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ABSTRACT

How Do Credit Supply Shocks Propagate Internationally? A GVAR approach*

We study how credit supply shocks in the US, the euro area and Japan are transmitted to other economies. We use the recently-developed GVAR approach to model financial variables jointly with macroeconomic variables in 33 countries for the period 1983-2009. We experiment with inter-country links that distinguish bilateral trade, portfolio investment, foreign direct investment and banking exposures, as well as asset-side vs. liability-side financial channels. Capturing both bilateral trade and inward foreign direct investment or outward banking claim exposures in a GVAR fits the data better than using trade weights only. We use sign restrictions on the short-run impulse responses to financial shocks that have the effect of reducing credit supply to the private sector. We find that negative US credit supply shocks have stronger negative effects on domestic and foreign GDP, compared to credit supply shocks from the euro area and Japan. Domestic and foreign credit and equity markets respond clearly to the credit supply shocks. Exchange rate responses are consistent with a "flight to quality" to the US dollar. The UK, another international financial centre, is also responsive to the shocks. These results are robust to the exclusion of the 2007-09 crisis episode from the sample.

JEL Classification: C3, F15, F36, F41 and F44
Keywords: credit supply shocks, global VAR, international business cycles, sign restrictions, trade and financial integration

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Contents

1 Introduction

The rapid emergence and spread of the global financial and economic crisis have galvanised interest in the financial system's contribution to international economic dynamics. Recent theoretical models highlight financial markets and institutions as sources of shocks and as vehicles transmitting shocks across borders, alongside more traditional trade and productivity effects. For example, financial shocks feature heavily in Christiano et al. (2010)'s monetary DSGE model augmented with a banking sector and financial markets. Shocks can be transmitted across borders via markets, as arbitrage equalises asset prices and the cost of credit in international markets (e.g. Dedola and Lombardo (2010), Perri and Quadrini (2011)), or as leverage-constrained investors rebalance internationally diversified portfolios (referred to as the "international financial multiplier" by Krugman (2008); see also Devereux and Yetman (2010) and Devereux and Sutherland (2011)). Shocks can also spill across borders via multinational financial institutions, as they raise capital, contract lending or dump illiquid assets in some countries to maintain global capital and liquid asset ratios when faced with loan losses (e.g. Enders et al. (2011)) or funding squeezes (Gorton (2009), Borio et al. (2011)) in other countries.

In this paper, we use a rich multi-country dataset to examine empirically the international propagation of financial shocks. More specifically, we are interested in shocks that have the effect of reducing the supply of credit to the private sector. Such shocks could reflect unexpected changes in the financial condition or risk aversion of banks and other investors, or in regulatory requirements on them. We look at the effects on foreign output and financial markets of credit supply shocks originating in the US, the euro area and Japan, three major international financial centres. This focus reflects the strong current interest in the role of advanced-country credit and funding markets in the recent global crisis (see e.g. Imbs (2010), Cetorelli and Goldberg (2011), Committee on the Global Financial System (2011)), which among other things has provoked wide-ranging reforms to the regulation of credit markets (see e.g. Drehmann et al. (2010), Basel Committee on Banking Supervision (2010)).

We use as an econometric strategy the recently developed Global VAR (GVAR) approach (Pesaran et al. (2004), Pesaran and Smith (2006)), which allows rich and flexible modelling of the different ways in which shocks propagate around the world, while keeping dimensionality manageable. Our dataset comprises quarterly macroeconomic and financial variables from 33 advanced and emerging countries over the period 1983 to 2009, covering for each country (where available) GDP, inflation, short term interest rates, government and corporate bond yields, credit to the non-financial private sector, equity prices and exchange rates. The GVAR model is composed of VARs for each country. The countries are linked together via inclusion of foreign variables in the country VARs, and these foreign variables are either global variables or weighted averages of all other countries' variables.

The weights capture each country's bilateral exposures to the other countries due to trade and financial linkages.

We make three main contributions. First, we add to the empirical literature on the international transmission of financial shocks, which remains small because of the technical challenges involved in dealing with high-dimension multi-country models. Second, using the GVAR we identify, by means of sign restrictions, credit supply shocks disentangled from other domestic shocks. Previous GVAR studies have mostly looked at generalised impulse responses to shocks that are not necessarily orthogonal, making economic interpretation difficult. Third, we use a range of country weighting schemes that distinguish the more typically-used trade exposures from financial exposures, themselves further separated out into portfolio investment, direct investment and banking exposures. Further, we distinguish asset-side from liability-side exposures in each financial exposure category. We formally evaluate the empirical validity of the different weighting schemes using information criteria and (in-sample) forecasting performance under each scheme, and examine the extent to which the impulse response results are robust to the choice of scheme.

Our main findings underscore the importance of financial markets and exposures in international financial and economic dynamics. First, a GVAR which uses a more sophisticated weighting scheme involving a combination of trade and inward foreign direct investment or outward banking claim exposures fits the data best. A GVAR model which uses trade exposures alone performs relatively badly. We find that US credit supply shocks substantially affect GDP in other countries. Such shocks appear to be propagated internationally with the involvement of foreign credit and equity markets, producing a clear international financial cycle. The transmission of Japanese and euro-area credit supply shocks to foreign GDP is weaker and less statistically significant, but is still marked by an apparent "flight to quality" effect towards the US dollar in foreign exchange markets.

The rest of the paper is structured as follows. In Section 2, we briefly review the literature most relevant to our contributions. The GVAR framework is set out in Section 3. In Sections 4 and 5, we provide details on the data and the results of GVAR model selection and estimation, respectively. Section 6 sets out our identification scheme in detail. Section 7 presents impulse response results, using our benchmark model, on the domestic and international transmission of credit supply shocks. In Section 8 we look at the effect on the results when the benchmark weighting scheme is replaced with other schemes and conduct other robustness checks. Section 9 concludes.

2 Literature relevant to our contributions

2.1 Empirical international financial shock transmission literature

Empirical work on the international transmission of financial shocks faces the challenge of potentially many more variables and parameters than observations. Without some way of (heavily) restricting the parameter space, such models are not estimable by standard econometric techniques. This technical difficulty may partly explain why the empirical literature on international financial shock transmission remains sparse.

An obvious way to reduce dimension is to apply weighted-averaging to the variables. Two broad approaches to this process have been used in the study of international economic dynamics. The first is the GVAR, whose applications to international financial shock transmission include Galesi and Sgherri (2009), Chen et al. (2010), Beaton and Desroches (2011), Xu (2010) Chudik and Fratzscher (2011) and Bussière et al. (2011). The second approach is the factor-augmented VAR (or FAVAR) (Stock and Watson (2002), Bernanke et al. (2005)), whose applications to international financial shock transmission include Helbling et al. (2011), Eickmeier et al. (2011a) and Bagliano and Morana (2011).

We use the GVAR approach because of its advantages (i) that country-specific dynamics are modelled explicitly, and (ii) that cointegration among variables is allowed for. By contrast, most factor model applications to multi-country international dynamics capture country-specific dynamics only implicitly through the idiosyncratic components, and use datasets that have been rendered stationary by differencing, thus discarding information about long-run relationships.

Helbling et al. (2011)'s FAVAR and Beaton and Desroches (2011)' and Xu (2010)'s GVAR studies are perhaps most closely related to our paper, in that they also look at the international transmission of credit shocks. The other applications cited above look at different types of financial shocks, such as "financial conditions" (Eickmeier et al. (2011a)) or "financial distress" shocks (Chen et al. (2010)) as distinct from macroeconomic and monetary policy shocks. However, we broaden Helbling et al. (2011)'s, Beaton and Desroches (2011)'s and Xu (2010)'s examinations of US-sourced credit shocks to consider the euro area and Japan also as sources of credit shocks. We also investigate the transmission of credit supply shocks to many individual countries of the world, shedding light on the heterogeneity with which credit supply shocks in international financial centres spread around the world. While Xu (2010) also looks at the transmission to many economies, the former two studies concentrate on foreign shock transmission to the G7 aggregate and to a single country (Canada), respectively.

2.2 Credit supply shock identification

To identify credit supply shocks, we use theoretically-motivated sign restrictions on short-run impulse responses. This goes beyond most previous schemes to identify financial shocks in multi-country models. Most other GVAR studies (including Xu (2010) and Beaton and Desroches (2011)) calculate "generalized" impulse responses to shocks that have not been orthogonalised, which makes economic interpretation of the shocks difficult. Other studies which examine financial shocks tend to use simple recursive schemes (e.g. Bagliano and Morana (2011)) or exploit financial shock heteroscedasticity (Rigobon (2003)). Some studies use theoretically justified sign restrictions (e.g. Peersman (2010), Hristov et al. (2011), Bean et al. (2010), Helbling et al. (2011), Meeks (2011), Chudik and Fratzscher (2011), Bussière et al. (2011)), but generally in closed economy setups (Helbling et al. (2011), Chudik and Fratzscher (2011) and Bussière et al. (2011) are exceptions). Our identification scheme yields shocks which are orthogonal within countries, but we allow them to be correlated across countries. We show, however, that the cross-country correlation of shocks is negligible due to the way we include foreign variables in the model.

2.3 Examination of different GVAR weighting schemes

In FAVARs, the weights on variables are estimated (usually by principal components) and hence determined on statistical grounds, whereas GVAR modelling involves greater use of prior information in choosing (observed) weights. In GVARs the bilateral exposure weights are typically chosen on loosely theoretical or intuitive grounds. Most previous GVAR studies of international business cycles use trade weights (e.g. Dées et al. (2007)). However, although trade is no doubt an important driver of international business cycles (e.g. Baxter and Kouparitsas (2005)), the crisis experience and the recent theoretical work cited above strongly suggest that financial linkages between countries are also important.

We investigate this possibility with a range of weighting schemes, which in various ways combine trade with financial exposures. The range of financial weighting schemes we test includes schemes corresponding not only to asset-side exposures (for example, credit and valuation risks), as other studies have done[1], but also to liability-side exposures (for example, rollover risks) which to our knowledge have not been explored to date in a GVAR. On both asset and liability sides, we distinguish between direct investment, portfolio investment and banking claims. This is to test for whether differences in creditor control of the management of the investment, and for whether the type of intermediation (securitised versus intermediary-based) matters. Some differences across these asset classes relevant for behaviour could be, for example, the different risk/return profiles, investment

[1]Beaton and Desroches (2011) (who use the same banking claims data as we do) use only asset-side exposures. Chen et al. (2010) use gross financial asset exposures aggregated across different types of claim (portfolio equity, direct investment, portfolio debt, other general bank-related debt and official reserves, as constructed by Lane and Shambaugh (2010)).

horizons and frequencies of trading.

We assess formally the effects of using different schemes on model fit by means of information criteria and (in-sample) forecasting performance, and use the results from these tests as an input into our choice of benchmark model for the production of impulse response results. We test the robustness of the impulse response results to weighting schemes other than the benchmark scheme. We also compare the foreign financial variables constructed for the GVAR with "statistical factors" such as principal components calculated from the foreign financial data.

3 The GVAR model and its estimation

3.1 Theoretical framework

A GVAR is a set of linked country VARX models. We start with a general VARX(q_i, q_i^*) model for each country $i = 0, ..., N$:

$$x_{i,t} = a_{i,0} + a_{i,1}t + \sum_{j=1}^{q_i} \alpha_{i,j} x_{i,t-j} + \sum_{j=0}^{q_i^*} \beta_{i,j} x_{i,t-j}^* + \sum_{j=1}^{l_i} \gamma_{i,j} d_{t-j} + u_{i,t}, \tag{3.1}$$

where $x_{i,t}$ is a $k_i \times 1$ vector of endogenous variables, $x_{i,t}^*$ a $k_i^* \times 1$ vector of country-specific foreign variables, d_t a vector of "global" variables that appear in every country VARX, $a_{i,0}$ a constant, t a linear trend and $u_{i,t}$ a $k_i \times 1$ vector of serially uncorrelated innovations, $u_{i,t} \sim iid(0, \Sigma_{u,i})$. $\alpha_{i,j}$, $\beta_{i,j}$ and $\gamma_{i,j}$ are the coefficient matrices.

The foreign variables in a country's VARX are constructed as weighted averages of other countries' variables. We define $x_{i,g,t}$ as the gth element of $x_{i,t}$,

$$x_{i,g,t}^* = \sum_{j=0}^{N} w_{i,g,j} x_{j,g,t}, \tag{3.2}$$

where $w_{i,g,j}$ is a weight capturing the exposure of country i to country j coming from variable g. $\sum_{j=0}^{N} w_{i,g,j} = 1$ and $w_{i,g,j} = 0$ for $i = j$.

Defining $z_{i,t} = \left(x_{i,t}', x_{i,t}^{*\prime}\right)'$, neglecting d_t for simplicity and setting $p_i = \max(q_i, q_i^*)$, equation 3.1 can be written as

$$A_{i,0} z_{i,t} = a_{i,0} + a_{i,1}t + \sum_{j=1}^{p_i} A_{i,j} z_{i,t-j} + u_{i,t}, \tag{3.3}$$

where $A_{i,0} = (I_{k_i}, -\beta_{i,0})$ and $A_{i,j} = (\alpha_{i,j}, \beta_{i,j})$.

$z_{i,t}$ is then linked to $x_t = \left(x_{0,t}', x_{1,t}', ..., x_{N,t}'\right)'$, a $K \times 1$ vector including all endogenous variables of the system, via the link matrix W_i:

$$z_{i,t} = W_i x_t. \tag{3.4}$$

W_i is of dimension $(k_i + k_i^*) \times K$ and contains the weights capturing bilateral exposures between the countries under investigation:

$$W_i = \begin{pmatrix} 0 & \cdots & I_{k_i} & \cdots & 0 \\ w_{i,0} I_{k_i^*} & \cdots & w_{i,i} I_{k_i^*} & \cdots & w_{i,N} I_{k_i^*} \end{pmatrix}. \tag{3.5}$$

Equation 3.1 is then (again neglecting $d_{i,t}$) equivalent to

$$A_{i,0} W_i x_t = \sum_{j=1}^{p_i} A_{i,j} W_i x_{t-j} + u_{it}. \tag{3.6}$$

The individual country VARX models are then stacked, yielding the model for all the variables in the global model x_t:

$$G_0 x_t = a_0 + a_1 t + \sum_{j=1}^{p} G_j x_{t-j} + u_t, \tag{3.7}$$

where $G_0 = \begin{pmatrix} A_{0,0} W_0 \\ A_{1,0} W_1 \\ \vdots \\ A_{N,0} W_N \end{pmatrix}$, $G_j = \begin{pmatrix} A_{0,j} W_0 \\ A_{1,j} W_1 \\ \vdots \\ A_{N,j} W_N \end{pmatrix}$, $a_0 = \begin{pmatrix} a_{0,0} \\ a_{1,0} \\ \vdots \\ a_{N,0} \end{pmatrix}$, $a_1 = \begin{pmatrix} a_{0,1} \\ a_{1,1} \\ \vdots \\ a_{N,1} \end{pmatrix}$,

$u_t = \begin{pmatrix} u_{0,t} \\ u_{1,t} \\ \vdots \\ u_{N,t} \end{pmatrix}$ and $p = \max(p_1, ..., p_N)$.

