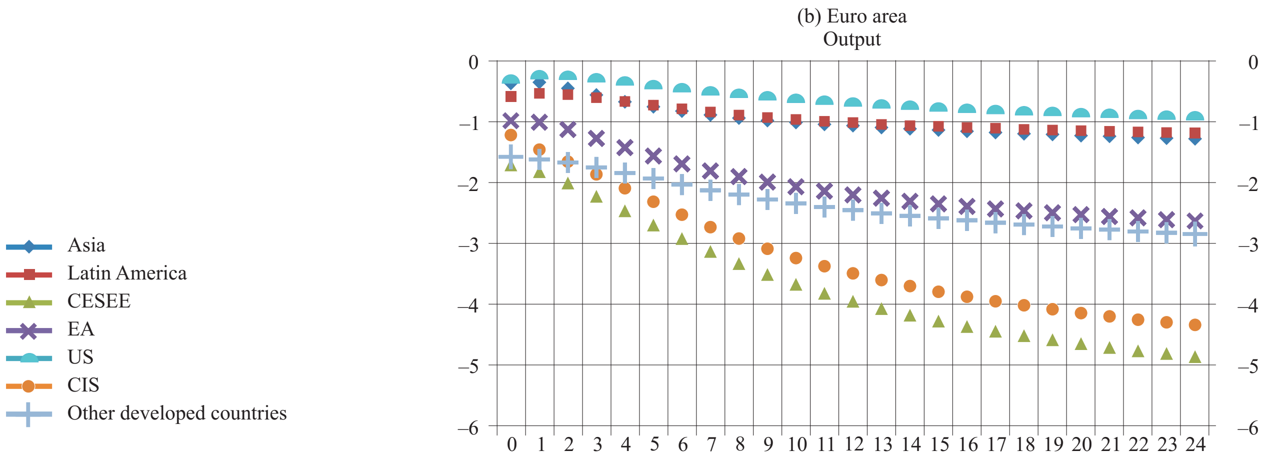
The empirical literature has established significant spillovers that emanate from the US economy to developed and emerging countries. Helbling et al. (2011) reveal that credit market shocks shaped the global business cycle during the latest global recession, especially if the shock emanated from the US. In line with Helbling et al. (2011), Eickmeier and Ng (2011) find a pivotal role of the US in shaping economic conditions in the global economy, while the effects of credit supply shocks emanating from the euro area are comparably milder. This paper aims at providing the analysis of a less explored topic, namely, the euro area credit supply shock transmission to output and credits in CESEE countries. This region is of particular interest, since a large part of the domestic banking sector in CESEE is owned by banks located in the euro area. The extent to which these parent-to-affiliate relationships exist is unique in the global economy, which renders it perfect to study the transmission and effect of a credit supply shock to the host countries' economies.

Before moving to a detailed analysis of CESEE countries, we first wanted to provide bird's eye view on transmission strength of the credit supply shock in the euro area and the US on credits and output internationally (see Figure 7). Impulse responses are constructed by taking simple average over the countries in the region. Alternatively, impulse responses can be weighted by PPP-adjusted GDPs averaged over some period.

Figure 7
Response of output and domestic credit to credit supply shock in US and euro area







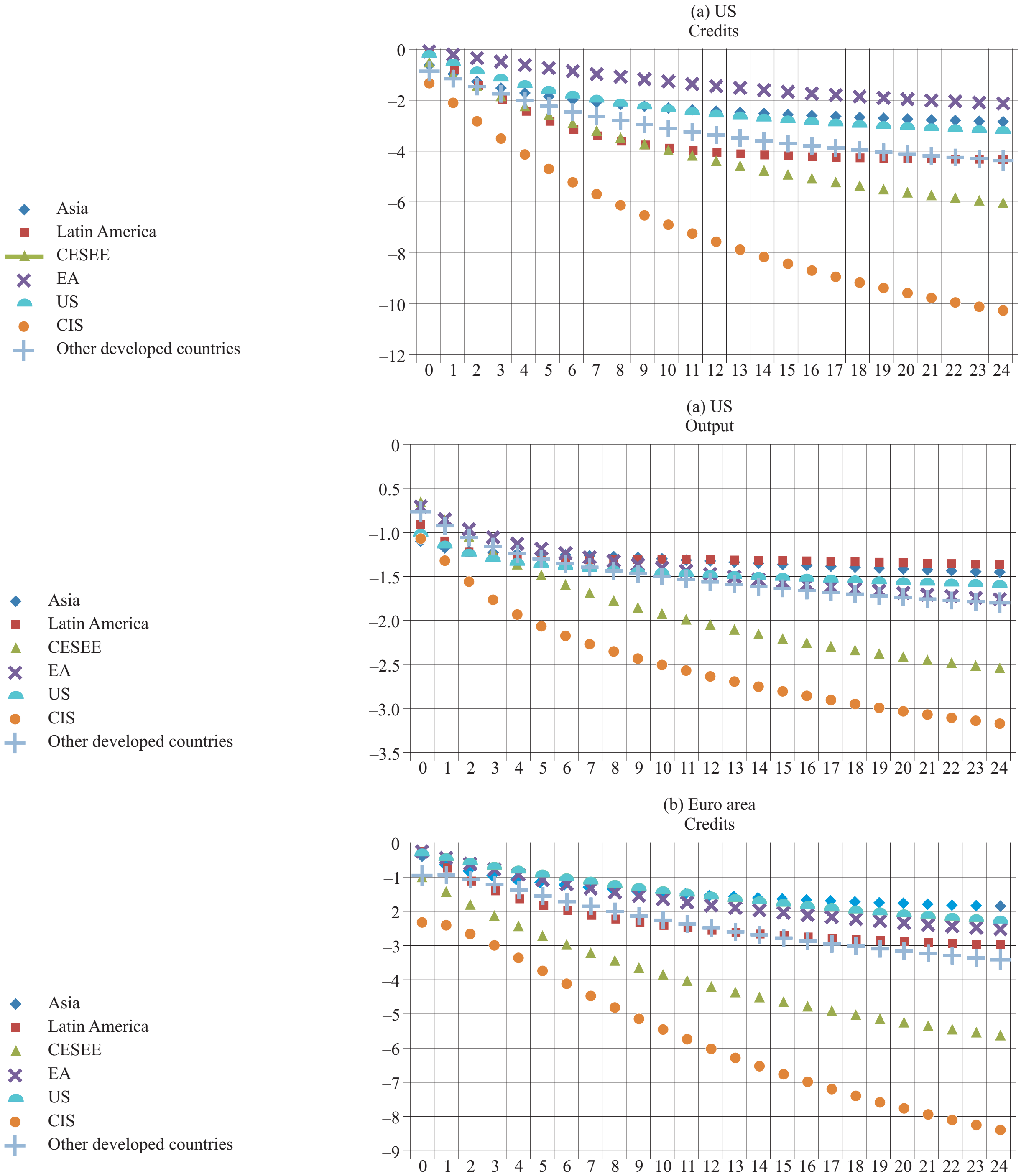
Note. Asia (JP, CN, KR, PH, SG, TH, IN, ID, MY, TR), Latin America (AR, BR, CL, MX, PE), CESEE (AL, BG, CZ, EE, HR, HU, LT, LV, PL, RO, SI, SK), CIS (BY, GE, RU, UA), other developed countries (UK, AU, NZ, CA, CH, NO, SE, DK, IS).

