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Credit, asset prices and business cycles at the global level

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Abstract

This paper assesses the role of financial variables in real economic fluctuations, in view of analysing the link between financial cycles and business cycles at the global level. A Global VAR modelling approach is used to first assess the contribution of credit and asset price variables to real economic activity in a number of countries and regions. The GVAR model is based on 38 countries estimated over 1987-2013. An analysis on a sample excluding the post-financial crisis period is also provided to check whether financial variables have gained importance in explaining business cycle fluctuations over the recent past. In a second step, financial shocks are identified through sign restrictions in order to illustrate how financial and business cycles could be related. Overall, the paper shows that the importance of credit and asset price variables in explaining real economic fluctuations is relatively large, but has not significantly increased since the global financial crisis. The international transmission of financial shocks on business cycle fluctuations also tends to be large and persistent.

Keywords: *international transmission of shocks, financial cycle, business cycle, GVAR model.*

JEL Classification: E32, E37, E44, E51, F47.

Non-technical summary

The global financial crisis has led to a renewed interest in studying the linkages between financial variables and real economic developments. While financial factors played a minor role in macroeconomics in the pre-crisis period, the most recent research focuses on the inclusion of financial variables and financial channels in macroeconomic analyses and models. The global nature of the crisis also implies that including financial variables may not be sufficient to fully capture real-financial linkages. Therefore, the role of the international transmission of financial shocks on business cycle developments also requires a modelling of the cross-country interactions through which such shocks propagate.

The importance of the links between financial factors and the real economy and their global dimension call for a rethinking of macroeconomic modelling, which should account both for the inclusion of credit and asset prices and for international linkages. The analysis of business cycle fluctuations and the corresponding analytical and policy challenges cannot ignore the understanding of the financial cycle, characterised by booms and busts in asset prices associated with fluctuations in credit developments. Against this background, the most parcimonious description of the financial cycle is in terms of credit and property prices, owing to their strong comovements. These two variables also combine prices and quantities and capture the two-way interaction between financing constraints (credit) and risk perceptions (property prices).

This paper investigates the transmission of financial shocks to the real economy, domestically and cross border, in order to assess the role of the financial cycle on the business cycle. In particular, it assesses the role of financial variables in real economic fluctuations, in view of analysing the link between financial cycles and business cycles at the global level. A modelling of international linkages including financial variables has been developed with the global VAR model approach that allows for the interdependencies across a large number of countries between national and international factors, including real, monetary and financial variables. This modelling approach has been shown to be quite effective in dealing with the common factor interdependencies and international co-movements of business cycles. In this paper, a Global VAR modelling approach is used to assess the contribution of credit and asset price variables to real economic activity in a number of countries and regions. The GVAR model is based on 38 countries estimated over 1987-2013. This paper extends previous research in three dimensions. First, the GVAR model includes - in addition to the macroeconomic, monetary and credit variables - property prices in view of capturing all the features of the financial cycle. Second, the sample analysed includes a rather long post-financial crisis period, verifying whether financial variables have gained importance in explaining business cycle fluctuations over the recent years. Third, through to the inclusion of both credit and asset price variables (both equity and property prices) in the GVAR model, the paper proposes an identification of financial shocks through sign restrictions in order to illustrate how financial and business cycles could be related.

Overall, the results show that the importance of credit and asset price variables in explaining real economic fluctuations is relatively large but has not significantly increased since the global financial crisis. The international transmission of financial shocks on business cycle fluctuations also tends to be large and persistent. The extended version of GVAR model (through the inclusion of credit and property price variables) shows first that such financial-cycle related variables change the dynamic properties of the model, making the responses of real variables to financial shocks more persistent. There are however strong cross-country differences in terms of responses, notably within the euro area. Second, the 2007-8 global financial crisis is shown not to lead to strong, significant changes in the model properties. The transmission of financial shocks remain similar whether we consider a sample including or excluding the crisis period. At the same time, the stability tests point however to possible changes in the reaction of financial variables to other variables. The paper also confirms the role of the US economy in the global financial cycle and shows that global financial shocks, although leading to similar responses on credit and asset prices, have stronger impacts on real variables. Finally, the paper shows that imposing restrictions on both credit and property prices in the identification of financial shocks is key to investigate the link between financial and business cycles.