Premultiplying equation 3.7 by G_0^{-1} yields the autoregressive representation of the GVAR(p) model

$$x_t = b_0 + b_1 t + \sum_{j=1}^{p} F_j x_{t-j} + \varepsilon_t, \tag{3.8}$$

where $F_j = G_0^{-1} G_j$, $b_0 = G_0^{-1} a_0$, $b_1 = G_0^{-1} a_1$ and $\varepsilon_t = G_0^{-1} u_t$.

Equation 3.8 can be solved recursively and impulse response and variance decomposition analysis performed as usual.

3.2 Estimation

To estimate the model we use the routines included in the GVAR toolbox provided by Vanessa Smith and Alessandro Galesi[2]. The basic elements are as follows.

Writing the country VARX models (equation 3.1) in error correction form allows for cointegrating relationships between non-stationary variables, both within and across coun-

[2] The GVAR toolbox can be downloaded from www-cfap.jbs.cam.ac.uk/research/gvartoolbox/index.html.

tries:

$$\Delta x_{i,t} = c_{i,0} + \alpha_i \beta_i^{'} \left(z_{i,t-1} - \gamma_i (t-1) \right) + \beta_{i,0} \Delta x_{i,t}^{*} + \sum_{j=1}^{p_i} \Gamma_{i,j} \Delta z_{i,t-j} + u_{i,t}, \tag{3.9}$$

where α_i and $\beta_i$are of rank r_i and dimension $k_i \times r_i$ and $(k_i + k_i^*) \times r_i$ respectively.

Following Pesaran and Smith (2006), it is assumed that the $x_{i,t}^*$ are I(1) weakly exogenous with respect to the parameters of the VARX model. The VARX models are estimated separately for each country conditional on $x_{i,t}^*$ using reduced rank regression. This provides estimates of the rank orders of the VARX models r_i, the speed of adjustment coefficients α_i and the cointegrating vectors β_i for each country. Conditional on the estimate for β_i, the remaining parameters of the VARX model for country i are then estimated using OLS and the error correction terms $\beta_i^{'} \left(z_{i,t} - \gamma_i t \right)$ corresponding to the r_i cointegrating relations.

Each variable is tested for the presence of a unit root by weighted symmetric ADF tests (Park and Fuller (1995)). The rank orders of the VARX models are estimated based on Johansen's trace statistic. We restrict the trend coefficients to lie in the cointegrating space, and leave the intercepts unrestricted (case IV in the GVAR toolbox and in Pesaran et al. (2000)). The lag orders q_i, q_i^* for the VARX models are determined by the AIC subject to a maximum lag order across models of $p = 2$ that we impose.

4 Data and VARX setups

4.1 Data

We construct our dataset, consisting of modelled time series and weights to capture bilateral exposures, to cover in rich detail for many countries each of the financial transmission channels set out in the Introduction.

4.1.1 Modelled time series

Our dataset includes the entire (updated) dataset used in Dées et al. (2007) and is taken from the GVAR toolbox. The dataset comprises 33 countries[3], 8 of them are from the euro area. We combine these to form a euro-area aggregate because of the common monetary policy across euro-area countries since 1999. Hence we have 26 economies in the model.

[3]The countries are Argentina, Australia, Austria, Belgium, Brazil, Canada, China, Chile, Finland, France, Germany, India, Indonesia, Italy, Japan, Korea, Malaysia, Mexico, the Netherlands, Norway, New Zealand, Peru, the Philippines, South Africa, Saudi Arabia, Singapore, Spain, Sweden, Switzerland, Thailand, Turkey, the United Kingdom and the United States. For the purposes of modelling we combine the euro-area countries into a single economy.

The following variables enter each country's VARX (if available for that country): GDP, the real bilateral exchange rate against the US dollar, real equity prices, the oil price (all in logs), the first difference of the CPI in logs, and the quarterly (not annualized) short-term interest rate and long-term government bond yield. These variables were used in the GVAR with basic macroeconomic and financial variables of Dées et al. (2007), and the sources for the data are documented in that paper and in the GVAR toolbox manual.

To enable our GVAR to provide further colour on the role of financial markets in international macroeconomic dynamics, we add to this dataset further financial variables: the logarithm of real private credit (defined as nominal credit to the domestic non-financial private sector divided by the GDP deflator) and the corporate bond spread (defined as the corporate bond yield minus the 10-year government bond yield, again in quarterly terms).

Where possible, we use the private credit data constructed by the Basel Committee on Banking Supervision (BCBS) for its study of indicator variables for banking system distress (Basel Committee on Banking Supervision (2010)). For the countries where BCBS data are not available, we use claims on the private sector by depository institutions from the IFS (series 32d), which in any case is the basis for the bank lending component of many of the BCBS series, or from national sources.[4] The primary data sources for the BCBS credit series are documented in Basel Committee on Banking Supervision (2010).

We use as broad a measure of credit as possible because we are interested in capturing the effects of shocks that affect the broad supply of credit to the economy, whether in the form of loans by financial institutions or debt securities (although the limitations of the private credit surveys mean that we are unable to capture direct cross-border lending, we are able to capture lending by local affiliates of foreign-headquartered institutions). The BCBS study found that broader measures of credit to the private sector performed better as predictors of financial system distress. Developments in broader credit would also seem more likely to have detectable international macroeconomic consequences, especially if they result from credit supply shocks in large international financial centres. Sufficiently lengthy quarterly credit data series are available for all countries except Saudi Arabia, China and Brazil.

To measure the price of credit we use corporate bond yields, rather than bank lending rates or an aggregate "broad private credit" interest rate. This is for a number of reasons. First, the price of a bank loan is less likely to reflect purely the price of the credit itself, but rather will typically bundle a range of other important contractual provisions such as collateral, early repayment provisions and the like, as well as a "relationship banking" component where the bank takes into account monitoring costs and long-term revenue opportunities associated with the relationship (Borio (1995)). Such provisions are difficult to measure and therefore to control for. Second, bank loan contracts are typically negotiated

[4] 32d for Argentina, Austria, Chile, Finland, India, Indonesia, Korea, Malaysia, Mexico, Norway, Peru, Philippines, Singapore, South Africa, Thailand and Turkey. National sources for New Zealand.

over the counter rather than publicly traded as many corporate bonds are, meaning that measurement is reliant on surveys of lenders rather than observed prices.

Corporate bond yields are available for Australia, Canada, the US, the UK, Germany, Sweden, Switzerland and Japan, sourced from the Bank for International Settlements and Datastream. We use maturities closest to 10 years, to match the maturity of the government bond yield series. The maturities of all corporate bond yields are at least 5 years. We also use the broadest bond returns index available for each country. For all countries except Australia, the corporate bond yields are based on a basket of bonds.

As we explain below, our identification of credit supply shocks involves imposing sign restrictions on corporate bond spread responses jointly with restrictions on the responses of other domestic variables. For the euro area, we have corporate bond yield data for Germany only, but the other euro-area variables are aggregates of all euro-area countries in our sample, which might be seen as inconsistent. As a robustness check, we confirm that our results do not change if euro-area variables are replaced by German variables in the GVAR, so that all variables in the identification are based on the same set of countries. This means that the check is to identify a German credit supply shock rather than a euro-area one.

The corporate bond yield series limit our sample start date to 1983Q4. The last observation is 2009Q4. This sample is long enough to cover a handful of business and financial cycles for each of the countries in the sample (Claessens et al. (2010)). We show below that our main results are robust to the exclusion of the global financial crisis episode from the sample.

4.1.2 Weights used to construct foreign variables

Early GVAR applications tended to use trade weights to construct foreign variables, in the context of studies of the international transmission of "macro" shocks such as output shocks or interest rate shocks. Later studies used financial weights in studies of international financial shock transmission. However, few if any of these studies test formally how well the choice of the weighting scheme is accepted by the data. In our study, we both consider a range of intuitively reasonable weighting schemes to capture different types of financial exposure, and formally assess the empirical support for each scheme (Section 5). We compare a specification that uses trade weights to construct $x^*_{i,g,t}$ for all g, with specifications in which we replace the trade weights for the financial variables (credit, interest rates and spreads, equity prices, exchange rate) with weights based on inward or outward portfolio or foreign direct investment or banking claims (while continuing to use trade weights for GDP and inflation).

The trade (exports plus imports of goods) weights are based on the IMF's Direction of Trade Statistics and are taken from the GVAR toolbox.

We construct the financial weights based on three sets of gross bilateral financial claims data: (i) total portfolio investment asset positions, covering equity and debt instruments, from Table 8 of the IMF Coordinated Portfolio Investment Survey (CPIS; see IMF (2002) for details); (ii) total foreign direct investment asset positions, from Table 6.1-o of the IMF Foreign Direct Investment Survey (CDIS; IMF (2010));[5] and (iii) consolidated international claims of banking groups headquartered in each sample country, from Table 9D of the BIS international banking statistics (IBS) where possible, and otherwise (for Brazil and Mexico) Table 9B (BIS (2008)).[6]

To distinguish asset- vs. liability-side channels, we use the same bilateral claims data (which are measured by surveying creditor countries), but reverse the direction of assignment by country. For asset-side exposures of country i, the weights $w_{i,g,j}$ for constructing foreign variable $x^*_{i,g,t}$ are given by the claims on country j held by residents or banking groups of country i. For liability-side exposures of country i, the $w_{i,g,j}$ are the claims in country i held by residents or banking groups of country j.

Altogether we have seven different weighting schemes corresponding to different channels for international transmission of developments in our financial variables: (i) trade weights (as for foreign GDP and inflation); (ii) outward portfolio investment (hereafter and in the tables and figures, PIout); (iii) inward portfolio investment (PIin); (iv) outward foreign direct investment (FDIout); (v) inward foreign direct investment (FDIin); (vi) outward claims of domestically headquartered banks (BCout); and (vii) inward claims of foreign-headquartered banks (BCin).

For manageability, we constrain the schemes used for each foreign financial variable in each country VARX to be the same across all financial variables and all countries, although one could in principle choose different weighting schemes for each country and variable. We leave for future study the question of whether it is worth allowing for more differentiation of weighting matrices.

Financial claims in the CPIS, CDIS and IBS are unavailable for 3, 10 and 12 countries respectively.[7] We deal with this missing data as follows. For a non-reporting country i, under the PIout, FDIout and BCout weighting schemes we include only foreign GDP and

[5] In the CPIS and CDIS, a small number of bilateral portfolio investment exposures are known to be non-zero, but are not reported for confidentiality reasons. We set these observations (which one might expect to be small relative to the reported exposures) to zero. A very small number of negative gross exposures are also recorded in these surveys. We set these also to zero.

[6] 9D shows international claims on an ultimate risk basis, that is, taking account of cross-border risk transfers due to guarantees, collateral or credit derivatives held in the banking book; 9B shows claims on an immediate-borrower basis (that is, not taking account of cross-border risk transfers). See Fender and McGuire (2010) for a discussion of the role of international bank structure in shock transmission across borders.

[7] The non-reporting countries are Saudi Arabia, Peru and China (CPIS); Norway, Sweden, Argentina, Brazil, Chile, Saudi Arabia, India, Indonesia, Singapore and China (CDIS); and Norway, New Zealand, South Africa, Argentina, Saudi Arabia, Indonesia, Korea, Malaysia, Philippines, Singapore, Thailand and China (IBS).

inflation as foreign variables in the VARX model for i, and not foreign financial variables. For the PIin, FDIin and BCin schemes, we assign a weight of zero to i when constructing foreign financial variables in the VARX model for j.[8]

All weights in our study are fixed over time.[9] Although trade weights are available for all years covered by our sample, we use, for comparability, weights for trade and portfolio investment averaged over the years 2005-2008. For banking claims we average over the years 2006-07. The FDI-based weights are only available for a single year, 2009.

Figure 1 shows the trade and financial weights based on inward and outward portfolio investment, direct investment and banking claims for selected countries or groups of countries.[10] The full trade and financial weighting matrices are available upon request.

The figure shows that the weights can be quite different. The US and euro area are in general more important for Japan and for each other in terms of financial exposures, than they are as trading partners. The UK is also for all countries or regions a more important source of financial exposure than of trade exposure. Asia (excluding Japan) has substantial importance as a trade destination for almost all regions, but much less as a source of financial exposure.

4.1.3 Comparison with statistical factors for foreign variables

As noted before, one difference between GVARs and factor models is that GVARs use observed data to construct weights for foreign variables, while factor models used for international modelling typically estimate factors to represent foreign influences, usually based on principal components (PC). It is thus interesting to compare the foreign variables constructed using the seven weighting schemes with factors estimated using the foreign data and PC. We also compare the GVAR foreign variables with factors estimated using partial least squares (PLS) (see Groen and Kapetanios (2008) and Eickmeier and Ng (2010) for details of the PLS procedure).

There are three key differences between the foreign variables based on observed weights and the statistical factors. First, PC and PLS factors are constructed as solutions to explicit statistical maximisation problems (to maximise the fraction of the variance of the whole dataset explained, and to maximise correlation with a "target variable" (in this

[8] The use of a weight of zero is an approximation for the actual outward foreign investments and claims of non-reporting countries. In reality, such claims are likely to be small compared to those of countries reporting claims, but not zero.

[9] The GVAR results of Dées et al. (2007) using a similar dataset essentially did not change under time-varying instead of constant trade weights. Hence, the use of fixed instead of time-varying trade weights should not be too restrictive. Financial weights are not available over the entirety of our sample period, precluding time-variation in that case.

[10] In the figures and tables, "Latin America" comprises Argentina, Brazil, Chile, Mexico, Peru; "Asia" comprises China, India, Indonesia, Korea, Malaysia, Phillipines, Singapore, Thailand; and "Other European countries" comprises Norway, Sweden, Switzerland. We also aggregate in the figures and tables Australia and New Zealand.

case, the variable on the left hand side of the VARX equation), respectively). Second, our GVAR foreign variables are weighted averages of the levels of the variables, while the PC and PLS factors are estimated, as is the usual practice, from stationary variables, with stationarity achieved by differencing if necessary. We therefore difference the GVAR foreign variables where necessary before comparing with the statistical factors. Third, the PC and PLS weights (which are proportional to the PC or PLS loadings) can be negative or exceed one in absolute terms while the observed trade or financial weights are by construction between 0 and 1.

We produce PC and PLS factors for country i from credit growth and equity price growth (as example financial variables) using data for all other countries (where available) $j = 0, ..., N$, where $j \neq i$. The "target variable" for the PLS credit and equity price factors is credit growth and equity price growth, respectively, of country i. Table 1 shows the mean correlations over all country factors between the PC, the PLS and the first differences of our GVAR foreign variables. (Correlations for the other variables were very similar.)

Two main results arise. First, both credit and equity price foreign variables in the GVAR are very highly correlated with the respective statistical factors with correlations above 0.7 and 0.9, respectively. Second, the GVAR foreign credit growth aggregates are more highly correlated with the respective PCs than with the PLS factors. This is despite the fact that the GVAR weights capture bilateral exposures for which the "target country" matters and, are, in this sense, more closely related to PLS than to PC weights. For equity price growth, no such difference in the correlations of GVAR aggregates with the PC and the PLS factors is, however, found. Third, correlations of the GVAR factors with the PC and the PLS factors are very similar across weighting schemes.

In section 5.1, we evaluate the fit of our various GVAR specifications using the seven alternative weighting schemes (Trade, PIin, PIout, FDIin, FDIout, BCin, BCout). This is to assess whether any model stands out in terms of fit, even though there were not large differences across weighting schemes in terms of correlation with statistical factors.