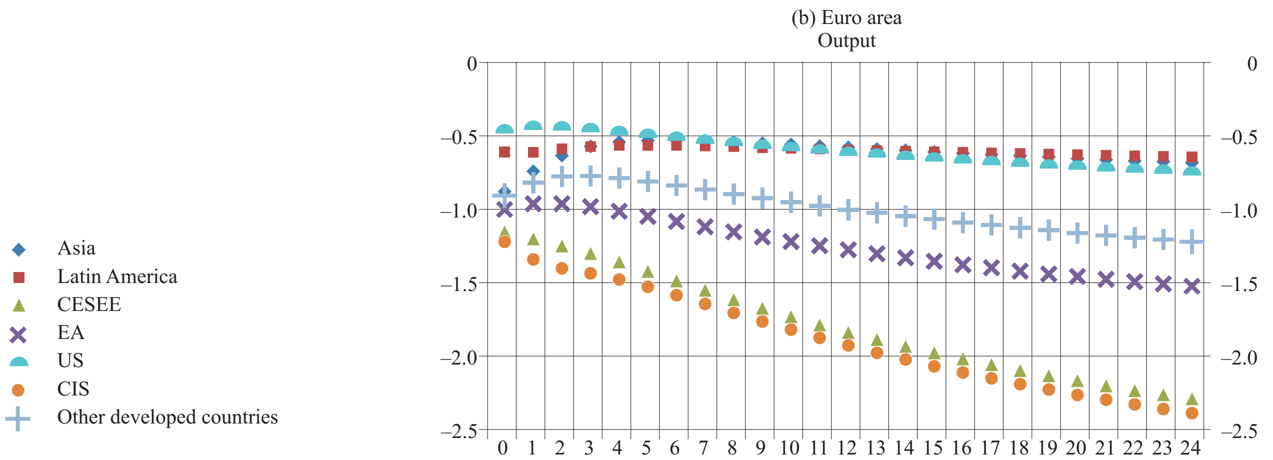
We find a strong negative impact of US credit supply shock on credits in euro area and other developed countries. The average effect on Asia and Latin America is much weaker. Interestingly, the long-run effect on output in the euro area and other developed countries is higher than the one for the US itself, which most probably depicts a second-round effect resulting from a decline in international activity. During the first 4 quarters, the response of CESEE and CIS regions is on average in line with the response of the other European countries; however, in the long run, the effect of the US credit supply shock is more pronounced.

The effect of the euro area credit supply shock on Asia, Latin America and the US is very mild. Output and credits in CIS and CESEE countries, on the other hand, react strongly to changes in credit supply in the euro area. In the long run, the reaction of output and credits exceeds the corresponding variables of the euro area by factor two. It is important that the transmission is very fast, which is in line with tight trade and financial links across countries.

Figure 8

Response of output and credit to aggregate demand shock in US and euro area





Note. Asia (JP, CN, KR, PH, SG, TH, IN, ID, MY, TR), Latin America (AR, BR, CL, MX, PE), CESEE (AL, BG, CZ, EE, HR, HU, LT, LV, PL, RO, SI, SK), CIS (BY, GE, RU, UA), other developed countries (UK, AU, NZ, CA, CH, NO, SE, DK, IS).

To be consistent, we also provide a snapshot of the transmission of aggregate demand shock in the euro area and the US internationally (see Figure 8). As was presented in Figures 5 and 6, it seems that domestic economic downturn caused by a credit supply shock can bring more harm in the long run than the aggregate demand shock. However, despite the milder domestic effect of the aggregate demand shock, its international spillover is stronger than in the case of the credit supply shock. This effect can be explained by difference in the transmission mechanism. The aggregate demand shock mainly affects output and, therefore, is expected to propagate mostly through the trade channel. It is wider than the bilateral banking sector exposures, which should dominate in the transmission of the credit supply shock.