1 Introduction

The global financial crisis has led to a renewed interest in studying the linkages between financial variables and real economic developments. While financial factors played a minor role in macroeconomics in the pre-crisis period, the most recent research focuses on the inclusion of financial variables and financial channels in macroeconomic analyses and models. The global nature of the crisis also implies that including financial variables may not be sufficient to fully capture real-financial linkages. Therefore, the role of the international transmission of financial shocks on business cycle developments also requires a modelling of the cross-country interactions through which such shocks propagate.[1]

The importance of the links between financial factors and the real economy and their global dimension call for a rethinking of macroeconomic modelling, which should account both for the inclusion of credit and asset prices and for international linkages. Borio (2012), considering the environment that has prevailed for at least three decades, recognises that it is not possible to understand business fluctuations and the corresponding analytical and policy challenges without understanding the financial cycle. The author defines the financial cycle as "self-reinforcing interactions between perceptions of value and risk, attitudes towards risks and financing constraints, which translate into booms followed by busts" (p2). Against this background, the most parcimonious description of the financial cycle is in terms of credit and property prices owing to their strong comovements (Drehmann et al., 2012), as shown by Figure 1 based for a sample of 38 countries used in the empirical exercise below. As advocated by Borio

[1] See Morley (2013) for a survey on macro-financial linkages, including empirical research on spillovers from the financial sector to the rest of the economy, as well as across financial markets in different countries.

(2012), these two variables also combine prices and quantities and capture the two-way interaction between financing constraints (credit) and risk perceptions (property prices).

A modelling of international linkages including financial variables has been proposed by Pesaran et al. (2004), who propose a global VAR model (GVAR) to allow for the interdependencies across a large number of countries between national and international factors, including real, monetary and financial variables. This modelling approach has been further developed by Dees et al. (2007), showing that it is quite effective in dealing with the common factor interdependencies and international co-movements of business cycles. More recently, the GVAR methodology has been applied to study how credit supply shocks propagate internationally. Xu (2012) shows that the inclusion of credit variables provides a significant improvement in modeling and forecasting real variables for countries with developed banking sector. There is also strong evidence of the international spillover of US credit shocks and their propagation to the real economy. Eickmeier and Ng (2015) also use a GVAR approach to model financial variables jointly with macroeconomic variables and identify financial shocks through sign restrictions on the short-run impulse responses. They find negative macroeconomic impacts of credit supply shocks, especially when they originate from the US. Domestic and foreign credit and equity markets also respond significantly to credit supply shocks. Cesa-Bianchi (2013) also uses a GVAR modelling approach to investigate the international spillovers of housing demand shocks on real economic activity and finds evidence for the existence of strong international spillovers of U.S. housing demand shock to advanced economies.

This paper assesses the role of financial variables in real economic fluctuations, in view of analysing the link between financial cycles and business cycles at the global level. A Global VAR modelling approach is used to assess the contribution of credit and asset price variables to real economic activity in a number of countries and regions. The GVAR model is based on 38 countries estimated over 1987-2013. This paper extends previous research in three dimensions. First, the GVAR model includes - in addition to the macroeconomic, monetary and credit variables - property prices in view of capturing all the features of the financial cycle, as defined by Borio (2012). Second, the sample analysed includes a rather long post-financial crisis period, verifying whether financial variables have gained importance in explaining business cycle fluctuations over the recent years. Third, through to the inclusion of both credit and asset price variables (both equity and property prices) in the GVAR model, the paper proposes an identification of financial shocks through sign restrictions in order to illustrate how financial and business cycles could be related.

Overall, the results show that the importance of credit and asset price variables in explaining real economic fluctuations is relatively large but has not significantly increased since the global financial crisis. The international transmission of financial shocks on business cycle fluctuations also tends to be large and persistent.