4.2 VARX setups

In all country VARX models except that for the US, we include as endogenous variables, if available, GDP, inflation, short-term interest rates, long-term government bond yields, corporate bond yields, private credit, equity prices and bilateral real exchange rates with the US dollar. All non-US models contain foreign aggregates and the oil price as weakly exogenous variables.[11]

The model for the US is different and reflects the dominant role of the US in the world

[11] We have, as a robustness check, re-estimated the GVAR without inflation, short-term interest rates and exchange rates of Latin American countries which experienced a hyperinflation in the first half of our sample (Argentina, Brazil, Peru and Mexico). Results remain broadly unaffected, but confidence bands of some impulse responses are somewhat tighter compared to our baseline.

financial markets. The US model thus does not contain foreign interest rates, foreign equity prices and foreign credit. It also uses the trade weighted average of the US dollar exchange rate against the other countries in the GVAR, rather than a bilateral exchange rate. Finally, the oil price enters the US model as endogenous variable. This specification is the same as in Dées et al. (2007), except that we include US credit and corporate bond spreads in the country models; see also the GVAR applications with credit variables included (Beaton and Desroches (2011) and Xu (2010)). Table 2 provides an overview of the included variables.

5 Model selection and estimation results

In this section we look at the (in-sample) forecasting performance of and compute information criteria for the GVARs under alternative weighting schemes and select, based on the results, our benchmark model. We then present the results of cointegration and lag order testing for the country VARX models and the validity of the weak exogeneity assumptions needed for estimation for the benchmark model.

5.1 Forecasting performance tests and information criteria for alternative GVAR specifications

Turning first to the forecasts, we look at the forecasting performance for GDP (as the key variable) and all variables in each of our 26 economies. The forecasts are iterative in-sample forecasts for horizons 1-4. We compute root mean squared error (RMSE) statistics for forecasts from the GVARs under each of the seven weighting schemes, relative to the benchmark random walk model. We should note that the RMSEs are computed using the residuals from the fitted GVAR model, and that they are not pseudo out-of-sample forecasts. Nevertheless in-sample forecasts especially for longer horizons get quite close to the out-of-sample forecast setup.[12]

We show in Table 3a the mean, the median, the minima and maxima relative RMSEs and in Table 3b the fraction of times a GVAR under a particular weighting scheme achieves a particular rank across the 26 economies, for each horizon. We find that all (for GDP forecasts) and almost all (for all variables' forecasts) relative RMSEs are smaller than 1, i.e. the GVAR models almost always outperform the random walk model. The dispersion across weighting schemes tends to be larger for longer than for shorter horizons.

The GVAR model which uses FDIin weights performs best for all horizons (average RMSEs are between 0.53 and 0.61) in terms of GDP forecasts and for horizon 1 also in terms of all variables' forecasts (the average RMSE is at 0.74). The BCout specification

[12] In-sample forecast evaluation is fairly common in the literature on large-dimensional models, see e.g. Stock and Watson (2008) and Eickmeier et al. (2011b).

performs best for horizons 2 and 3 in terms of all variables's forecasts. The GVAR models using the PIin, FDIout and, for GDP forecasts, BCout weighting schemes perform similarly well. The model using trade weights only clearly performs worst.

The message from looking at the RMSEs is confirmed when looking at the fraction of times the weightings schemes yield the best, second best and worst models. The GVAR using the FDIin scheme produces most often the best forecasts for GDP, while for all variables, the GVAR using the BCout scheme is the best model. The PIin and the FDIout models are most often second best for GDP and all variables' forecasts, respectively. The FDIin, BCout as well as the PIin, FDIout schemes are almost never the worst models, whereas the Trade model most often produces the worst forecasts.

One possible drawback of in-sample forecasts is that they are not independent of the number of parameters which differ across the specifications.[13] We therefore complement the forecasting exercise with a comparison of models based on information criteria which correct for the number of estimated parameters. We compute them for the GVARs as follows:

$$IC = \sum_{i=0}^{N} \left(\ln |\Sigma_{u,i}| + \varrho \left(k_i((q_i - 1)k_i + q_i^* k_i^*) + k_i r_i + (k_i + k_i^* + 1)r_i - r_i^2 \right) \right), \qquad (5.10)$$

where $\varrho = 2/T$ or $\varrho = \ln(T)/T$ for the Akaike criterion and the Schwarz criterion, respectively (Phillips and McFarland (1997)). The results for the seven weighting schemes are presented in Table 4. Both criteria are minimal for the BCout specification of the GVAR. The information criteria, thus, yield the same result as the forecasting performance evaluation. The FDIin model that produced the best overall forecasts for GDP performs second best on the information criteria. According to the criteria the PIin, the BCin and the Trade models perform relatively badly.

The main messages from this section are, hence, as follows. First, trade weights do not seem to be sufficient to capture the international linkages between countries, but financial linkages seem to matter as well. Second, the FDIin and BCout models tend to deliver the best forecast, depending on whether the focus is solely on GDP or on all variables included in the GVAR, and the lowest values for the information criteria.

On the basis of these results, we select FDIin as our benchmark model. The foreign variables constructed using FDIin weights were also highly correlated with the PC or PLS factors estimated from the credit and equity price data (as were the GVAR factors computed based on the other weighting schemes) (Table 1). We show in Section 7 detailed

[13] Different weighting schemes may imply different dynamics with different lag and rank orders. Moreover, foreign financial aggregates are not included for some (non-reporting) countries for certain GVARs using asset-side weighting schemes which may also explain why the number of estimated parameters varies over specifications.

results for the benchmark model. We assess the robustness of the impulse responses with respect to the weighting scheme in Section 8.

5.2 Estimation results for benchmark specification

Across the country VARX models using the FDIin (benchmark) weighting scheme, we find between 1 and 5 cointegrating relations. Using the AIC we find the number of lags on domestic variables most often to be 2 and sometimes 1. We set the number of lags for foreign variables equal to 1. We also verify that the country VARX models and the assembled GVAR are stable and that persistence profiles quickly converge to zero.

We test the weak exogeneity assumptions by testing the joint significance of the estimated error correction terms in an auxiliary regression model for $x^*_{i,t}$ (see Dées et al. (2007) for details). This procedure reflects that I(1) weak exogeneity in a cointegrating model implies no long-run feedback from $x_{i,t}$ to $x^*_{i,t}$ ($x^*_{i,t}$ is said to be "long-run forcing" for $x_{i,t}$). (The VARX models, however, do not rule out lagged short-run feedback between the two sets of variables.) We find that the weak exogeneity assumption is rejected at the 5% significance level in only 4 percent of our cases. The results of unit root, cointegration, lag order and weak exogeneity testing for each country VARX using FDIin weights are available upon request.

6 Credit supply shock identification

Our identification scheme differs from those in most existing GVAR applications, which use the generalized impulse response function (GIRF) approach of Koop et al. (1996) and Pesaran and Shin (1998) (e.g. Dées et al. (2007), Galesi and Sgherri (2009), Hiebert and Vansteenkiste (2009)). With GIRFs, the impulse response functions do not depend on the ordering of the variables. This avoids the problem of having to choose orderings that are consistent with theoretical considerations or are otherwise widely accepted, which would be particularly difficult in a multi-country setup. However, GIRFs are impulse responses to non-orthogonal shocks, and therefore more difficult to interpret as corresponding to an event with a particular economic meaning (in our case, a shock that has the effect of restricting credit supply), than impulse responses to orthogonalized shocks.

We identify credit supply shocks via sign restrictions on the short-run impulse responses in the GVAR. Our approach yields shocks which are uncorrelated with other domestic shocks but which can still be correlated across countries.[14] Hence, it can be seen as a combination of the Koop et al. (1996) method and orthogonalized shocks.

[14] Dées et al. (2007) proceed in a similar way to identify a US monetary policy shock adopting a recursive ordering within the US block while leaving US shocks correlated with other countries' shocks. Also, Dées et al. (2010) identify supply, demand and monetary policy shocks (based on a New Keynesian rational expectations model) which are uncorrelated within but not across countries.

We impose the following sign restrictions to identify credit supply shocks in the US, Japan and the euro area (summarized in Table 5). After a negative credit supply shock, the volume of credit is restricted to decline.[15][16] GDP is restricted to decline as well, but by less than credit. The corporate bond rate, the spread between the corporate bond rate and the long-term government bond yield and the spread between the corporate bond rate and the short-term interest rate are all restricted to increase. This restriction on credit relative to GDP distinguishes credit shocks from "macro shocks" such as aggregate demand and supply shocks after which GDP, by contrast, can be assumed to initially react more strongly than credit.[17] The restrictions on the corporate bond rate and credit distinguish shocks involving credit supply, which move corporate bond rates and credit in opposite directions, from credit demand shocks, which would move them in the same direction. The restriction on the corporate bond yield / short-term interest rate spread distinguishes the credit shock from a monetary policy (tightening) shock, which would tend to lower that spread. The restriction on the response of the corporate bond yield / long-term government yield spread reflects that the credit risk premium should rise under an adverse credit supply shock. The responses of inflation and the short-term interest rate are left unrestricted since the signs of the reactions of inflation and of short-term interest rates to a credit supply shock depend on whether aggregate demand or aggregate supply effects dominate and on the monetary policy reaction. In some theoretical models inflation and short-term interest rates rates increase after an adverse credit supply shock (Gerali et al. (2010), Atta-Mensah and Dib (2008)), and in some they decrease (Cúrdia and Woodford (2010), Gertler and Karradi (2009)).

The sign restrictions are consistent with DSGE models containing a banking sector (as summarized in Table 2 in Hristov et al. (2011)). Similar restrictions restrictions have been used in previous empirical work (Helbling et al. (2011), Busch et al. (2010), Peersman (2010), Hristov et al. (2011), Bean et al. (2010), Meeks (2011), De Nicolò and Lucchetta (2010)). In these models (negative) credit supply shocks reflect either a weakening of financial positions of financial institutions (such as a worsening in the quality of bank's assets (Gertler and Karradi (2009)), a decline in bank capital (Gerali et al. (2010)) or an increase in expected or realized credit default risk (Christiano et al. (2010), Atta-Mensah and Dib (2008))) or heightened risk aversion by investors unrelated to credit default (Gilchrist et al. (2009), Peersman (2010)).[18] It is of course possible to identify

[15] All +/- sign restrictions presented in Table 6 are implemented as $\geq$ / ≤ 0.

[16] Helbling et al. (2011) and Gilchrist et al. (2009) emphasize that it is important to consider not only the price, but also the volume of credit in order to identify credit supply shocks.

[17] Other papers impose contemporaneous zero restrictions on GDP and inflation after credit or other financial shocks and, hence, restrict the macroeconomy to react to credit shocks only with a delay (e.g. Peersman (2010), Ciccarelli et al. (2010), Buch et al. (2010), Eickmeier and Hofmann (2011)). Our identification scheme is consistent with these papers in that it allows output not to react to financial shocks, but is less restrictive because output is allowed to fall on impact, but not by more than credit.

[18] Financial innovation (e.g. securitization) may also be a source of (positive) credit supply shocks as

credit supply shocks in different ways, e.g. by imposing restrictions on additional variables, which might also differentiate further between different types of credit supply shocks. We simply define our credit supply shocks as those shocks that satisfy the restrictions described above.

The sign restrictions on credit and GDP are imposed on the impulse response functions from impact to lag 3, while those on the credit-to-GDP ratio and on the corporate bond rates and spreads are imposed on impact only, to allow the short-term and government bond rates to adjust quickly to the shock.

We implement the sign restrictions using the approach suggested by Rubio-Ramírez et al. (2010) and Fry and Pagan (2007), as follows. We carry out a Cholesky decomposition of the covariance matrix of the vector of residuals $u_{i,t}$ for each country model i to obtain the lower triangular Cholesky matrix P_i for model i. We then construct the $K \times K$ matrix P as

$$P = \begin{pmatrix} P_0 & 0 & \cdots & \cdots & 0 \\ 0 & \ddots & & & \vdots \\ \vdots & & P_i & & \vdots \\ \vdots & & & \ddots & 0 \\ 0 & \cdots & \cdots & 0 & P_N \end{pmatrix} \tag{6.11}$$

so that we can obtain the impulse responses of all endogenous variables in the GVAR to shocks to the error terms $v_t = \begin{pmatrix} v_{0,t} & \cdots & v_{i,t} & \cdots & v_{N,t} \end{pmatrix}' = P^{-1} G_0 \varepsilon_t$ as $\Psi^h = \Phi^h G_0^{-1} P$where the $K \times K$ matrix of impulse responses at horizon h is denoted by Φ^h and the element in row m and column n indicates the impulse response of the m^{th} endogenous variable to an innovation to the n^{th} endogenous variable in the GVAR.

For the US, the euro area and Japan, we then multiply $v_{i,t}$ (i.e. the orthogonalized (Cholesky) residuals) by randomly drawn $k_i \times k_i$ orthonormal rotation matrices R_i and select the rotations that imply impulse responses satisfying the sign restrictions. We draw until we retain 100 valid R_is. The credit supply shock for country i we are interested in is given by the corresponding element of $w_{i,t} = (R_i v_{i,t})'$, with the impulse responses to it given by the corresponding element of $\Theta_i^h = (\Psi_i^h R_i^{'})'$ for a given R_i.

The elements of each $v_{i,t}$ are uncorrelated, but elements of v_t (as well as u_t and w_t) associated with different countries may be correlated. Interpretation of our shocks as country-specific thus hinges also on the magnitude of the cross-country correlations. Here, we rely on the inclusion of contemporaneous foreign variables in the VARX models, which should help to capture most of the cross-country correlation. To check this, we calculated the average pairwise correlations between the variables and the individual country VECMX residuals (detailed results are available upon request). While there is substantial

emphasised, e.g., by Peersman (2010) or Atta-Mensah and Dib (2008).

correlation between the variables across countries, the correlation between the residuals is much lower. The absolute pairwise correlation between residuals of the corresponding equations across countries is 0.17 at the most, and 0.04 on average.[19] Finally, the correlations between the three identified credit supply shocks are also very low, at -0.03 (US-euro area), 0.12 (US-Japan) and 0.08 (euro area-Japan). Hence, we are comfortable regarding the shocks as essentially country-specific and neglecting the cross-country shock covariance.

7 Impulse response analysis

In this section we discuss impulse response results obtained using our benchmark GVAR model (FDIin). The median impulse responses using the benchmark model are shown in solid lines, with dotted lines showing 90% confidence bands. Confidence bands are based on a bootstrap (for details on the bootstrap, see the GVAR toolbox manual). The bootstrap is based on 200 draws.

7.1 Domestic transmission of credit supply shocks

Figure 2 shows the responses of respective domestic variables to one standard deviation negative credit supply shocks in the US, the euro area and Japan. The response of credit following the shocks is persistent in all countries. It declines most strongly in the euro area (by about 3 percent, median estimate) and less in Japan and the US (-1 and -0.6 percent, respectively). Credit spreads rise in all three cases (between 0.005 and 0.02 percentage points (quarterly rate)). The effect on credit spreads is long-lasting in the US, but turns insignificant after one quarter in the euro area and Japan.

The credit supply shocks have a significant overall negative impact on domestic GDP in all three cases. The response is largest in Japan (about -0.4 percent), followed by the US (-0.3 percent) and the euro area (-0.2 percent). It is persistent in the US and Japan, but not in the euro area.