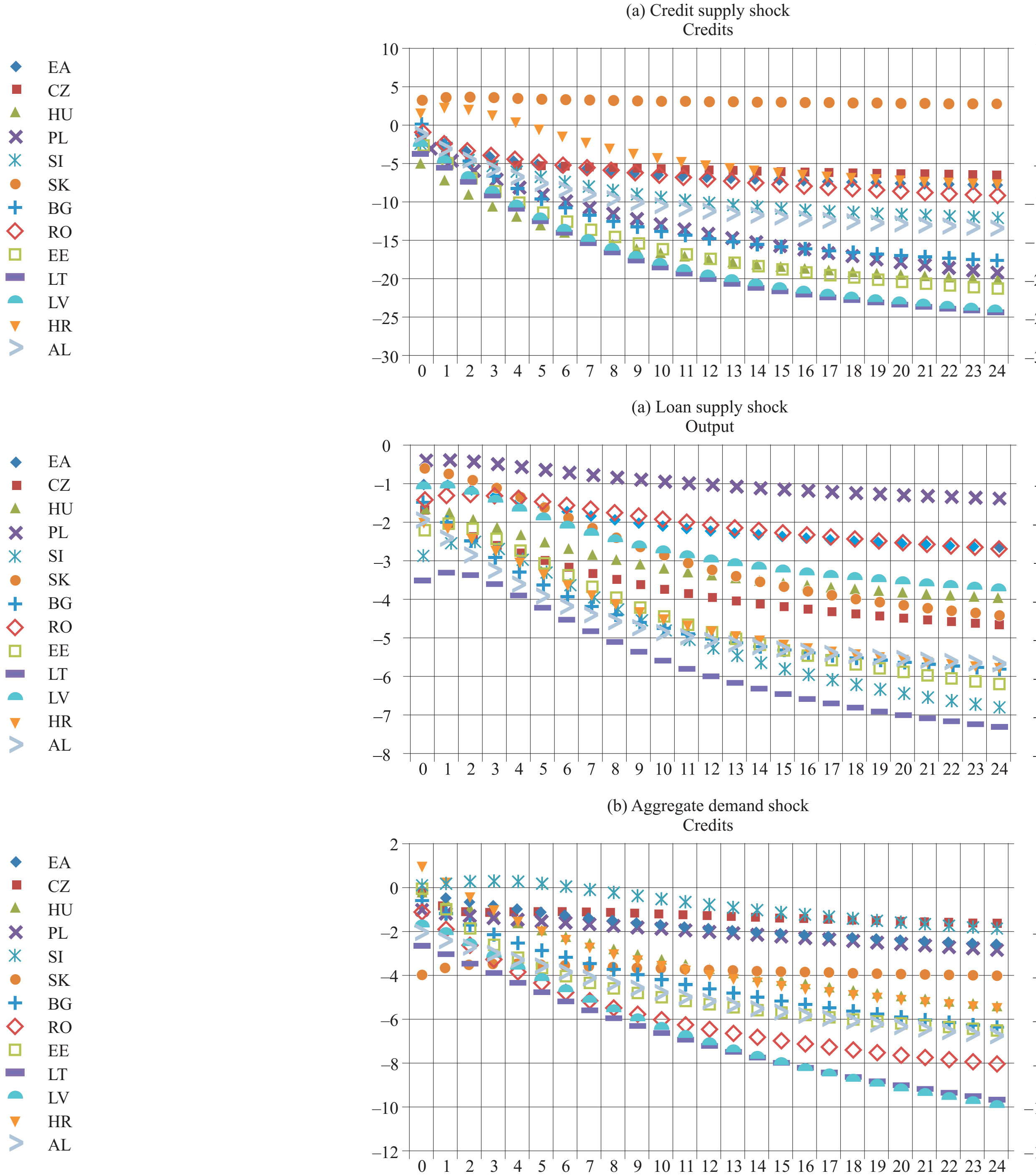
The results of this study show that the US aggregate demand shock causes similar effect on output and credit in the US, Latin America, Asia and the euro area, which confirms stronger international propagation of the aggregate demand shock compared to the credit supply shock. The euro area-specific aggregate demand shock, on the other hand, has a more heterogenous effect on different regions. Close trade and financial ties with CESEE countries explain the immediate pronounced effect on output and credits in this region. Interestingly, the euro area aggregate demand shock has a more pronounced effect on credits in the US than the euro area credit supply shock directly, which is an evidence of the trade channel strength. As a result, as was depicted in historical decomposition, a negative credit supply shock coupled with second-round effects of an adverse aggregate demand shock can cause a plunge in the credit growth internationally.

4.4 CESEE Countries Response to Adverse Credit Supply Shock and Aggregate Demand Shock in Euro Area and US

Summarising the effects of aggregate demand and credit supply shocks on CESEE countries from the previous Subsection, we can conclude that on average the response of output and credits is pronounced and twice as large as the original euro area output and credit reaction in the long run. The transmission of US-specific aggregate demand and credit supply shock is slower than in the case of euro area shocks. However, the ratio between responses of the euro area and CESEE variables remains unchanged. If we look closer at the country level responses, we can see strong heterogeneity in the results (see Figures 9 and 10).

Figure 9

Response of CESEE output and credits to adverse euro area credit supply shock and aggregate demand shock