The next section describes the methodology followed for our analysis. Sections 3 and 4 present the empirical results, focusing first on the role of financial variables in real economic developments and, thereafter, by identifying shocks related to the financial cycle and to measure their effect on the business cycle. Section 5 concludes.

2 Methodology

The analysis is based on a Global VAR model, following Pesaran et al. (2004) and Dees et al. (2007). The GVAR approach consists of specifying and estimating a set of country-specific vector error-correcting models that are consistently combined to generate a global model that can be simultaneously solved for all the variables in the world economy. The GVAR approach principles are first presented, before looking more precisely at the version used in this paper.

2.1 The GVAR approach

The GVAR modelling approach provides a relatively simple yet effective way of modelling complex high-dimensional systems. This methodology relies on a two-step approach. In the first step, country-specific models are estimated conditional on the rest of the world. This addresses the problem of consistently modelling interdependencies among many economies through the construction of "foreign" variables, which are included in each individual country model. Thus, each country model includes domestic variables together with variables obtained from the aggregation of data on the foreign economies using weights derived from bilateral trade statistics. Because the weighting scheme for each country reflects its specific geographical trade composition, foreign variables vary across countries. Subject to appropriate testing, the country-specific foreign variables are treated as weakly exogenous during the estimation of the individual country models. In the second step, the individual country models are stacked and solved simultaneously as one large global model.

In the rest of this section we present a short overview of the GVAR approach, while referring the reader to Dees et al. (2007) for a more detailed discussion.

Suppose that there are $N+1$ countries indexed by $i = 0, 1, ..., N$, with $i = 0$ for the U.S., the numeraire country. The GVAR can be written as the collection of individual country VAR(p_i, q_i) models:

$$\mathbf{\Phi}_i \left(L, p_i\right) \mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1} t + \Upsilon_i \left(L, q_i\right) \mathbf{d}_t + \mathbf{\Lambda}_i \left(L, q_i\right) \mathbf{x}^*_{it} + \mathbf{u}_{it}, \tag{1}$$

where $\mathbf{x}_{it}$ is the $k_i \times 1$ (with k_i usually five or six) vector of modelled variables,

$\mathbf{d}_t$ is the vector of observed international variables common to all countries, and $\mathbf{x}_{it}^*$ is the $k_i^* \times 1$ vector of foreign variables specific to country i. $\mathbf{\Phi}_i\left(L, p_i\right)$ and $\mathbf{\Lambda}_i\left(L, q_i\right)$ are the $k_i \times k_i$ and $k_i \times k_i^*$ matrix polynomials in the lag operator L of the coefficients of the domestic and country-specific foreign variables, respectively. $\mathbf{a}_{i0}$ and $\mathbf{a}_{i1}$ are the $k_i \times 1$ vectors of coefficients of the deterministic variables, here intercepts and linear trends. $\mathbf{\Upsilon}_i\left(L, p_i\right)$ is the $k_i \times k^d$ matrix polynomial of coefficients of the international variables $\mathbf{d}_t$. $\mathbf{u}_{it}$ is a $k_i \times 1$ vector of idiosyncratic country-specific shocks.

The country-specific models can be consistently estimated separately, treating $\mathbf{x}_{it}^*$ as weakly exogenous (or long-run forcing), which is compatible with a certain degree of weak dependence across $\mathbf{u}_{it}$.[2] The country-specific foreign variables $\mathbf{x}_{it}^*$ are constructed as country-specific trade-weighted averages over the values of the other countries

$$\mathbf{x}_{it}^* = \sum_{j=0}^{N} w_{ij}\mathbf{x}_{jt}, \text{ with } w_{ii} = 0, \tag{2}$$

where w_{ij} is the share of country j in the trade (exports plus imports) of country i.[3]

After selecting the lag length-order p_i and q_i for each country by means of the Akaike Information Criterion (allowing for a maximum lag-order of 2), the VAR(p_i, q_i) models are estimated separately for each country, allowing for the possibility of cointegration among $\mathbf{x}_{it}$, $\mathbf{x}_{it}^*$ and $\mathbf{d}_t$.