Looking at the responses of other domestic and foreign variables suggests a range of other mechanisms (besides the credit market reactions) contributing to the overall domestic GDP impact, which are not the same for each economy. First, in the US, equity prices decline strongly after the US credit shock, suggesting a generalised loss of financial confidence or a decline in lending by leverage-constrained banks following such a shock (Gertler and Karradi (2009)). Equity price movements are, of course, not independent from developments in credit markets: the observed equity price decline may, through a (further) worsening of banks' balance sheets, have contributed to the reduction of lending

[19] The absolute cross-country correlations between the (Cholesky) residuals which are orthogonal within each country are almost identical to the correlations between the reduced form residuals.

in the US we observe in Figure 2. In the euro area and in Japan, by contrast, equity prices barely move significantly after credit supply shocks in those economies (the euro-area response is even temporarily slightly positive). Second, the US dollar exchange rate also appreciates significantly against several other currencies in response to the US credit supply shock (Figure 3h). By contrast, in response to the euro-area and Japanese credit supply shocks, the euro and the Japanese yen depreciate against the US dollar (third currencies also depreciate against the US dollar in response, but generally less so). A generalised flight to the "safe haven" US dollar seems to be a feature of foreign exchange markets' response to credit supply shocks in all three financial centres. Third, as we discuss in more detail in Section 7.2, the negative responses of foreign GDP (Figure 3a) to the US credit supply shock are generally larger, suggesting a stronger feedback loop to US GDP. Finally, there is a significant fall in the domestic short-term interest rate in response to the US credit supply shock, indicating a monetary policy loosening response to the tightening of financial conditions, partially cushioning the impact on GDP, which is also a feature of the domestic response to the euro-area, but not to Japanese credit supply shocks.[20]

The responses of inflation, whose sign we did not restrict in the identification scheme, are generally not significant apart from on impact, where the response is positive in the US and Japan and negative in the euro area. Hence, aggregate demand effects seem to dominate aggregate supply effects om impact in the euro area, whereas the opposite is true for the US and Japan. The responses of long-term government bond rates are basically insignificant in all three cases.

7.2 International transmission of credit supply shocks

In Figure 3 we show the effects of the US, euro-area and Japanese credit supply shocks on other countries. In the interests of brevity, we show results for the large advanced countries and the four country aggregates formed above only. Impulse responses for these aggregates are constructed by weighting impulse responses of individual countries together using their PPP-adjusted GDPs, averaged over 2006-2008 and taken from the GVAR toolbox.

Figure 3a shows the responses of GDP to the US, the euro-area and the Japanese credit supply shocks. We find a strong and persistent negative impact of the US credit supply shock on GDP in Japan especially, but also, less strongly and significantly, in the euro area, the UK, Latin America, Other European countries and Australia-New Zealand. The effects of the US credit supply shock on these economies is about as large as on the US itself, as observed during the global financial crisis (van Wincoop (2011)), and consistent with the empirical findings of Helbling et al. (2011) and Eickmeier et al. (2011a). The

[20] Another factor may have cushioned the negative impact of the shocks on GDP. A decline in the return on investment triggered by the shocks may have induced substitution between consumption and investment and, hence, a positive consumption response partly offsetting a negative investment response (Cooper and Ejarque (2000)). It would be interesting to explore this hypothesis more closely in future work.

effects on the other regions are insignificant.

The euro-area credit supply shock hits GDP significantly in Japan and the UK. The Japanese credit supply shock has a significant negative effect on GDP only in the UK; its effects on GDP in the euro area, Canada and other European countries are only marginally significant. Similarly to the US case, the effect of the euro-area shock on GDP in Japan and the UK is at least as large as the effect on domestic GDP, while the effect of the Japanese shock is largest on Japanese GDP. In general, the effects of the euro-area and Japanese shocks are weaker than the effects of the US credit supply shock.

Figures 3b-h show a clear involvement of foreign credit and equity markets in the international transmission of credit supply shocks, especially those emanating from the US. The US credit supply shock has a strong and significant negative effect on credit (Figure 3c) in most other countries or regions, the exceptions being Latin America and Japan, where credit does not move significantly. Credit in most regions also responds negatively to euro-area and Japanese credit supply shocks. Corporate bond spreads (Figure 3d) in the US, UK and Australia-New Zealand increase significantly in response to credit supply shocks in all three financial centres, even though the significant response of the respective domestic corporate bond spreads in the euro area and Japan are very short-lived. This may reflect the greater development of the US, UK and Australian corporate bond markets in comparison to those of the other regions (Borio (1995)). (Corporate bond spreads for the Latin American and Asian countries are missing in our sample.)

There is a very clear equity market response in all other regions to the US credit supply shock (Figure 3g). However, such a response to the euro-area and Japanese credit supply shocks is not evident, probably partly because equity prices in the euro area and Japan themselves also do not (or barely) move significantly.

As mentioned above, the foreign exchange markets also are responsive to credit supply shocks emanating from the three international financial centres examined here, and in a way consistent with a "flight to quality" that, in the case of the US credit supply shock may be strengthening the adverse effect of the shock on US GDP. The exchange rate responses are also consistent in some cases with the loosening of monetary policy in many foreign countries that follows the US credit supply shock.[21]

How important are the three credit supply shocks for international business cycles? Table 6 shows forecast error variance shares of GDP in the nine countries/country groups at the 1- and 4-year horizons explained by the shocks. US credit supply shocks make a considerable contribution to fluctuations in the US itself, where they explain a quarter of

[21] Our results on the international effects of US credit supply shocks are roughly in line with Xu (2010)'s results for (non-orthogonal) US credit shocks. Exceptions are the equity price responses in the US, the UK and the euro area which are not or only marginally significant in Xu (2010) (the author provides, in her paper, equity price responses for these three economies). Our findings are also broadly in line with Beaton and Desroches (2011) for Canada's responses to US credit shocks. However, while Beaton and Desroches (2011) find a statistically significant effect on Canadian GDP, our estimated effect is insignificant.

the variance at medium horizons, but also abroad where they account for 4-26 percent. The explained shares are particularly large for Japan, Latin America and Europe, but relatively small for Asia and Canada. The small share of Canadian GDP forecast error variance explained by US credit supply shocks is interesting in light of Canada's large trade exposure to the US, but perhaps is further evidence supporting the reputation of the Canadian financial system as being particularly stable (see e.g. Bordo et al. (1994)).

The forecast error variance shares explained are somewhat smaller at shorter horizons, confirming results from the impulse response analysis that US credit supply shocks have persistent effects on GDP. The variance shares explained by euro-area and Japanese shocks are much smaller, accounting for 0-8 percent and 0-1 percent, respectively, of foreign output. More than 1/10 of fluctuations in euro-area and Japanese GDP are at most explained by domestic credit supply shocks. The three shocks together thus explain sizeable fractions, between 7 and 47 percent, of the forecast error variance of GDP at medium-term horizons.

To sum up, we find a strong transmission of US credit supply shocks and a weaker transmission of euro-area and Japanese credit supply shocks to GDP in other countries. This seems to be due to foreign credit markets and equity markets being less affected by Japanese shocks and by both Japanese and euro-area shocks, respectively. One explanation is smaller direct exposures of most economies to the euro area and Japan compared to the US (Figure 1). Also, an "international financial multiplier" seems to operate clearly after the US credit supply shock (while this is less clear for the shocks to the other two financial centres). The impulse responses after the US shocks are consistent with financial institution balance-sheet effects (Devereux and Yetman (2010), Devereux and Sutherland (2011), Krugman (2008)), arbitrage (Dedola and Lombardo (2010)) and portfolio reallocation mechanisms (van Wincoop (2011)).[22] The stronger international financial multiplier in the case of US credit supply shocks could also reflect a greater incidence of global "financial panic" phenomena compared to (similar scale) credit supply shocks in the euro area and Japan (van Wincoop (2011)), to the extent that the US financial markets are seen as a global bellwether. The high cross-country correlations of equity prices and cor-

[22] van Wincoop (2011) lists five distinct financial transmission channels. (i) Direct exposure channel: foreign leveraged institutions are exposed to home short-term assets which may default. (ii) Balance sheet valuation channel: foreign leveraged institutions are exposed to home long-term assets. A decline in home asset prices worsens balance sheets of the foreign institutions. (iii) Portfolio growth or lending channel: The drop in net worth of home leveraged institutions leads to a drop in demand for foreign assets and in lending to the foreign country. (iv) Borrowing constraints: A drop in home asset prices raises expected excess returns on the home asset. This raises the demand for home assets and increases optimal leverage, also for foreign institutions. This increases the effective borrowing rate (under constant leverage constraints) or the effective rate of risk aversion (under margin constraints), leading to a further decline in the demand for assets by foreign institutions and a further drop in asset prices. (v) Portfolio reallocation channel (not specific to leveraged institutions): Lower home asset prices or higher home lending rates imply higher expected returns on home assets which reduces the demand for foreign assets. Our results are consistent with the operation of all five channels, although we can in our setup not distinguish between them.

porate bond rates we observe after the US credit supply shock are consistent with this interpretation.

The generally significant response of variables in the UK, also an international financial centre, to credit supply shocks from all three of the US, euro area and Japan contrasts with the tendency of emerging market economies such as Latin America, Other Europe and Asia (excluding Japan) not to show much (significant) response to the shocks. The emerging market countries in our sample are in general (in some cases considerably) less internationally financially integrated than the other countries (Lane and Milesi-Ferretti (2007)). This result underscores the importance of the strength of financial linkages in the transmission of foreign credit supply shocks.

8 Robustness analysis

In this section we assess whether our results are robust against various alterations such as use of different weighting schemes for foreign variables, or a different sample period.

8.1 The effects of alternative weighting schemes

In Section 3 we showed that the FDIin model tends to outperform, in terms of forecasting, the GVAR models based on other weighting schemes. The forecast gains were particularly large and significant over the Trade model. Also, the information criteria adopted relatively low values when the FDIin scheme was applied. But do different weighting schemes also lead to different impulse response functions to the credit supply shocks? Table 7 provides impulse responses after the shocks estimated from GVARs using our benchmark weighting scheme and the other six weighting schemes. For the sake of brevity we only show median impulse responses of GDP one year after the shocks. The full set of impulse responses and confidence bands is available on request.

Impulse response results are similar in terms of shape (not shown), sign and magnitude, and the confidence bands from the benchmark FDIin model and bands from the other models (not shown) generally overlap, suggesting that the estimated impulse responses do not differ significantly. There is one exception: Japanese credit supply shocks seem to lead to a significantly stronger decline of GDP with the Trade specification compared to the benchmark model (and the other models). The trade exposures of other countries to Japan are larger than the FDI exposures (Figure 1), and in Australia-New Zealand, other European countries and Asia, they are also large compared to other financial exposures, which may explain this finding. However, qualitative results are still the same.

Overall, the impulse response results seem to be fairly robust with respect to the weighting scheme.

8.2 Further robustness checks

We perform two further robustness checks. First, we compare our benchmark GVAR results with results obtained from a sample which excludes the global financial crisis (1983Q4-2007Q2). This allows us to assess the influence of the crisis episode on the results and whether more complex structure or dynamics need to be taken into acocunt. Second, we remove all euro-area countries from the benchmark GVAR except for Germany and identify a German instead of a euro-area credit supply shock. This is to address the issue that the euro-area credit supply shock is identified using German corporate bond yields to represent euro-area corporate bond yields, because of data limitations.

Impulse responses to the credit supply shocks are, again, very similar to the benchmark impulse responses (Table 7), and confidence bands (not shown) overlap. Hence, our results are also robust with respect to the exclusion of the crisis episode and to the replacement of the euro area with Germany.

9 Concluding remarks

In this paper, we looked at the international transmission of credit supply shocks. More specifically, we focused on shocks that have the effect of restricting private credit supply in the US, euro area and Japan. We used the recently developed GVAR approach, which allows the financial and real interactions (including long-run interactions) between economies to be richly and flexibly captured, while still keeping dimensionality manageable.

Via the weights linking countries together, we explored alternative assumptions regarding how countries are exposed to each other via trade and finance, distinguishing portfolio investment, direct investment and banking claims, via both asset- and liability-side channels. A weighting scheme using both trade and financial weights for macroeconomic and financial variables respectively generally led to better model fit than a scheme based on trade weights alone, suggesting that a GVAR based on more sophisticated and carefully chosen weighting schemes can characterise the data better. The generally best-performing weighting schemes in terms of forecasting accuracy and information criteria were the schemes based on inward foreign direct investment exposures and outward banking claims.

Foreign credit supply shocks were identified using short-run sign restrictions on impulse response functions. Within this framework, we examined in considerable country-level detail the mechanisms by which credit supply shocks in major international financial centres propagate domestically and affect the rest of the world.

The main results are that negative US credit supply shocks in particular have strong negative effects on GDP in foreign countries, explaining up to a quarter of forecast error variance in the medium run. The transmission of Japanese and euro-area credit supply shocks to foreign GDP tends to be weaker and less statistically significant. We find that foreign credit and equity markets respond quite strongly to US credit supply shocks, consistent with "international financial multiplier" mechanisms. This is especially true for responses in international financial centres. Our results are robust to the exclusion of the 2007-09 crisis episode from the sample.

References

Atta-Mensah, J. and Dib, A. (2008). Bank lending, credit shocks, and the transmission of Canadian monetary policy. *International Review of Economics & Finance*, 17(1):159–176.

Bagliano, F. and Morana, C. (2011). The Great Recession: US dynamics and spillovers to the world economy. *Journal of Banking & Finance*, 36(1):1–13.

Basel Committee on Banking Supervision (2010). *Guidance for national authorities operating the countercyclical capital buffer*. December.

Baxter, M. and Kouparitsas, M. (2005). Determinants of business cycle comovement: a robust analysis. *Journal of Monetary Economics*, 52(1):113–157.

Bean, C., Paustian, M., Penalver, A., and Taylor, T. (2010). Monetary policy after the fall. *Mimeo.*, Bank of England; Paper presented at the Federal Reserve Bank of Kansas City Annual Conference, Jackson Hole, Wyoming.

Beaton, K. and Desroches, B. (2011). Financial spillovers across countries: the case of Canada and the United States. *Bank of Canada Discussion Paper*, 2011-1.

Bernanke, B., Boivin, J., and Eliasz, P. (2005). Measuring the effects of monetary policy: a factor-augmented vector autoregressive (FAVAR) approach. *The Quarterly Journal of Economics*, 120(1):387.

BIS (2008). *Guidelines to the international consolidated banking statistics*. Monetary and Economic Department, BIS.

Bordo, M., Rockoff, H., and Redish, A. (1994). The US banking system from a northern exposure: Stability versus efficiency. *Journal of Economic History*, 54(2):325–41.

Borio, C. (1995). The structure of credit to the non-goverment sector and the transmission mechanism of monetary policy: a cross-country comparison. *BIS Working Paper*, 24.

Borio, C., McCauley, R., and McGuire, P. (2011). Global credit and domestic credit booms. *BIS Quarterly Review*, September.

Buch, C., Eickmeier, S., and Prieto, E. (2010). Macroeconomic factors and micro-level bank risk. *Deutsche Bundesbank Discussion Paper*, 2010/20.

Busch, U., Scharnagl, M., and Scheithauer, J. (2010). Loan supply in Germany during the financial crisis. *Deutsche Bundesbank Discussion Paper*, 2010/05.