(b) Aggregate demand shock
Output

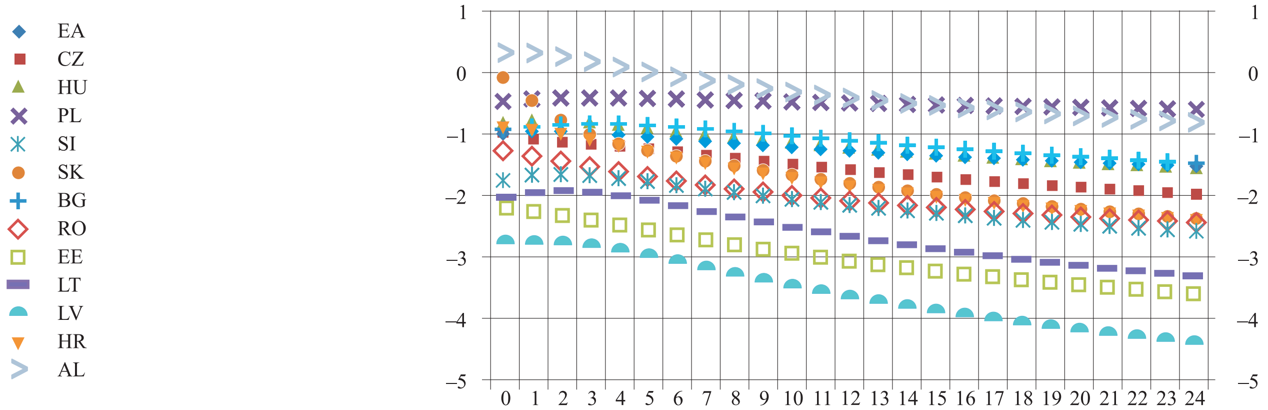
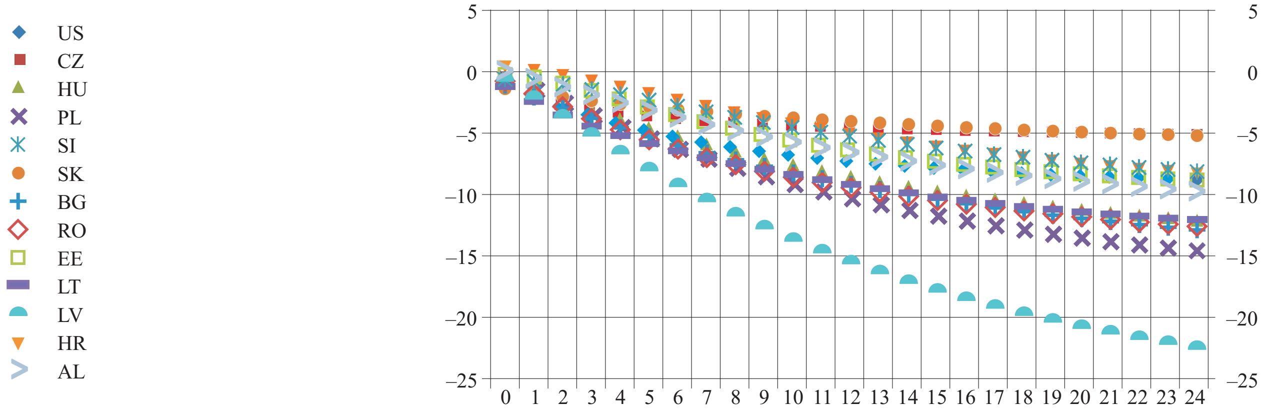
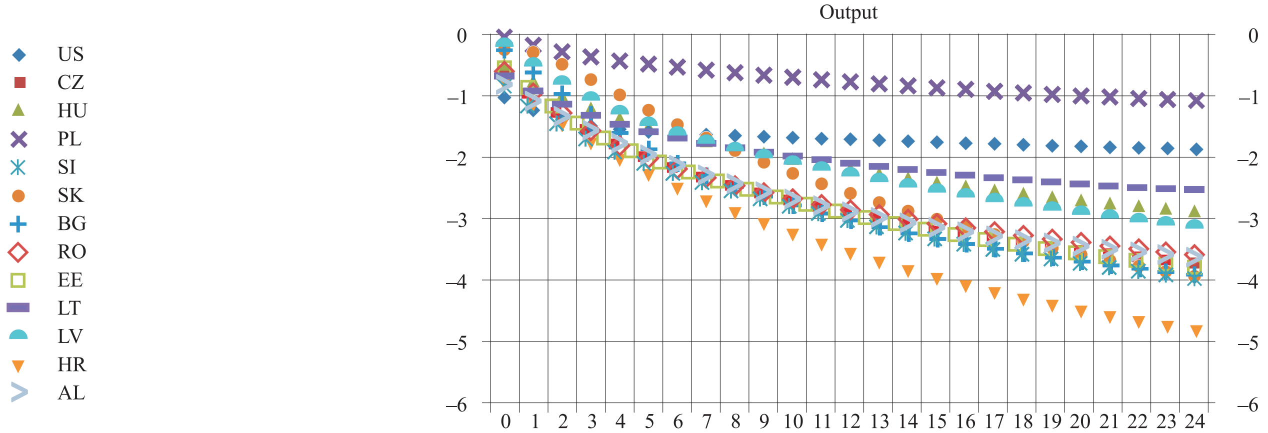


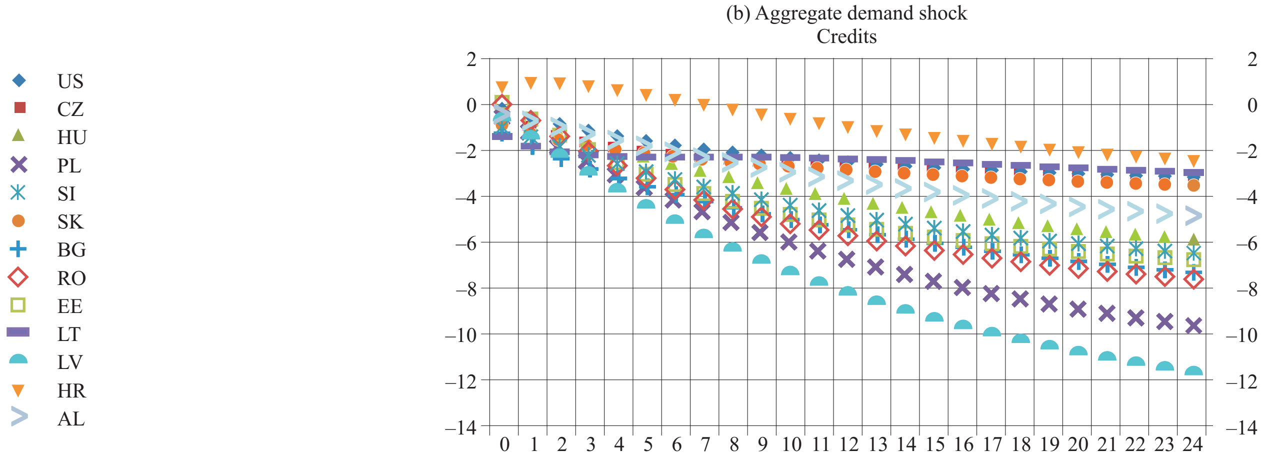
Figure 10
Response of CESEE output and credits to adverse US credit supply and aggregate demand shock