Once the individual country models are estimated, all the $k = \sum_{i=0}^{N} k_i$ endogenous variables of the global economy, collected in the $k \times 1$ vector $\mathbf{x}_t = (\mathbf{x}'_{0t}, \mathbf{x}'_{1t}, ..., \mathbf{x}'_{Nt})'$, are solved simultaneously. To do this (1) can be written as

$$\mathbf{A}_i(L, p_i, q_i)\mathbf{z}_{it} = \boldsymbol{\varphi}_{it}, \text{ for } i = 0, 1, 2, ..., N \tag{3}$$

[2] For further details see Dees et al. (2007).

[3] See Appendix 1 for more details on the computation of the trade-based weights.

where

$$\mathbf{A}_i(L,p_i,q_i) = [\mathbf{\Phi}_i(L,p_i), \ -\mathbf{\Lambda}_i(L,q_i)], \ \mathbf{z}_{it} = \begin{pmatrix} \mathbf{x}_{it} \\ \mathbf{x}^*_{it} \end{pmatrix},$$

$$\boldsymbol{\varphi}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \Upsilon_i(L,q_i)\,\mathbf{d}_t + \mathbf{u}_{it}.$$

Let $p = \max(p_0, p_1, ..., p_N, q_0, q_1, ..., q_N)$ and construct $\mathbf{A}_i(L,p)$ from $\mathbf{A}_i(L,p_i,q_i)$ by augmenting the $p - p_i$ or $p - q_i$ additional terms in powers of L by zeros. Also note that

$$\mathbf{z}_{it} = \mathbf{W}_i\mathbf{x}_t, \quad i = 0, 1, 2, ..., N, \tag{4}$$

where $\mathbf{W}_i$ is a $(k_i + k_i^*) \times k$ matrix, defined by the country specific weights, w_{ji}.

With the above notations (3) can be written equivalently as

$$\mathbf{A}_i(L,p)\mathbf{W}_i\mathbf{x}_t = \boldsymbol{\varphi}_{it}, \ i = 0, 1, ..., N,$$

and then stack to yield the VAR(p) model in $\mathbf{x}_t$:

$$\mathbf{G}(L,p)\,\mathbf{x}_t = \boldsymbol{\varphi}_t, \tag{5}$$

where

$$\mathbf{G}(L,p) = \begin{pmatrix} \mathbf{A}_0(L,p)\mathbf{W}_0 \\ \mathbf{A}_1(L,p)\mathbf{W}_1 \\ \vdots \\ \mathbf{A}_N(L,p)\mathbf{W}_N \end{pmatrix}, \ \boldsymbol{\varphi}_t = \begin{pmatrix} \boldsymbol{\varphi}_{0t} \\ \boldsymbol{\varphi}_{1t} \\ \vdots \\ \boldsymbol{\varphi}_{Nt} \end{pmatrix}. \tag{6}$$

The GVAR(p) model (5) can be solved recursively and used for generalised forecast error variance decomposition or generalised impulse response analysis in the usual manner.

2.2 A GVAR model with credit and asset price variables

The version of the GVAR model developed in this paper covers 38 countries, which are modeled individually (see Table 7 in Appendix).

The models are estimated on quarterly data over the period 1987Q1-2013Q1. The variables included in the current version of the GVAR differ from those considered by Dees et al. (2007). In order to capture more fully the effect of the financial cycle, two additional financial variables are added: credit to the private nonfinancial sector in real terms (cr_{it}) and real property prices (hp_{it}), for country i during the period t. However, given the data limitations and problems associated with compiling comparable credit and housing market measures, these variables are only included for the individual euro area countries, Sweden, the UK and the US. Real equity prices (q_{it}), when available, are also included in the model. Together with real house prices, these two variables capture asset price fluctuations in the global economy. Other variables included are real output (y_{it}), consumer prices (p_{it}), real interest rates (r_{it}), and the real exchange rate ($e_{it} - p_{it}$).