Bussière, M., Chudik, A., and Mehl, A. (2011). Does the euro make a difference? Spatio-temporal transmission of global shocks to real effective exchange rates in an infinite VAR. *ECB Working Paper*, 1292.

Cetorelli, N. and Goldberg, L. (2011). Global banks and international shock transmission: evidence from the crisis. *IMF Economic Review*, 59(1):41–46.

Chen, Q., Gray, D., N'Diaye, P., Oura, H., and Tamirisa, N. (2010). International transmission of bank and corporate distress. *IMF Working Paper*, 10/124.

Christiano, L., Motto, R., and Rostagno, M. (2010). Financial factors in economic fluctuations. *ECB Working Paper*, 1192.

Chudik, A. and Fratzscher, M. (2011). Identifying the global transmission of the 2007-2009 financial crisis in a GVAR model. *European Economic Review*, 55:325–339.

Ciccarelli, M., Maddaloni, A., and Peydró, J.-L. (2010). Trusting the bankers: a new look at the credit channel of monetary policy. *ECB Working Paper*, 1228.

Claessens, S., Kose, M., and Terrones, M. (2010). How do business and financial cycles interact? *Mimeo*, IMF.

Committee on the Global Financial System (2011). Global liquidity - concepts, measurement and policy implications. *CGFS Paper*, 45.

Cooper, R. and Ejarque, J. (2000). Financial intermediation and aggregate fluctuations: A quantitative analysis. *Macroeconomic Dynamics*, 4:423–447.

Cúrdia, V. and Woodford, M. (2010). Credit spreads and monetary policy. *Journal of Money, Credit and Banking*, 42(6):3–35.

De Nicolò, G. and Lucchetta, M. (2010). Systemic risks and the macroeconomy. *IMF Working Paper*, 10/29.

Dedola, L. and Lombardo, G. (2010). Financial frictions, financial integration and the international propagation of shocks. *Mimeo*, ECB.

Dées, S., Mauro, F., Pesaran, M., and Smith, L. (2007). Exploring the international linkages of the euro area: A global VAR analysis. *Journal of Applied Econometrics*, 22(1):1–38.

Devereux, M. and Yetman, J. (2010). Leverage constraints and the international transmission of shocks. *Journal of Money, Credit and Banking*, Supplement to No. 42(6):71–105.

Devereux, M. B. and Sutherland, A. (2011). Evaluating international financial integration under leverage constraints. *European Economic Review*, 55:427–442.

Drehmann, M., Borio, C., Gambacorta, L., Jiménez, G., and Trucharte, C. (2010). Countercyclical capital buffers: exploring options. *BIS Working Paper*, 317.

Dées, S., Pesaran, M., Smith, L., and Smith, R. (2010). Supply, demand and monetary policy shocks in a multi-country New Keynesian model. *ECB Working Paper*, 1239.

Eickmeier, S. and Hofmann, B. (2011). Monetary policy, housing booms and financial (im)balances. *Macroeconomic Dynamics*, forthcoming.

Eickmeier, S., Lemke, W., and Marcellino, M. (2011a). The changing international transmission of financial shocks: Evidence from a classical time-varying FAVAR. *CEPR Discussion Paper*, 8341.

Eickmeier, S., Lemke, W., and Marcellino, M. (2011b). Classical time-varying favar models - estimation, forecasting and structural analysis. *Bundesbank Discussion Paper (Series 1)*, 04/2011.

Eickmeier, S. and Ng, T. (2010). Forecasting national activity using lots of international predictors: an application to New Zealand. *International Journal of Forecasting*, 27:496–511.

Enders, Z., Kollmann, R., and Müller, G. (2011). Global banking and international business cycles. *European Economic Review*, 55(3):407–426.

Fender, I. and McGuire, P. (2010). Bank structure, funding risk and the transmission of shocks across countries: concepts and measurement. *BIS Quarterly Review*, September:63–79.

Fry, R. and Pagan, A. (2007). Some issues in using sign restrictions for identifying structural VARs. *NCER Working Paper*, 14.

Galesi, A. and Sgherri, S. (2009). Regional financial spillovers across Europe: a Global VAR analysis. *IMF Working Paper*, 09/23.

Gerali, A., Neri, S., Sessa, L., and Signoretti, F. (2010). Credit and banking in a DSGE model of the euro area. *Journal of Money, Credit and Banking*, 42(6):108–141.

Gertler, M. and Karradi, P. (2009). A model of unconventional monetary policy. *Mimeo.*

Gilchrist, S., Yankov, V., and Zakrajsek, E. (2009). Credit market shocks and economic fluctuations: Evidence from corporate bond and stock markets. *Journal of Monetary Economics*, 56(4):471–493.

Gorton, G. (2009). Information, liquidity, and the (ongoing) panic of 2007. *American Economic Review*, 99(2):567–572.

Groen, J. and Kapetanios, G. (2008). Revisiting useful approaches to data-rich macroeconomic forecasting. *Federal Reserve Bank of New York Staff Reports*, 327.

Helbling, T., Huidrom, R., Kose, A., and Otrok, C. (2011). Do credit shocks matter? A global perspective. *European Economic Review*, 55:340–353.

Hiebert, P. and Vansteenkiste, I. (2009). Do house price developments spill over across euro area countries? Evidence from a Global VAR. *ECB Working Paper*, 1026.

Hristov, N., Hülsewig, O., and Wollmershäuser, T. (2011). Loan supply shocks during the financial crisis: evidence for the euro area. *CESifo Working Paper*, 3395.

Imbs, J. (2010). The first global recession in decades. *IMF Economic Review*, 58(2):327–354.

IMF (2002). *Coordinated portfolio investment survey guide*. International Monetary Fund, second edition.

IMF (2010). *The coordinated direct investment survey guide*. International Monetary Fund, Statistics Department.

Koop, G., Pesaran, M., and Potter, S. (1996). Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics*, 74:119–147.

Krugman, P. (2008). The international financial multiplier. *Mimeo*.

Lane, P. and Milesi-Ferretti, G. (2007). The external wealth of nations Mark II: Revised and extended estimates of foreign assets and liabilities, 1970-2004. *Journal of International Economics*, 73(2):223–250.

Lane, P. and Shambaugh, J. (2010). Financial exchange rates and international currency exposures. *American Economic Review*, 100(1):518–540.

Meeks, R. (2011). Do credit market shocks drive output fluctuations? Evidence from corporate spreads and defaults. *Mimeo.*, Federal Reserve Bank of Dallas.

Park, H. and Fuller, W. (1995). Alternative estimators and unit root tests for the autoregressive process. *Journal of Time Series Analysis*, 16:415–429.

Peersman, G. (2010). Macroeconomic consequences of different types of credit market disturbances and non-conventional monetary policy in the euro area. *Mimeo*, University of Ghent.

Perri, F. and Quadrini, V. (2011). International recessions. *NBER Working Paper*, 17201.

Pesaran, H. and Shin, Y. (1998). Generalized impulse response analysis in linear multivariate models. *Economics letters*, 58(1):17–29.

Pesaran, M., Schuermann, T., and Weiner, S. (2004). Modeling regional interdependencies using a global error-correcting macroeconometric model. *Journal of Business and Economic Statistics*, 22(2):129–162.

Pesaran, M., Shin, Y., and Smith, R. (2000). Structural analysis of vector error correction models with exogenous I(1) variables. *Journal of Econometrics*, 97:293–343.

Pesaran, M. and Smith, R. (2006). Macroeconometric modelling with a global perspective. *The Manchester School*, 74(1):24–49.

Phillips, P. and McFarland, J. (1997). Forward exchange market unbiasedness: the case of the Australian dollar since 1984. *Journal of International Money and Finance*, 16(6):885–907.

Rigobon, R. (2003). Identification through heteroskedasticity. *Review of Economics and Statistics*, 85(4):777–792.

Rubio-Ramírez, J., Waggoner, D., and Zha, T. (2010). Structural vector autoregressions: theory of identification and algorithms for inference. *Review of Economic Studies*, 77(2):665–696.

Stock, J. and Watson, M. (2002). Macroeconomic forecasting using diffusion indexes. *Journal of Business & Economic Statistics*, 20(2):147.

Stock, J. and Watson, M. (2008). Forecasting in dynamic factor models subject to structural instability. The Methodology and Practice of Econometrics, A Festschrift in Honour of Professor David F. Hendry, Jennifer Castle and Neil Shephard (eds.), Oxford: Oxford University Press.

van Wincoop, E. (2011). International contagion through leveraged financial institutions. *Mimeo*.

Xu, T. (2010). The role of credit in international business cycles. *Mimeo*.

Table 1: Correlation between statistical factors and GVAR foreign variables (average over all economies)

	Trade	PIout	PIin	FDIout	FDIin	BCout	BCin
Credit growth							
PC	0.84	0.83	0.84	0.80	0.84	0.83	0.84
PLS	0.79	0.78	0.73	0.78	0.73	0.80	0.71
Equity price growth							
PC	0.95	0.93	0.93	0.92	0.93	0.93	0.92
PLS	0.96	0.94	0.94	0.95	0.93	0.93	0.92

Table 2: Variables included in the country VARX models

	All economies but the US		US	
	Domestic	Foreign	Domestic	Foreign
y	x	x	x	x
Dp	x	x	x	x
credit	x	x	x	
crspread	x	x	x	
sr	x	x	x	
lr	x	x	x	
eq	x	x	x	
ep	x			x
poil		x	x	

Notes: y: real GDP, Dp: inflation, credit: volume of credit, crspreads: corporate bond yield – 10-year government bond yield, sr: short rate, lr: long-term government bond yield, eq: equity price, ep: exchange rate, poil: oil price.

Table 3: Forecasting using GVARs with different weighting schemes

(a) GVAR RMSEs divided by RMSEs from random walk model

	GDP				All variables			
	h = 1	h = 2	h = 3	h = 4	h = 1	h = 2	h = 3	h = 4
Mean								
Trade	0.64	0.64	0.68	0.70	0.81	0.87	0.93	0.96
PIout	0.64	0.61	0.59	0.58	0.78	0.77	0.77	0.76
PIin	0.61	0.57	0.55	0.55	0.75	0.75	0.74	0.74
FDIout	0.63	0.59	0.56	0.55	0.75	0.74	0.73	**0.72**
FDIin	**0.61**	**0.56**	**0.54**	**0.53**	**0.74**	0.74	0.74	0.74
BCout	0.63	0.58	0.56	0.55	0.75	**0.73**	**0.73**	0.73
BCin	0.63	0.58	0.56	0.56	0.82	0.82	0.80	0.79
Median								
Trade	0.64	0.69	0.69	0.72	0.80	0.84	0.88	0.92
PIout	0.64	0.58	0.57	0.58	0.79	0.80	0.78	0.78
PIin	**0.59**	0.56	0.55	0.55	0.76	0.76	0.76	0.75
FDIout	0.62	**0.55**	0.52	0.51	0.77	0.76	**0.75**	**0.74**
FDIin	0.60	0.56	0.54	**0.50**	**0.75**	0.76	0.75	0.75
BCout	0.62	0.55	**0.50**	0.51	0.76	**0.75**	0.76	0.75
BCin	0.62	0.56	0.54	0.52	0.81	0.81	0.80	0.79
Minimum								
Trade	0.46	0.39	0.34	0.31	**0.31**	**0.23**	0.23	0.24
PIout	0.47	0.42	0.39	0.35	0.33	0.24	0.24	0.24
PIin	0.45	0.39	0.37	0.31	0.33	0.24	0.24	0.25
FDIout	0.46	0.41	0.40	0.35	0.33	0.24	0.23	0.23
FDIin	0.44	0.39	**0.32**	**0.26**	0.34	0.25	0.26	0.26
BCout	0.46	0.40	0.38	0.35	0.32	0.23	**0.22**	**0.21**
BCin	**0.44**	**0.38**	0.34	0.30	0.26	0.23	0.23	0.26
Maximum								
Trade	0.81	0.84	0.92	0.95	1.40	1.56	1.72	1.77
PIout	0.86	0.85	0.87	0.92	1.12	1.06	1.06	1.08
PIin	**0.83**	**0.79**	**0.83**	0.86	1.09	1.07	1.05	**1.01**
FDIout	0.86	0.85	0.83	**0.82**	1.01	1.03	1.05	1.03
FDIin	0.88	0.84	0.85	0.84	1.07	1.04	1.04	1.07
BCout	0.90	0.86	0.86	0.91	**0.97**	**0.97**	**0.97**	1.03
BCin	0.94	0.89	0.85	0.84	1.60	1.55	1.32	1.26

(b) Ranking of models

	Best model				Second best model				Worst model			
	h = 1	h = 2	h = 3	h = 4	h = 1	h = 2	h = 3	h = 4	h = 1	h = 2	h = 3	h = 4
GDP												
Trade	0.08	0.08	0.08	0.08	0.15	0.12	0.08	0.00	0.31	0.58	0.62	0.69
PIout	0.12	0.12	0.12	0.08	0.04	0.04	0.04	0.08	0.23	0.08	0.12	0.08
PIin	0.12	0.08	0.12	0.12	**0.38**	**0.35**	**0.31**	**0.31**	0.04	**0.00**	**0.00**	0.04
FDIout	0.08	0.08	0.12	0.12	0.04	0.15	0.08	0.15	0.12	0.08	**0.00**	**0.00**
FDIin	**0.31**	**0.27**	**0.35**	**0.38**	0.19	0.15	0.08	0.00	**0.00**	**0.00**	0.04	0.04
BCout	0.15	0.15	0.15	0.15	0.08	0.15	0.19	0.23	0.08	0.08	0.12	0.08
BCin	0.15	0.23	0.08	0.08	0.12	0.04	0.23	0.23	0.23	0.19	0.12	0.08
All variables												
Trade	0.13	0.09	0.07	0.07	0.09	0.05	0.05	0.02	0.32	0.50	0.60	0.67
PIout	0.04	0.06	0.07	0.07	0.08	0.08	0.10	0.11	0.10	0.05	0.05	0.02
PIin	0.18	0.12	0.12	0.12	0.19	0.19	0.19	0.18	0.03	0.05	0.06	0.07
FDIout	0.13	0.12	0.16	0.16	**0.21**	**0.29**	**0.24**	**0.25**	0.08	0.05	**0.02**	**0.01**
FDIin	0.21	0.22	0.22	0.19	0.19	0.15	0.12	0.15	**0.02**	**0.04**	0.04	0.02
BCout	**0.24**	**0.30**	**0.28**	**0.29**	0.18	0.18	0.22	0.19	0.07	0.04	0.04	0.03
BCin	0.09	0.09	0.08	0.10	0.05	0.07	0.08	0.10	0.38	0.27	0.19	0.17

Notes: (a) Relative RMSEs. We report the mean, median, minima and maxima over all countries. Bold figures indicate minima. (b) Share of variables for which GVAR models with different weighting schemes (Trade, PI-out, PIin, FDIout, FDIin, BCout, BCin) provide the best, second best and worst forecasts for GDP and all variables. Bold figures indicate outperformance of a particular model.

Table 4: Information criteria – comparison between different weighting schemes

	AIC	BIC
Trade	-583.89	729.01
PIout	-614.02	654.67
PIin	-553.38	800.11
FDIout	-720.80	387.49
FDIin	-738.08	370.21
BCout	**-758.88**	**286.91**
BCin	-564.38	768.97

Notes: Figures in bold indicate the minimum. The criteria were computed as described in the text.