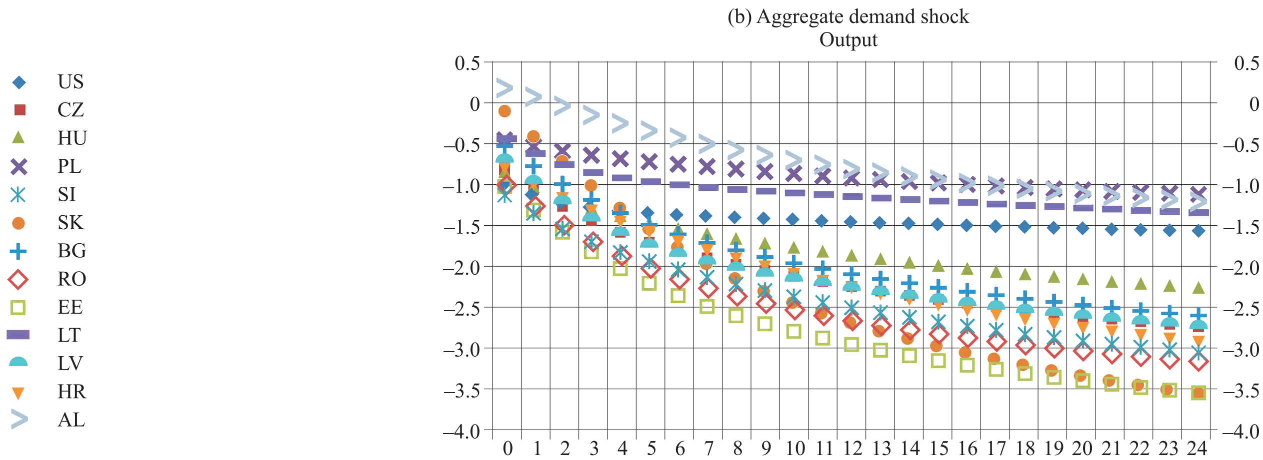
(a) Credit supply shock
Credits



(a) Loan supply shock
Output







In line with the output reaction in the euro area, output in CESEE responds negatively throughout the region to euro area credit supply and aggregate demand shocks. For most of the economies, the response of output is twice as large as the original euro area output reaction. Poland is the most resilient economy. The Baltic States rank among the countries with the most pronounced responses, with the average response of output three times higher than in the euro area.

In general, the variation of responses in credits tends to be higher compared to the output. With the exception of Slovakia, credits contract throughout the region in response to a euro area credit supply shock. The unorthodox behaviour of Slovak credits might be partially explained by the specific features of the Slovak financial system, which is characterised by deposit overhang compared to credits and the resulting stance of the economy as a holder of net foreign assets. The same applies to the Czech Republic, which, however, shows a response that is more in line with those of its peers. Consistent with previous responses, the reaction of the Baltic States is most pronounced and is on average 5 times stronger than the corresponding reaction in the euro area. Assessing spillovers of credits that emanate from aggregate demand disturbances in the euro area, we can notice that the Czech Republic (also Poland and Slovenia) is less affected than other countries in the region (as was the case with the credit supply shock). The response of credits in Slovakia, in contrast to an unusual increase resulting from a credit supply shock, is in line with the general pattern of other countries. Credits in the Baltic States are most affected again.

Figure 10 presents the country response to adverse US credit supply and demand shocks. In line with the finding in the previous Subsection, the transmission of US-specific aggregate demand and credit supply shock is slower, i.e. it affects the region indirectly. It takes approximately a year for the US shock to cause a reduction in the growth rates of output and credits similar to immediate effects of the euro area shock of the same magnitude. Also, in the long run, the size of the response in output and credits is smaller compared to the one caused by shocks in the euro area.

Looking at the country responses, one can notice that in the long run the relative strength of output and credit responses in some countries is robust to the source of shock. Thus the response of credits in the Czech Republic, Slovenia and Slovakia is still the weakest in the region. Similarly, the output growth in Poland is least affected. On the other hand, impulse responses of the Baltic States are not among most pronounced ones as was the case with the euro area shocks. The response of output in the region is smaller. This can be explained by important trade connections within the CESEE region, which is less affected by the US shocks in comparison with the euro area shocks. The response of credits in the Baltic States is becoming heterogeneous, indicating changes in the structure of second round effects, since the effect of US shocks in comparison with the euro area shocks is more widespread.

The above analysis shows that the reaction to shocks across countries in CESEE is very heterogeneous. Several reasons are likely to explain this phenomenon. First, historically the credit-to-deposit ratio in the Czech Republic and Slovakia was below 1, thus helping to ensure solvency of the financial system of the countries. Poland, the Czech Republic, Romania and Bulgaria had the lowest share of foreign-controlled subsidiaries and branches of total assets compared with other countries in the region (59%, 74%, 61% and 71% respectively in 2013 according to ECB monetary and financial statistics), which could restrict potential fund outflows during distress periods. In general, countries differ a lot with respect to the degree of foreign currency involvement in the functioning of their financial systems. As it is shown in the ESRB (2011) and Yesin (2013), over 60% of total outstanding credits by monetary financial institutions in Latvia, Lithuania, Hungary, Bulgaria and Romania was held in the foreign currency in 2011, adding risks to financial stability in these countries. Another important indicator explaining differences in the volatility of response to euro area shocks is the share of mortgage credits with floating interest rate. The interest rates on long-term credits in the Czech Republic and Slovakia are mostly fixed. In Estonia, Latvia, Lithuania, Poland and Slovenia, mortgage interest rates are mostly floating, and this facilitates the transmission of country-specific shocks to lending margins, thus increasing negative expectations about the ability of borrowers to repay the debt during the crisis. The propagation of shocks does not necessarily depend only on purely financial indicators; sound macroeconomic and fiscal policies provide the necessary prerequisites to scale down the effect of shocks as well.

5. CONCLUSIONS

In this paper, we use a GVAR model with credit variables to analyse international transmission of euro area and US credit and aggregate demand shocks. In order to pin down clearly the shocks of interest, we distinguish five structural shocks affecting the euro area and the US via sign restrictions: they are aggregate supply, monetary policy, aggregate demand, credit demand and credit supply shocks. We use trade and bilateral bank exposure to weight foreign macro and financial variables. In order to tackle a break in the long-run equilibrium between output and credit growth rates, we propose to include a structural break dummy into the cointegration equation of individual country VEC models.