The data used come from the most recent GVAR database (2013 vintage), available on the Global VAR Modelling website[4]. Data on house prices come from a confidential ECB database that compiles residential property price data for EU countries and the US from a range of public and private sources. Data on credit corresponds to total credit and domestic bank credit to the private nonfinancial sector from the BIS.

The country-specific foreign variables, $y^*_{it}, p^*_{it}, q^*_{it}, r^*_{it}, cr^*_{it}$, are constructed using trade weights. Given that housing markets are influenced by country-specific factors, housing-related foreign variable is not included in the country-specific models. Fixed trade weights, based on the average trade flows over the

[4] https://sites.google.com/site/gvarmodelling/data

three last year of our sample, are used to compute the matrix $\mathbf{W}_i$.[5]

With the exception of the US model, all models include the country-specific foreign variables, $y^*_{it}, p^*_{it}, q^*_{it}, r^*_{it}, cr^*_{it}$ and the log of oil prices (p^o_t), as weakly exogenous in the sense discussed above. In the case of the US model, oil prices are included as an endogenous variable, with $e^*_{US,t} - p^*_{US,t}$, $y^*_{US,t}$, and $p^*_{US,t}$ as weakly exogenous. Given the importance of the US financial variables in the global economy, the US-specific foreign financial variables, $q^*_{US,t}$, $\rho^{*S}_{US,t}$ and $cr^*_{US,t}$, are not included in the US model as they are unlikely to be long-run forcing with respect to the U.S. domestic financial variables. The US-specific foreign output and inflation variables, $y^*_{US,t}$ and $p^*_{US,t}$, are, however, included in the US model in order to capture the possible second round effects of external shocks on the U.S. Table 1 summarises the GVAR model specifications and the differences between the US and all the other models.

[5] Allowing for time-varying trade weights or using any other weighting scheme (e.g. using financial weights) is straightforward and could also been considered as a robustness check. However, previous research show that GVAR results are generally robust to various weighting schemes, except for the transmission of China-related shocks (see Dees et al., 2007 or Cesa-Bianchi et al., 2012).

Table 1: GVAR Model specification

US model		All other models	
Domestic	Foreign	Domestic	Foreign
$y_{US,t}$	$y^*_{US,t}$	y_{it}	y^*_{it}
$p_{US,t}$	$p^*_{US,t}$	p_{it}	p^*_{it}
$q_{US,t}$		q_{it}	q^*_{it}
$r_{US,t}$		r_{it}	r^*_{it}
$cr_{US,t}$		cr_{it}	cr^*_{it}
$hp_{US,t}$		hp_{it}	
	$e^*_{US,t} - p^*_{US,t}$	$e_{it} - p_{it}$	
p^o_t			p^o_t

3 The role of financial variables in real economic developments

In the GVAR, international linkages are taken into account through three distinct, but interrelated channels: (1) direct dependence of $\mathbf{x}_{it}$ on the vector of foreign variables $\mathbf{x}^*_{it}$; (2) dependence of $\mathbf{x}_{it}$ on common global exogenous variables $\mathbf{d}_t$ (in our case, only oil prices); and (3) non-zero contemporaneous dependence of shocks in country i on the shock in country j, as measured by the cross country covariances, Ω_{ij}.

3.1 Estimation and dynamic properties of the model

3.1.1 Estimation

While the GVAR modelling approach can be applied to stationary and/or integrated variables, we assume that the variables included in the country-specific models are integrated of order one, which allows us to distinguish between short-run and long-run relations. The long-run relations can be interpreted as cointegrating. Various unit root tests are performed and, except for very few cases, all variables can be considered as $I(1)$. It is worth noting that, unlike Dees et al. (2007), the start of our sample enables to model prices in levels. Modelling prices in levels has the advantage that a shock will not have permanent effects on inflation.