Table 5: Identifying restrictions for credit supply shocks

Variable	y	Dp	credit	crspread	sr	lr	eq	ep	credit-y	cr	cr-sr
Restrictions	-		-	+					-	+	+
Lags	0-3		0-3	0					0	0	0

Notes: See notes to Table 2. cr: corporate bond yield, computed as crspread+lr. The sign restrictions -/+ are implemented such that the impulse response is < or = 0/> or = 0.

Table 6: GDP forecast error variance shares explained by credit supply shocks (in percent)

	US credit sup	EA credit sup	JP credit sup
1 year			
US	17.5	0.0	0.2
EA	6.5	14.2	1.0
JP	11.0	7.7	24.5
CA	1.8	0.2	0.4
UK	4.7	5.8	1.0
LA	6.1	0.7	0.4
Asia	1.0	1.2	0.4
Oth Europe	6.8	2.0	0.6
AU-NZ	2.0	0.1	0.2
4 years			
US	25.3	0.3	0.1
EA	20.1	1.4	0.8
JP	26.5	7.7	12.7
CA	5.3	2.0	0.3
UK	15.3	0.9	0.4
LA	20.3	0.9	0.3
Asia	4.4	2.6	0.9
Oth Europe	17.5	1.3	0.4
AU-NZ	8.7	0.3	0.3

Notes: In percent. The forecast horizons considered are 1 and 4 years. Since the shocks are (weakly) correlated across countries, we show here “scaled” versions of the variance shares, similar to “generalised variance decompositions”.

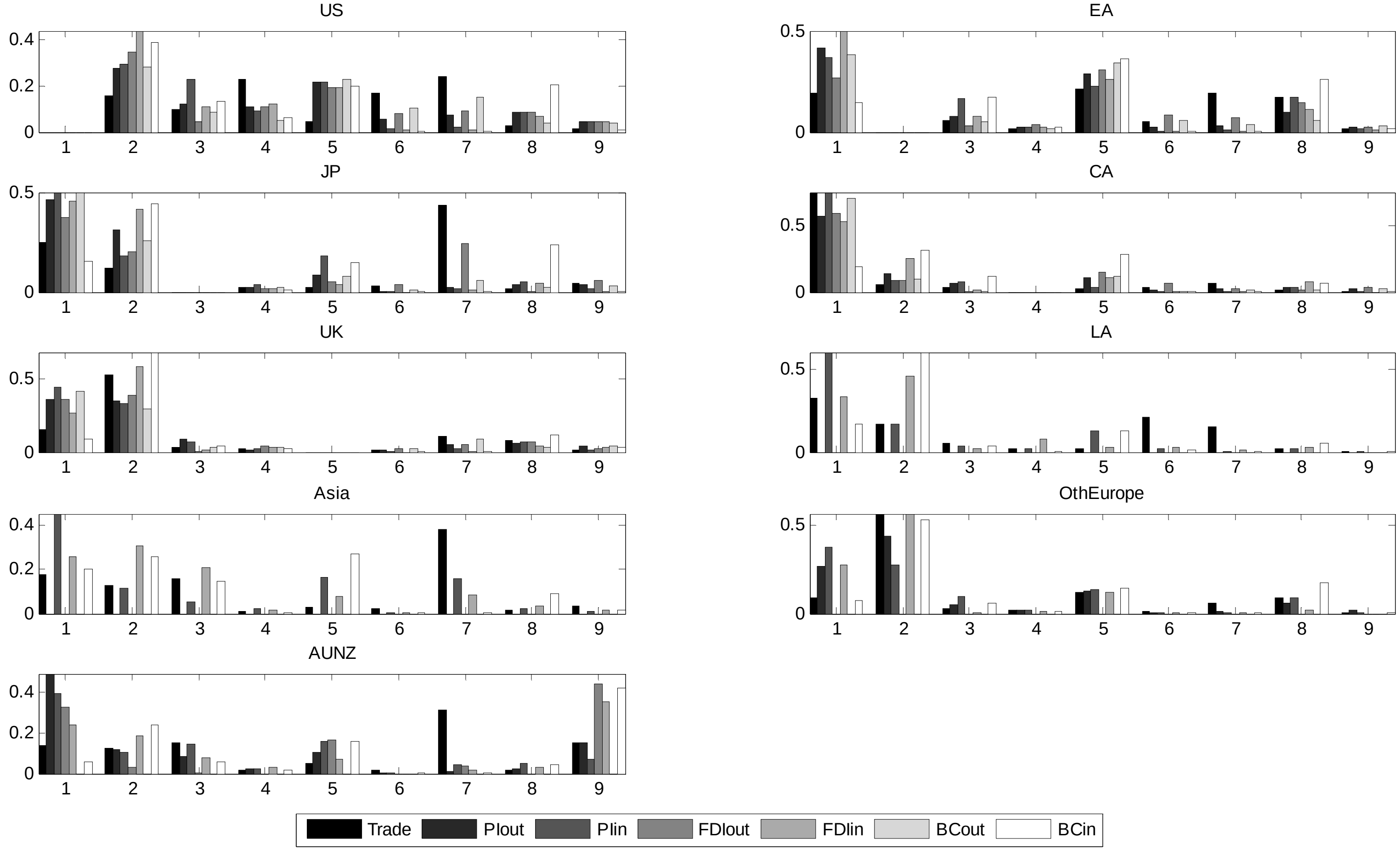
Table 7: Impulse responses of GDP to US, euro-area and Japanese credit supply shocks after 1 year – robustness checks

	Trade			PIout			PIin			FDIout			FDIin (benchmark)		
	US	EA	JP	US	EA	JP	US	EA	JP	US	EA	JP	US	EA	JP
US	-0.294 *	-0.187 *	-0.148 *	-0.262 *	-0.031	-0.018	-0.190 *	-0.012	-0.025	-0.236 *	-0.013	-0.013	-0.238 *	0.017	-0.014
EA	-0.370 *	-0.440 *	-0.352 *	-0.227 *	-0.133 *	-0.055 *	-0.176 *	-0.086 *	-0.113 *	-0.168 *	-0.093 *	-0.030 *	-0.175 *	-0.147 *	-0.045
JP	-0.306 *	-0.464 *	-0.340 *	-0.370 *	-0.289 *	-0.312 *	-0.356 *	-0.147 *	-0.474 *	-0.167 *	-0.221 *	-0.235 *	-0.388 *	-0.367 *	-0.378 *
CA	-0.295 *	-0.256 *	-0.228 *	-0.231 *	-0.065	-0.046	-0.086	-0.044	-0.116 *	-0.189 *	-0.065	-0.028 *	-0.104	-0.017	-0.043
UK	-0.364 *	-0.350 *	-0.306 *	-0.243 *	-0.133 *	-0.039	-0.290 *	-0.070	-0.147 *	-0.160 *	-0.136 *	-0.036 *	-0.170	-0.159 *	-0.059
LA	-0.656 *	-0.633 *	-0.508 *	-0.345 *	-0.210 *	-0.077	-0.190	-0.049	-0.134	-0.142	-0.129 *	-0.029	-0.399	-0.175	-0.084
Asia	-0.200	-0.515 *	-0.541 *	-0.166	-0.155 *	-0.076 *	-0.142	-0.104	-0.235 *	-0.080	-0.084	-0.029	-0.177	-0.278 *	-0.095
Oth Europe	-0.387 *	-0.258 *	-0.214 *	-0.238 *	-0.093	-0.012	-0.141	-0.018	-0.024	-0.163 *	-0.055	-0.020 *	-0.223 *	-0.040	-0.031
AU-NZ	-0.247 *	-0.079	-0.076	-0.118 *	-0.036	-0.013	-0.061	-0.021	-0.033	-0.109 *	-0.021	-0.009	-0.126	-0.029	-0.027

	BCout			BCin			FDIin excl. crisis			FDIin DE replacing EA		
	US	EA	JP	US	EA	JP	US	EA	JP	US	DE	JP
US	-0.326 *	-0.019	-0.019	-0.291 *	0.049	0.047	-0.109 *	0.026	0.001	-0.251 *	-0.007	-0.003
EA	-0.216 *	-0.055 *	-0.046 *	-0.141	-0.055 *	-0.021	-0.107	-0.072 *	-0.021	-0.439 *	-0.100 *	-0.059 *
JP	-0.156	-0.198 *	-0.313 *	-0.210	-0.255 *	-0.159 *	-0.333 *	-0.195 *	-0.289 *	-0.366 *	-0.068 *	-0.083 *
CA	-0.215 *	-0.048 *	-0.040 *	-0.139	0.108	0.060	-0.111	0.017	-0.014	-0.240 *	-0.018	-0.008
UK	-0.241 *	-0.055	-0.042 *	-0.185 *	-0.115 *	-0.142 *	-0.009	0.000	-0.002	-0.246 *	-0.072 *	-0.044 *
LA	-0.240	-0.109 *	-0.038	-0.313	-0.101	-0.107	-0.356	-0.082	-0.049	-0.451 *	-0.077 *	-0.059
Asia	-0.045	-0.068 *	-0.041	0.009	-0.156	-0.290 *	-0.095	-0.043	-0.069	-0.183	-0.023	-0.017
Oth Europe	-0.207 *	-0.013	-0.026	-0.203	-0.005	-0.020	-0.083	-0.002	0.026	-0.246 *	-0.036	-0.011
AU-NZ	-0.070	0.003	-0.012	-0.037	0.132	0.162 *	-0.086	-0.040	-0.038 *	-0.108	-0.013	-0.002

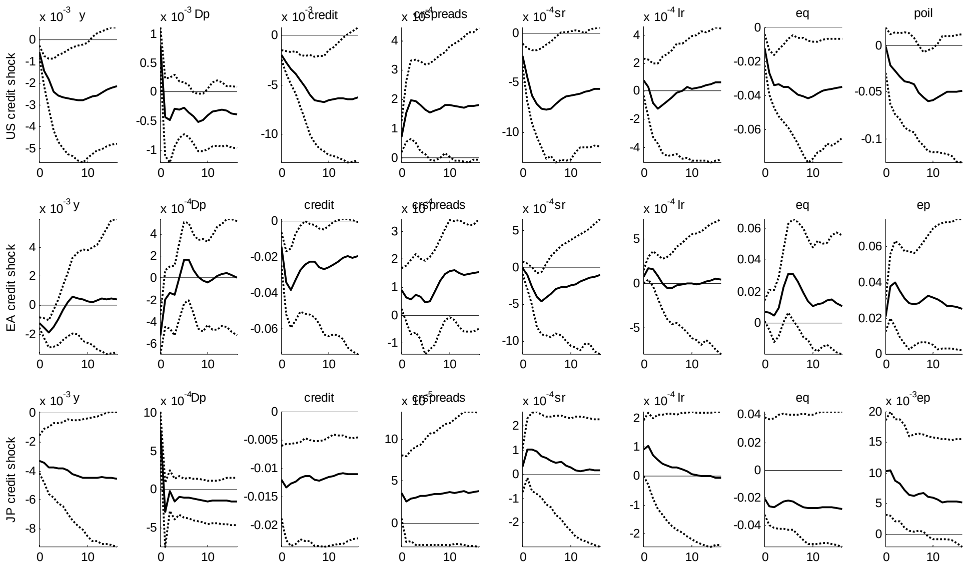
Notes: In percentage points (interest rates and spreads) and percent (all other variables). ‘*’ indicates significance of impulse response function at the 90% level.

Figure 1: Trade and financial weights



Notes: 1: US, 2: EA, 3: JP, 4: CA, 5: UK, 6: LA, 7: Asia, 8: Other Europe, 9: AU-NZ. The weights for the groups of countries are formed based on unweighted averages of individual countries belonging to the group.

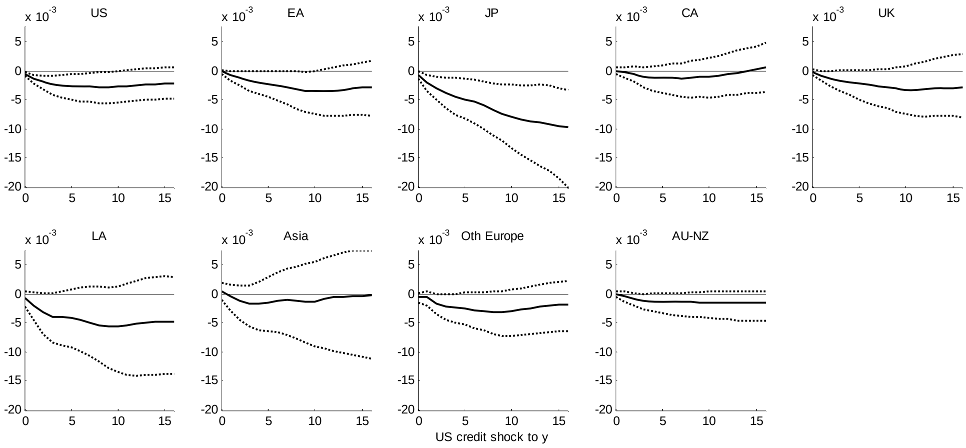
Figure 2: Domestic transmission of credit supply shocks (benchmark model FDIin)

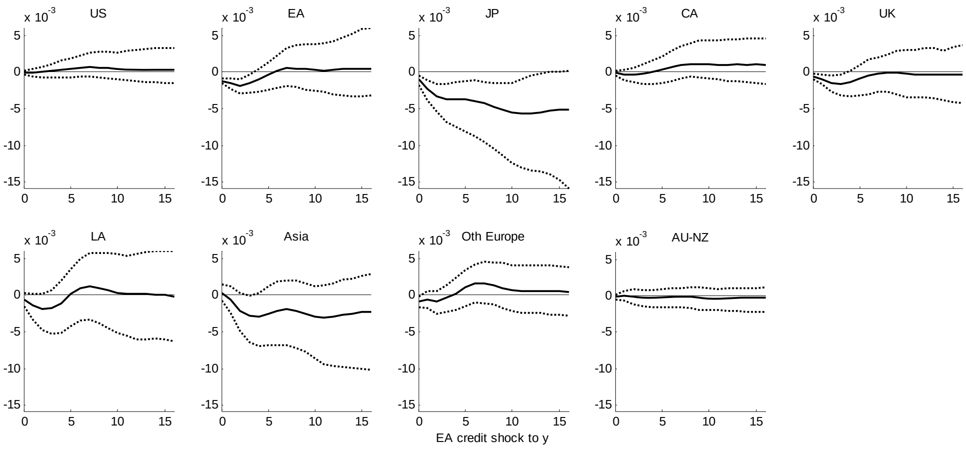


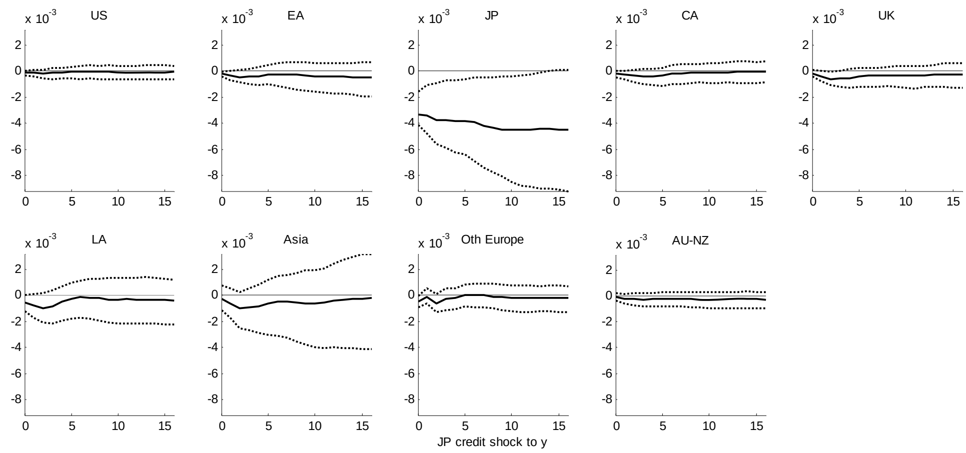
Notes: y: real GDP, Dp: inflation, credit: volume of credit, crspreads: corporate bond yield – 10-year government bond yield, sr: short rate, lr: long-term government bond yield, eq: equity price, ep: exchange rate, poil: oil price. sr, lr, crspreads, Dp are not annualized, but quarterly rates. The shock size is 1 standard deviation, and the median (solid line) and 90% confidence bands (dotted lines) are shown.