The results of historical decomposition analysis show that US-specific shocks account for a significant share in explaining deviations from growth trends in output and total credits in both the euro area and US variables. The euro area-specific shocks explain a large part of developments in credits and output in the euro area, with less pronounced effect for the US. The credit supply shock, coupled with lagged negative shock to credit demand, is an important driver behind the negative credit developments in both the euro area and the US. The aggregate demand shock explains the biggest share of output growth developments. Throughout 2010, aggregate demand shocks played a vital role in shaping the recovery of both credit and output growth in the US. In 2012–2013, negative shocks to credit supply and demand in both the euro area and the US translated into sluggish output developments.

The impulse response analysis shows that the domestic economic downturn caused by a credit supply shock can bring more harm in the long run than the aggregate demand shock. However, despite a milder domestic effect of an aggregate demand shock, its international spillover is stronger than in the case of a credit supply shock. Therefore, as is evident from historical decomposition, a negative credit supply shock coupled with the second round effect of an adverse aggregate demand shock can cause a plunge in the growth of credits and output internationally.

The US credit supply shock has had a strong negative effect on credits in the euro area and other developed countries, while effects on Asia and Latin America were weaker. The effect on euro area is mild yet important domestically and for CESEE countries. In the long run, the reaction of output and credits in CESEE countries on average exceeds the corresponding euro area variables by factor two. It is important that the transmission of euro area shocks in comparison with US-specific shocks is faster, which is in line with tight trade and financial links between the CESEE countries and the euro area. It takes approximately a year for the US shock to cause a similar reduction in output and credit growth rates as the immediate effect of the euro area shock of the same magnitude. Also, in the long run, the size of the response in output and credits is smaller compared to the one caused by shocks in the euro area.

The conducted detailed analysis of impulse responses in CESEE countries shows strong heterogeneity. The Czech Republic, Slovakia and Poland are the most resilient economies. The Baltic States seem to be more vulnerable to financial distress in the euro area (less so in the case of US shocks), which can be explained by the historically high volatility of macro fundamentals in the region as well as a high degree of shock propagation into the financial system and significant trade connections with highly volatile CIS countries.

APPENDIX

Table A1

Specification of country models (domestic and foreign variables)

Country	Domestic variables	Foreign variables	Deterministic component	Cointegration rank
EA	$y, \Delta p, e, dc, i_s, lr/i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	5*	1
US	$y, \Delta p, dc, i_s, lr/i_l, poil$	$y^*, \Delta p^*, e^*$	5*	1
UK	$y, \Delta p, e, dc, i_s, i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	5*	1
JP	$y, \Delta p, e, dc, i_s, i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
CN	$y, \Delta p, e, dc, i_s, i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{***}$	3	1
CZ	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	5*	1
HU	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	5*	1
PL	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	5*	1
SI	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	5*	1
SK	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	5*	1
BG	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	5*	1
RO	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	5*	1
EE	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	5*	1
LT	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	5*	1
LV	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	5*	1
HR	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
AL	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
RU	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{***}$	5*	1
UA	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	5*	1
BY	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
GE	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
AR	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
BR	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{***}$	3	2
CL	$y, \Delta p, e$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
MX	$y, \Delta p, e, dc, i_s, i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{***}$	3	1
PE	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
KR	$y, \Delta p, e, dc, i_s, i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*$	3	2
PH	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
SG	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
TH	$y, \Delta p, e, dc, i_s, i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
IN	$y, \Delta p, e, dc$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{***}$	3	1
ID	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
MY	$y, \Delta p, e, dc, i_s, i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	4	1
AU	$y, \Delta p, e, dc, i_s, i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	5*	1
NZ	$y, \Delta p, e, i_s, i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
TR	$y, \Delta p, e, dc, i_s$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
CA	$y, \Delta p, e, dc, i_s, i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{***}$	5*	2
CH	$y, \Delta p, e, dc, i_s, i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
NO	$y, \Delta p, e, dc, i_s, i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{***}$	3	1
SE	$y, \Delta p, e, dc, i_s, i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
DK	$y, \Delta p, e, dc, i_s, i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1
IS	$y, \Delta p, e, dc, i_s, i_l$	$y^*, \Delta p^*, dc*, i_s^*, i_l^*, poil^{**}$	3	1

Notes. The table represents the general specification and cross-country variable coverage of the GVAR model. Throughout the paper, we have used 1 lag for endogenous, weakly exogenous and strictly exogenous variables only. Deterministic components: 3 – intercept, 4 – intercept and trend, 5* – intercept and structural break dummy for 2009 Q1–2013 Q4. Poil*** indicates that oil was included in the long-run cointegration equation of the country model.

Table A2
Specification of country models (dummy variables)