Once the variables to be included in the different country models are selected, the number of cointegrating relationships is determined and the cointegrating VAR models are estimated. The order of the individual country VARX* is selected according to the Akaike information criterion. However, due to data limitations, the lag order of the foreign variables is set equal to one in all countries. For the same reason, the lag order of the domestic variablesare not allowed to be greater than two. The orders of the VARX* models, the number of cointegration relationships for selected countries are given in Table 2. For most countries a VARX*(2,1) specification is selected. As regards the number of cointegrating relationships, we find betwen 1 (only for emerging economies) and 4 (notably for Austria, Germany, the Netherlands, Spain and the UK). For the US, we find 3 cointegrating relationships. Once the cointegration analysis performed, the error-correction forms of the individual country equations given by (1) are derived.[6]

The estimations and tests of the individual VARX* models are also conducted under the assumption that the country-specific foreign variables are weakly exogenous. Table 3 presents the results of exogeneity tests for the euro area countries, the UK and the US. Following the approach described in Dees et al. (2007), these results show that the weak exogeneity assumptions are rejected only for prices and short-term interest rates in the model for Belgium.

[6] The cointegration results are based on the trace statistic (at the 95% critical value level).

This result can be neglected given that the weak exogeneity of foreign variables and oil prices are not rejected in the models of the largest euro area countries. The same applies to the foreign variables $(y^*_{US}, \Delta p^*_{US}, e^*_{US} - p^*_{US})$ included in the U.S. model. As expected foreign real equity prices, foreign interest rate and foreign credit cannot be considered as weakly exogenous and have thus not been included in the US model.

Table 2: VARX* order and number of cointegrating relationships in selected country-specific models

Country	VARX*(p_i, q_i)		Number of cointegrating
	p_i	q_i	relationships
Austria	2	1	4
Belgium	1	1	2
Finland	2	1	3
France	2	1	3
Germany	2	1	4
Italy	2	1	3
Netherlands	2	1	4
Spain	2	1	4
UK	2	1	4
US	2	1	3

Table 3: F Statistics for testing the weak exogeneity of the country-specific foreign variables and oil Prices

		Foreign Variables						
Country		y^*	p^*	q^*	r^*	cr^*	p^o	e^*-p^*
Austria	F(4 , 77)	1.83	0.63	0.86	0.59	1.72	1.77	-
Belgium	F(2 , 86)	0.38	$3.87^\dagger$	2.82	$3.58^\dagger$	2.36	0.05	-
Finland	F(3 , 78)	1.03	0.82	2.53	0.40	0.20	0.70	-
France	F(3 , 78)	0.45	0.81	1.86	0.07	1.23	1.16	-
Germany	F(4 , 77)	0.70	0.75	0.40	1.68	1.61	1.14	-
Italy	F(3 , 78)	0.89	1.39	0.87	0.18	0.60	0.07	-
Netherland	F(4 , 77)	0.33	0.82	1.92	0.73	2.07	0.61	-
Spain	F(4 , 77)	0.91	0.42	1.09	1.34	1.29	0.36	-
UK	F(4 , 77)	0.46	0.42	0.35	0.37	1.75	1.82	-
US	F(3 , 81)	0.59	0.19	-	-	-	-	0.19

Note: † denotes statistical significance at the 5% level.

3.1.2 Stability and dynamic properties of the GVAR model

The stability of the model is also checked by first considering the effects of system-wide shocks on the exactly identified cointegrating vectors using persistence profiles developed by Pesaran and Shin (1996). On impact, the persistence profiles (PPs) are normalized to take the value of unity, but the rate at which they converge to zero gives information on the speed needed for returning to equilibrium following a shock. Although the PPs can overshoot initially (exceeding temporarilly unity), they must tend to zero in the case the vector under consideration is cointegrated. To assess the role of the inclusion of credit and house price variables in the dynamic properties of our model, Figure 2 compares some selected PPs from a re-estimated version of the model by Dees et al. (2007), where no credit and house price variables are included – left panel – with those resulting from the current paper's specification – right panel. The comparison shows that the speed of convergence is much slower when credit and house price variables are included in the model, which shows the longer persistence of the impacts of shocks once variables related to the financial cycle are included in the model.