Figure 3: Impulse responses for selected countries/regions to foreign credit supply shocks (benchmark model FDIin)

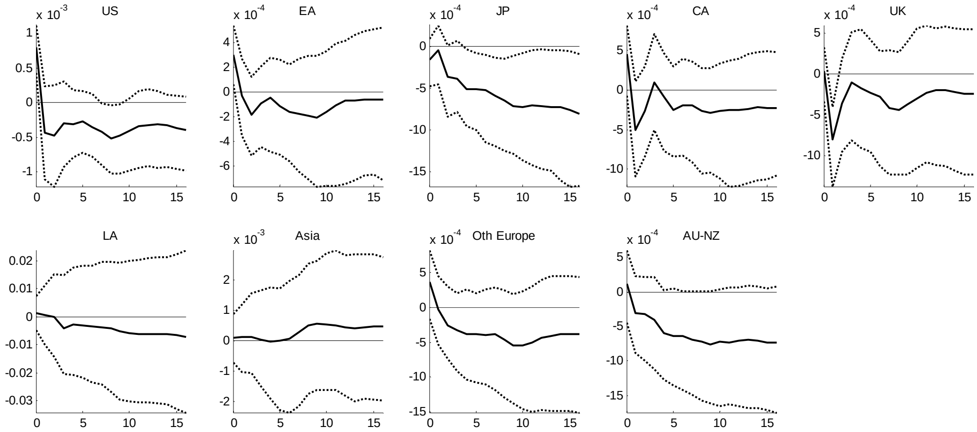
(a) GDP



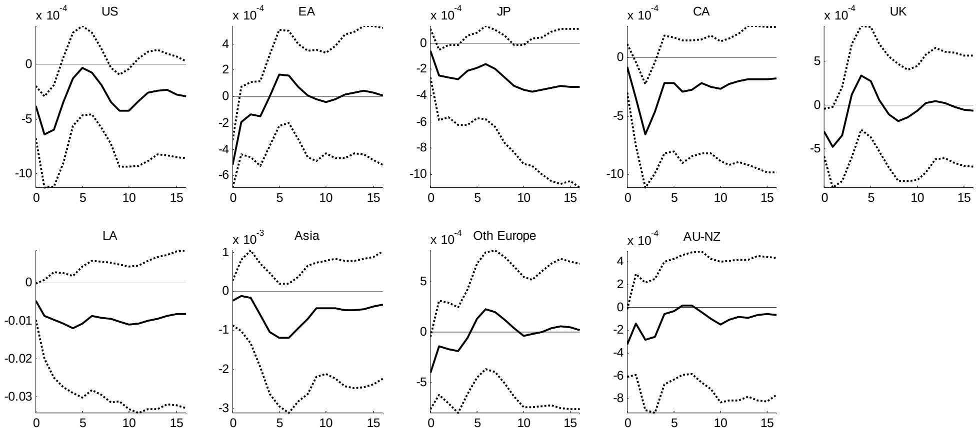




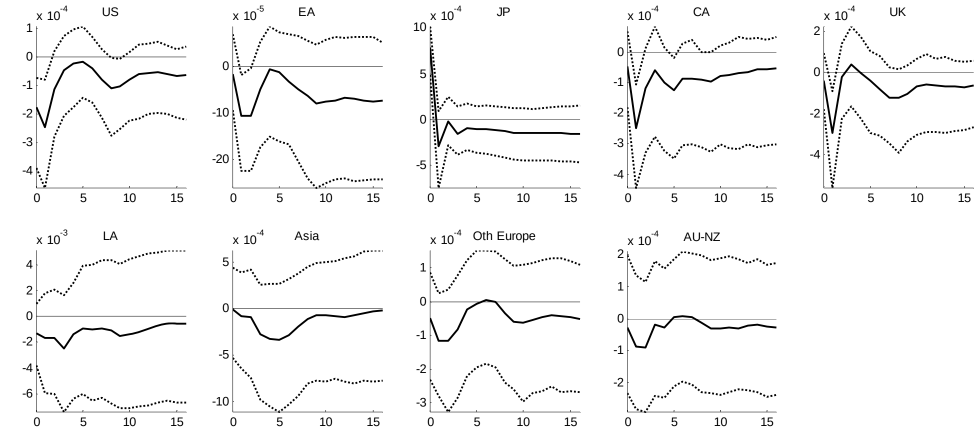
(b) Inflation



US credit shock to Dp

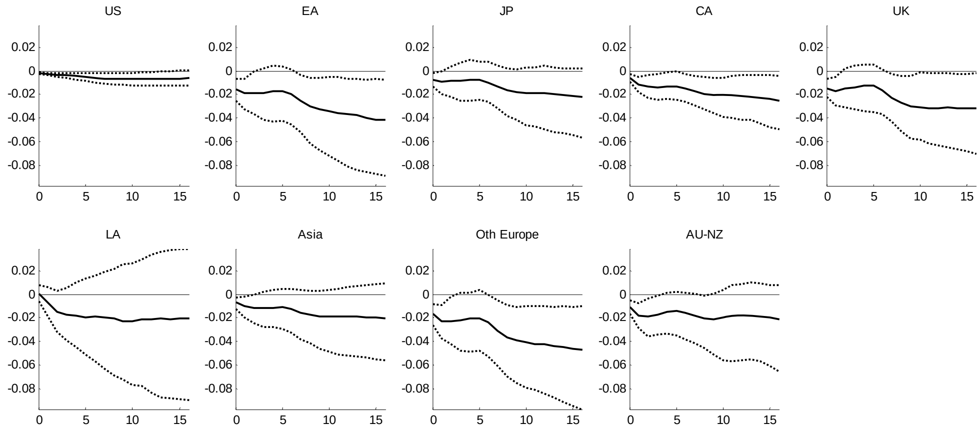


EA credit shock to Dp

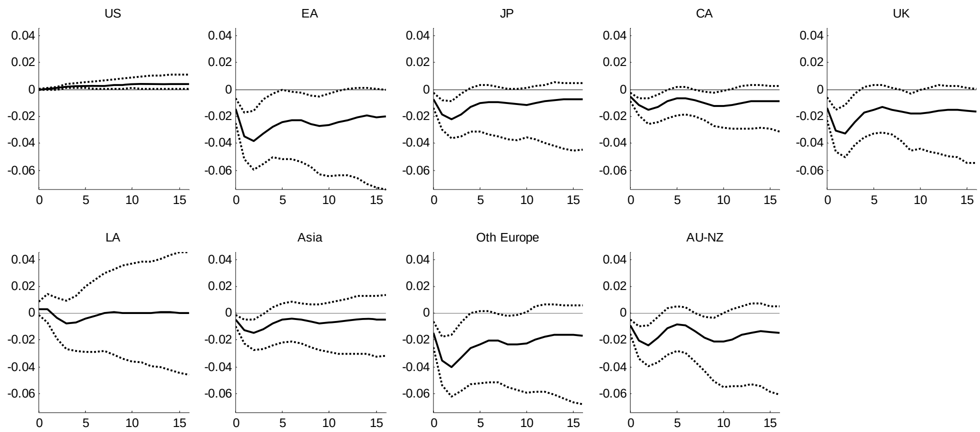


JP credit shock to Dp

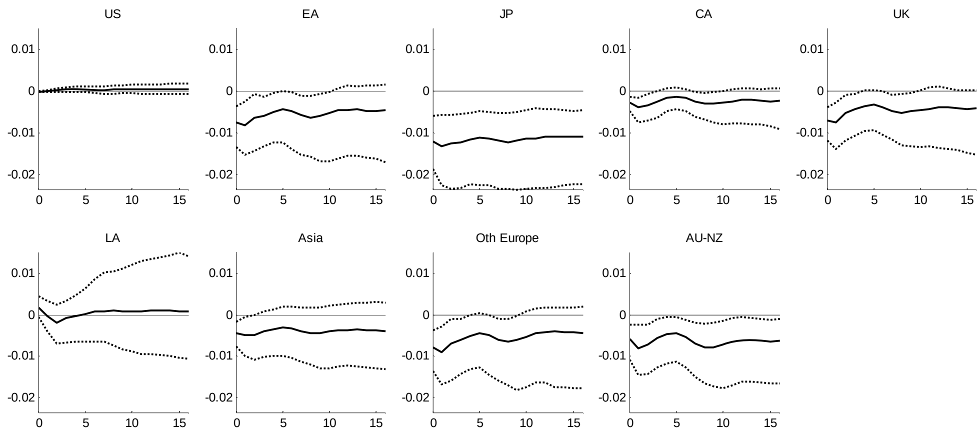
(c) Credit



US credit shock to credit

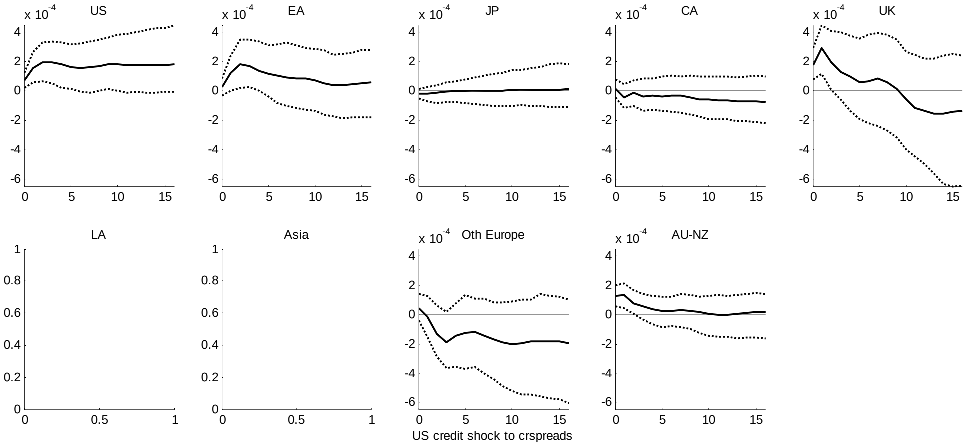


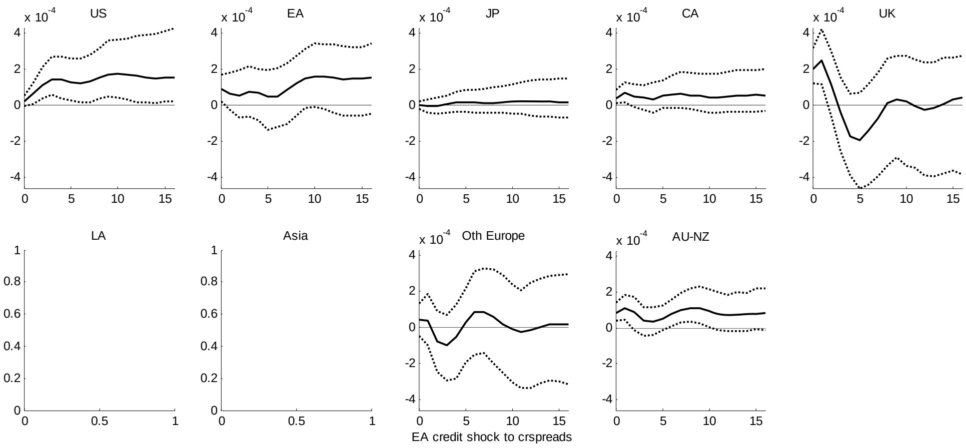
EA credit shock to credit

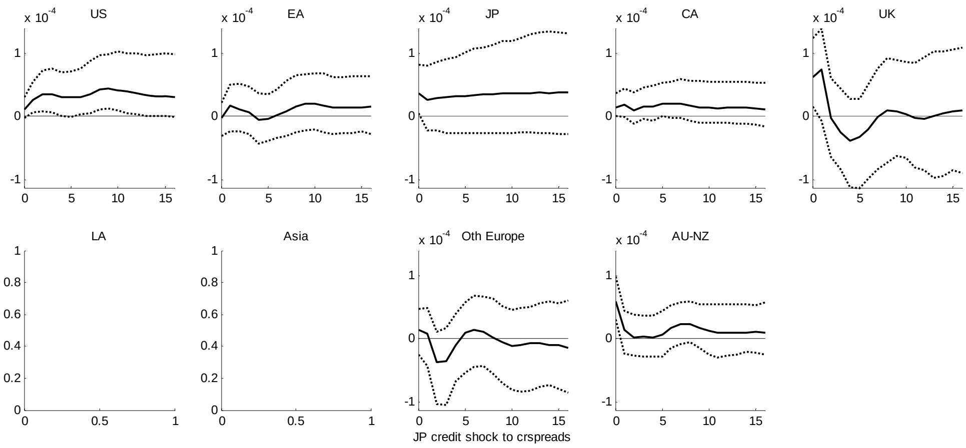


JP credit shock to credit

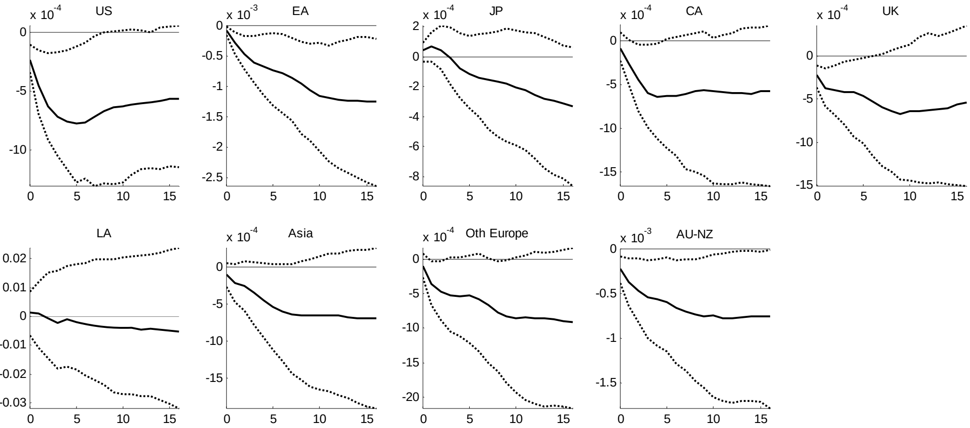
(d) Corporate bond spreads



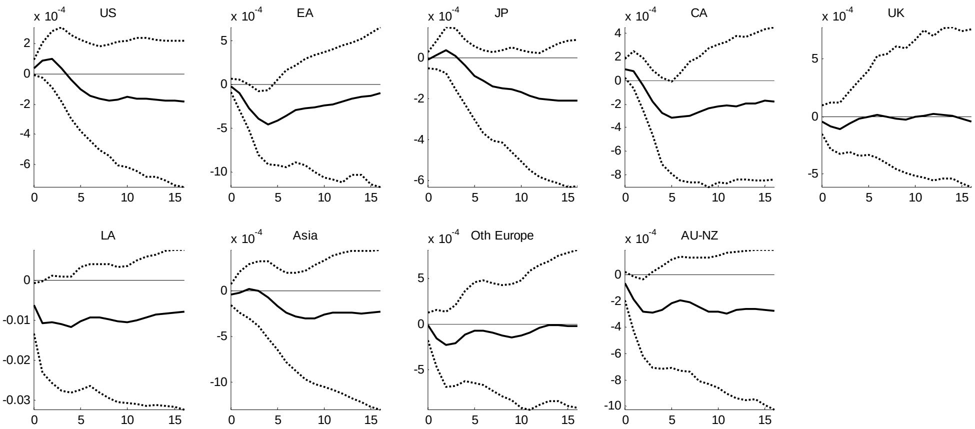




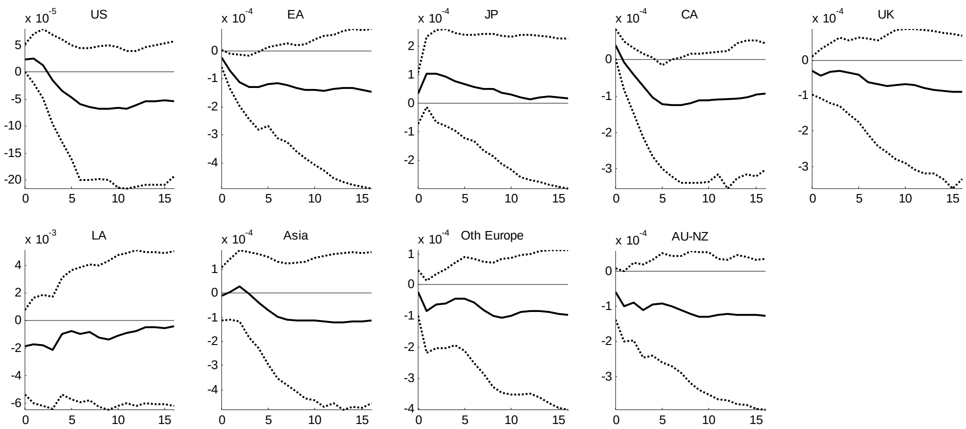
(e) Short rate



US credit shock to sr

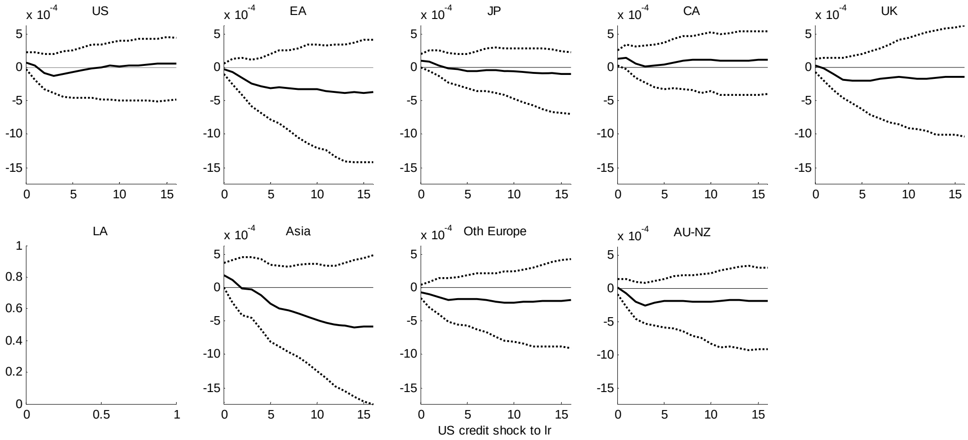