Country	Dummy variables
EA	–
US	$dc \times \mathrm{usD}_{(99Q4,12Q4)}$, $\mathrm{usD}_{(99Q4,12Q4)}$
UK	–
JP	$e \times \mathrm{jpD}_{(98Q4)}$, $\mathrm{jpD}_{(98Q4)}$
CN	$dc \times \mathrm{cnD}_{(01Q1)}$, $\mathrm{cnD}_{(01Q1)}$, $i_s \times \mathrm{cnD}_{(96Q1-Q2,08Q4)}$, $\mathrm{cnD}_{(96Q1-Q2,08Q4)}$
CZ	$i_s \times \mathrm{czD}_{(97Q2)}$, $\mathrm{czD}_{(97Q2)}$, $dc \times \mathrm{czD}_{(01Q3)}$, $\mathrm{czD}_{(01Q3)}$
HU	–
PL	$i_s \times \mathrm{plD}_{(96Q4-97Q1,98Q2-Q3)}$, $\mathrm{plD}_{(96Q4-97Q1,98Q2-Q3)}$
	$y \times \mathrm{plD}_{(95Q3,97Q4,96Q4-97Q1)}$, $\mathrm{plD}_{(96Q4-97Q1,98Q2-98Q3)}$
	$y \times \mathrm{plD}_{(95Q3,97Q4,96Q4-97Q1)}$, $\mathrm{plD}_{(95Q3,97Q4,96Q4-97Q1)}$
	$e \times \mathrm{plD}_{(08Q4)}$, $\mathrm{plD}_{(08Q4)}$
SI	$i_s \times \mathrm{siD}_{(96Q2-Q3)}$, $\mathrm{siD}_{(96Q2-Q3)}$, $cd \times \mathrm{siD}_{(00Q1,01Q1-Q3)}$, $\mathrm{siD}_{(00Q1,01Q1-Q3)}$
SK	$Dp \times 99\mathrm{Q3}$, skD_{99Q3}, $dc \times 97\mathrm{Q1}$, skD_{97Q1}, $i_s \times \mathrm{skD}_{(95Q3,98Q1-Q2,98Q4,09Q1)}$, $\mathrm{skD}_{95Q3,98Q1-Q2,98Q4,00Q1}$
	$y \times \mathrm{skD}_{(98Q4,07Q4-08Q1,09Q1)}$, $\mathrm{skD}_{98Q4,07Q4-08Q1,09Q1}$
BG	$i_s \times \mathrm{bgD}_{(95Q4-97Q3)}$, $\mathrm{bgD}_{(95Q4-97Q3)}$, $Dp \times \mathrm{bgD}_{(95Q4-97Q3,98Q1-Q2)}$, $\mathrm{bgD}_{(95Q4-97Q3,98Q1-Q2)}$
	$dc \times \mathrm{bgD}_{(95Q4,96Q2-Q3,97Q1,97Q4-98Q1)}$, $\mathrm{bgD}_{(95Q4,96Q2-Q3,97Q1,97Q4-98Q1)}$, $e \times \mathrm{bgD}_{(96Q1,96Q4)}$, $\mathrm{bgD}_{(96Q1,96Q4)}$
RO	$i_s \times \mathrm{roD}_{(97Q1-Q3)}$, $e \times \mathrm{roD}_{(97Q1-Q3)}$, $\mathrm{roD}_{(97Q1-Q3)}$, $Dp \times \mathrm{roD}_{(96Q1,97Q1-97Q3)}$
	$\mathrm{roD}_{(96Q4-97Q3,98Q1,98Q4-99Q2)}$
EE	$i_s \times \mathrm{eeD}_{(97Q4,98Q4-99Q1)}$, $\mathrm{eeD}_{(97Q4,98Q4-99Q1)}$, $y \times \mathrm{eeD}_{(08Q4)}$, $\mathrm{eeD}_{(08Q4)}$
	$Dp \times \mathrm{eeD}_{(95Q4,96Q2-Q3,97Q2)}$, $\mathrm{eeD}_{(95Q4,96Q2-Q3,97Q2)}$, $dc \times \mathrm{eeD}_{(95Q4,96Q4)}$, $\mathrm{eeD}_{(95Q4,96Q4)}$
LT	$i_s \times \mathrm{ltD}_{(96Q3-97Q1,00Q1)}$, $\mathrm{ltD}_{(96Q3-97Q1,00Q1)}$
	$Dp \times \mathrm{ltD}_{(95Q4-96Q1,96Q3)}$, $\mathrm{ltD}_{(95Q4-96Q1,96Q3)}$, $y \times \mathrm{ltD}_{(09Q1)}$, $\mathrm{ltD}_{(09Q1)}$
LV	$i_s \times \mathrm{lvD}_{(98Q4,09Q1-Q2)}$, $\mathrm{lvD}_{(98Q4,09Q1-Q2)}$, $Dp \times \mathrm{lvD}_{(95Q4)}$, $\mathrm{lvD}_{(95Q4)}$
	$dc \times \mathrm{lvD}_{(95Q4,96Q4)}$, $\mathrm{lvD}_{(95Q4,96Q4)}$, $y \times \mathrm{lvD}_{(08Q3,09Q1-Q2)}$, $\mathrm{lvD}_{(08Q3,09Q1-Q2)}$
HR	$i_s \times \mathrm{hrD}_{(95Q4-96Q3)}$, $\mathrm{hrD}_{(95Q4-96Q3)}$, $dc \times \mathrm{hrD}_{(96Q4-97Q1,97Q4,99Q2)}$, $\mathrm{hrD}_{(96Q4-97Q1,97Q4,99Q2)}$
	$y \times \mathrm{hrD}_{(97Q1,98Q1,98Q4)}$, $\mathrm{hrD}_{(97Q1,98Q1,98Q4)}$
AL	$i_s \times \mathrm{alD}_{(96Q2,97Q1-Q2,98Q3)}$, $\mathrm{alD}_{(96Q2,97Q1-Q2,98Q3)}$, $y \times \mathrm{alD}_{(97Q1,98Q1)}$, $\mathrm{alD}_{(97Q1,98Q1)}$
	$dc \times \mathrm{alD}_{(97Q1,00Q3-Q4,01Q3-Q4)}$, $\mathrm{alD}_{(97Q1,00Q3-Q4,01Q3-Q4)}$, $Dp \times \mathrm{alD}_{(96Q3,97Q2-Q3)}$, $\mathrm{alD}_{(96Q3,97Q2-Q3)}$
RU	$i_s \times \mathrm{ruD}_{(98Q3)}$, $dc \times \mathrm{ruD}_{(98Q3)}$, $\mathrm{ruD}_{(98Q3)}$, $Dp \times \mathrm{ruD}_{(96Q1,98Q3-99Q1)}$, $\mathrm{ruD}_{(96Q1,98Q3-99Q1)}$
UA	$i_s \times \mathrm{uaD}_{(98Q3,99Q3-00Q1)}$, $\mathrm{uaD}_{(98Q3,99Q3-00Q1)}$, $Dp \times \mathrm{uaD}_{(96Q1)}$, $\mathrm{uaD}_{(96Q1)}$, $dc \times \mathrm{uaD}_{(98Q3)}$
BY	$i_s \times \mathrm{byD}_{(96Q1)}$, $\mathrm{byD}_{(96Q1,97Q1)}$, $Dp \times \mathrm{byD}_{(96Q1,97Q1)}$, $dc \times \mathrm{byD}_{(97Q1,98Q4,00Q1)}$, $\mathrm{byD}_{(97Q1,98Q4,00Q1)}$
	$e \times \mathrm{byD}_{(98Q1,99Q4-00Q1)}$, $\mathrm{byD}_{(98Q1,99Q4-00Q1)}$
GE	$i_s \times \mathrm{geD}_{(98Q4-99Q1)}$, $\mathrm{geD}_{(98Q4-99Q1)}$, $Dp \times \mathrm{geD}_{(95Q4)}$, $\mathrm{geD}_{(95Q4)}$, $dc \times \mathrm{geD}_{(96Q2)}$, $\mathrm{geD}_{(96Q2)}$
AR	$i_s \times \mathrm{arD}_{(01Q4-02Q1,02Q4)}$, $\mathrm{arD}_{(01Q4-02Q1,02Q4)}$, $Dp \times \mathrm{arD}_{(02Q1)}$,$\mathrm{arD}_{(02Q1)}$, $dc \times \mathrm{arD}_{(01Q1,02Q1)}$,$\mathrm{arD}_{(01Q1,02Q1)}$
	$e \times \mathrm{arD}_{(02Q1-Q2)}$, $\mathrm{arD}_{(02Q1-Q2)}$

Country	Dummy variables
BR	$i_s \times \text{brD}_{(97Q4-98Q2,98Q4,99Q2)}$, $\text{brD}_{(97Q4-98Q2,98Q4,99Q2)}$, $Dp \times \text{brD}_{(96Q1,03Q2)}$, $\text{brD}_{(96Q1,03Q2)}$
	$Dc \times \text{brD}_{(00Q1)}$, $\text{brD}_{(00Q1)}$
CL	–
MX	$Dp \times \text{mxD}_{(96Q1-96Q2)}$, $\text{mxD}_{(96Q1-96Q2)}$, $i_s \times \text{mxD}_{(95Q4-96Q1,98Q3,99Q2)}$, $\text{mxD}_{(95Q4-96Q1,98Q3,99Q2)}$
PE	$i_s \times \text{peD}_{(98Q3-Q4)}$, $\text{peD}_{(98Q3-Q4)}$
KR	$dc \times \text{krD}_{(97Q1,97Q4,98Q4,99Q1-Q2)}$, $\text{krD}_{(97Q1,97Q4,98Q4,99Q1-Q2)}$, $e \times \text{krD}_{(97Q4-98Q1)}$, $\text{krD}_{(97Q4-98Q1)}$
	$i_s \times \text{krD}_{(97Q4-98Q1)}$
PH	$Dp \times \text{phD}_{(99Q2,00Q1-Q2)}$, $\text{phD}_{(99Q2,00Q1-Q2)}$, $dc \times \text{phD}_{(96Q4-97Q3,01Q4)}$, $\text{phD}_{(96Q4-97Q3,01Q4)}$
	$i_s \times \text{phD}_{(95Q4,97Q3,98Q1)}$, $\text{phD}_{(95Q4,97Q3,98Q1)}$
SG	–
TH	$i_s \times \text{thD}_{(96Q3,97Q3,98Q3)}$, $\text{thD}_{(96Q3,97Q3,98Q3)}$, $e \times \text{thD}_{(97Q3,98Q2)}$, $y \times \text{thD}_{(11Q4-12Q1,12Q4)}$, $\text{thD}_{(11Q4-12Q1,12Q4)}$
IN	$Dp \times \text{inD}_{(98Q1,99Q1)}$, $\text{inD}_{(98Q1,99Q1)}$
ID	$i_s \times \text{idD}_{(97Q3)}$, $e \times \text{idD}_{(97Q3)}$,$Dp \times \text{idD}_{(97Q4-98Q1)}$ $\text{idD}_{(97Q4-98Q1)}$,$e \times \text{idD}_{(98Q1,98Q4)}$, $e \times \text{idD}_{(98Q1,98Q4)}$
MY	$dc \times \text{myD}_{(95Q2-97Q4)}$, $\text{eD}_{(95Q2-97Q4)}$, $Dp \times \text{myD}_{(08Q4)}$, $\text{eD}_{(08Q4)}$
AU	$Dp \times \text{auD}_{(00Q3-Q4)}$, $\text{auD}_{(00Q3-Q4)}$, $i_s \times \text{auD}_{(08Q4)}$, $\text{auD}_{(08Q4)}$, $dc \times \text{auD}_{(01Q2)}$, $\text{auD}_{(01Q2)}$
NZ	$i_s \times \text{nzD}_{(98Q1,98Q3)}$, $\text{nzD}_{(98Q1,98Q3)}$, $y \times \text{nzD}_{(96Q1-Q3)}$, $\text{nzD}_{(96Q1-Q3)}$, $Dp \times \text{nzD}_{(10Q4,11Q4)}$, $\text{nzD}_{(10Q4,11Q4)}$
TR	$i_s \times \text{trD}_{(00Q1,00Q4)}$, $\text{trD}_{(00Q1,00Q4)}$, $Dp \times \text{trD}_{(01Q2,02Q3)}$, $\text{trD}_{(01Q2,02Q3)}$, $dc \times \text{trD}_{(08Q4)}$, $\text{trD}_{(08Q4)}$
CA	–
CH	–
NO	$i_s \times \text{noD}_{(98Q3)}$, $\text{noD}_{(98Q3)}$, $Dp \times \text{noD}_{(03Q2)}$, $\text{noD}_{(03Q2)}$
SE	–
DK	$Dp \times \text{dkD}_{(07Q4)}$, $\text{dkD}_{(07Q4)}$, $dc \times \text{dkD}_{(01Q4-02Q1)}$, $\text{dkD}_{(01Q4-02Q1)}$
IS	$i_s \times \text{isD}_{(01Q4,02Q1-Q2)}$, $\text{isD}_{(01Q4,02Q1-Q2)}$, $dc \times \text{isD}_{(08Q4)}$, $\text{isD}_{(08Q4)}$

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