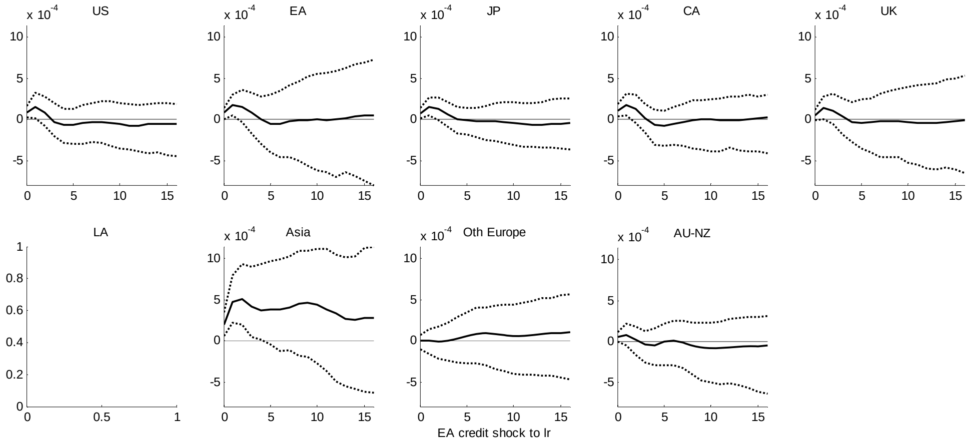
EA credit shock to sr



JP credit shock to sr

(f) Long rate


US
EA
JP
CA
UK
LA
Asia
Oth Europe
AU-NZ
US credit shock to lr


US
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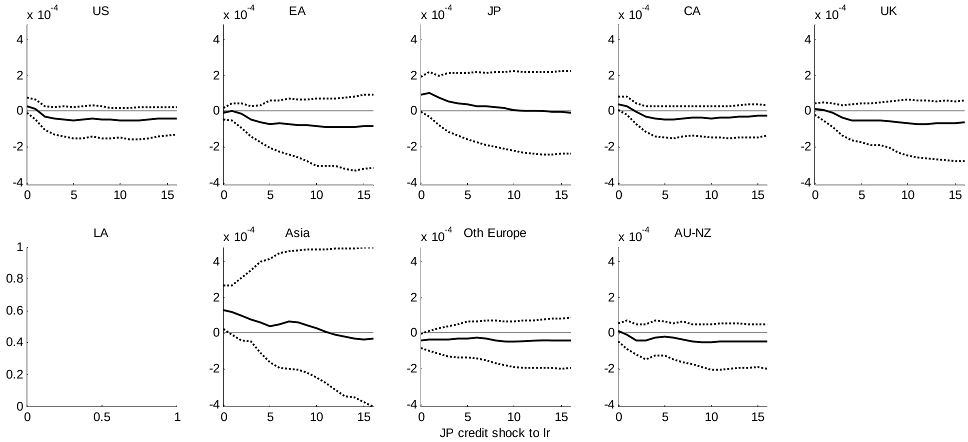
Asia
Oth Europe
AU-NZ
EA credit shock to lr


US
EA
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CA
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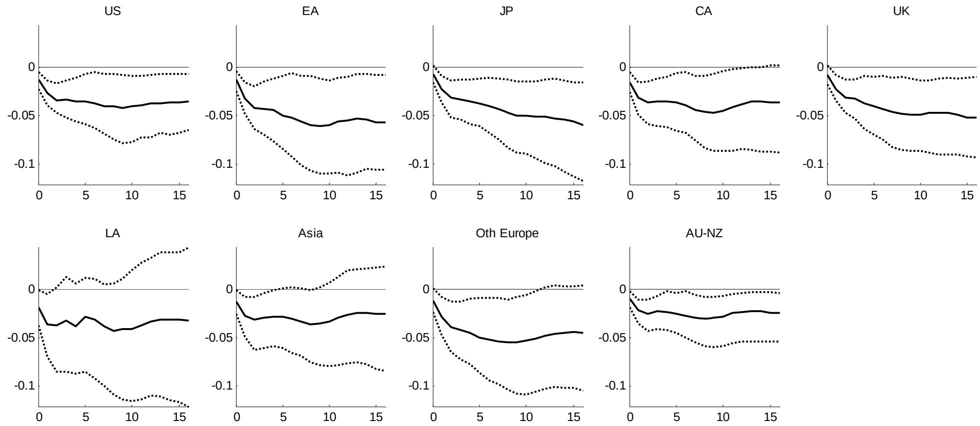
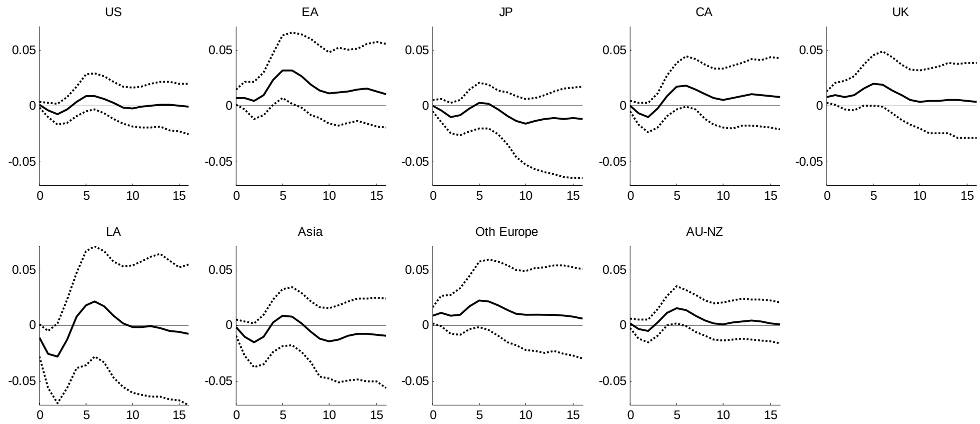
Asia
Oth Europe
AU-NZ
JP credit shock to lr

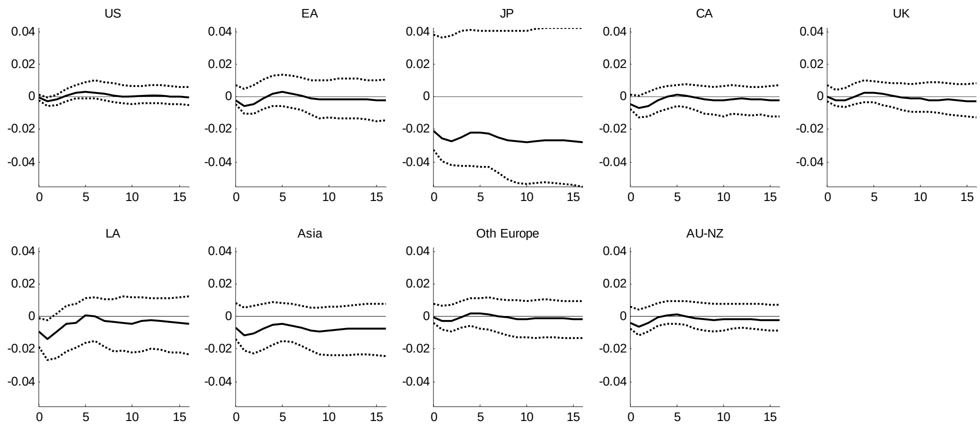
(g) Equity price



US credit shock to eq

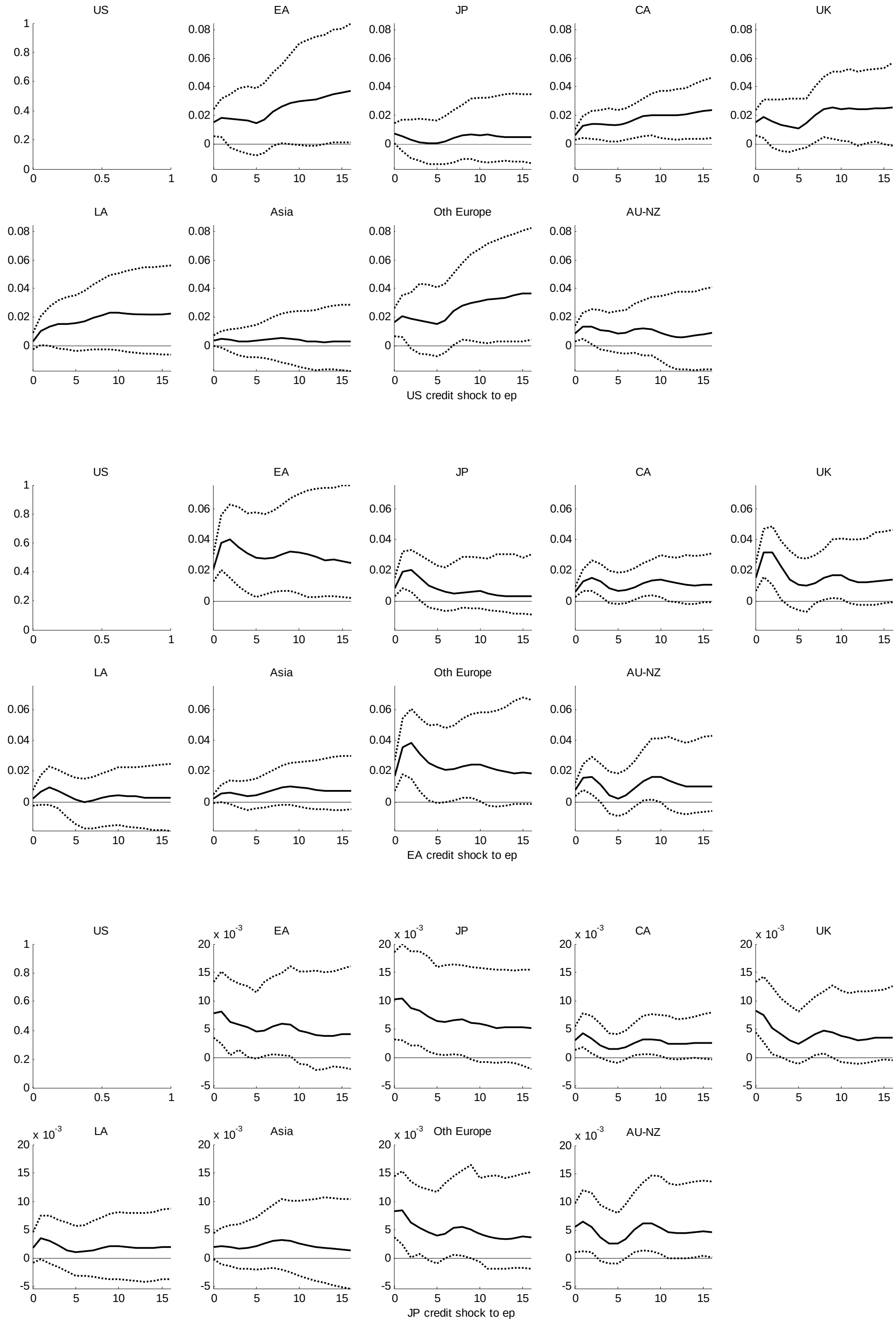


EA credit shock to eq



JP credit shock to eq

(h) Exchange rate



Notes: See notes to Figure 2. The axes are not identical for all economies for inflation and short-term interest rates because of large reactions in LA.