The stability of the model is then assessed by looking at the eigenvalues of the GVAR model, which are 324 in total.[7] From the individual country models, we do not expect the rank of the cointegrating matrix in the global model to exceed 77 (namely the number of cointegrating relations in all the individual country models). Hence, the global system should have at least 77 eigenvalues (i.e. $162 - 85$), that fall on the unit circle. The GVAR satisfies these properties and indeed has 77 eigenvalues equal to unity, with the remaining 247 eigenvalues having moduli all less than unity. However, while in the model by Dees et al. (2007), the three largest eigenvalues (in moduli) after the unit roots are .907, .884 and .879, implying a reasonable rate of convergence of the model after a shock to its long-run equilibrium, the three largest in the present model are .982, .962 and .951, which implies in this case a slower convergence to the model equilibrium after a shock.[8]

[7] The GVAR contains 162 endogenous variables with a maximum lag order of 2, which give rise to a companion VAR(1) model in 324 variables.

[8] Of these 247 eigenvalues, 174 (87 pairs) are complex, introducing cyclical features in the impulse responses. Given the unit eigenvalues of the system, some shocks will have permanent effects on the levels of the endogenous variables.

3.2 Generalised Impulse Response Functions and model stability after the crisis

3.2.1 Generalised Impulse Response Functions (GIRFs)

The dynamic properties showed above are confirmed by the analysis of the Generalised Impulse Response Functions (GIRFs), as proposed in Koop et al. (1996) and developed further in Pesaran and Shin (1998) for vector error correcting models. The GIRF approach considers shocks to individual errors and integrates out the effects of the other shocks using the observed distribution of all the shocks. However, we cannot give any structural interpretation to the shocks as they have not been identified as e.g. in the case of Orthogonalised Impulse Responses of Sims (1980).

Here we analyse the implications of three different shocks: (a) a one standard error positive shock to euro area real credit; (b) a one standard error positive shock to global real credit; (c) a one standard error positive shock to U.S. real credit. In Section 4, we will provide structural impulse response functions of more comprehensive financial shocks through shock identification with sign restrictions. Regional shocks (here on the euro area) or global shocks are considered as innovations that might not necessary originate from a particular country, but rather common to the region or the world economy as a whole. In particular, it is possible to consider the effects of a regional or global shock to a specific variable, defined as a weighted average of variable-specific shocks across all the countries in the model (see more details in Dees et al. 2007).

As this section also aims at checking to what extent the global financial crisis has impacted the transmission of credit shocks to the macroeconomy, the model has also been estimated on a shorter sample (until 2007Q4) and each GIRF includes both the full-sample and the limited-sample responses. Figure 3 shows the GIRFs of a one standard error positive shock to real credit in the euro area on output in the euro area, the UK and the US. For the euro area, the effect is positive and significant on impact and in the first two quarters, before becoming non-significant up to the second year following the shock. The response becomes significant again the second and the sixth year, confirming the lasting impact of such shocks on the real economy. The transmission of this shock abroad is positive and significant in the UK, but not in the US. The same shock using only the pre-crisis sample does not imply large differences in the responses (see red dotted line).

We consider next the impact of a one standard error positive shock to global real credit. This shock should be able to capture changes in the credit cycle that are shared worldwide. Figure 4 shows the impact of this shock on the euro area output. As for the previous (domestic) shock, the impact is positive and significant both in the very short term and also in the medium term (up to 5 years after the shock). This global shock is positive and significant not only for the euro area output, but also for the US, although the degree of significance is less than in the euro area case. For the UK, the impact is less clear cut. As for the previous shock, the responses based on the pre-crisis sample are very close to those based on the full sample.

Finally, the GIRFs of a one standard error positive shock to US real credit are performed. Overall, these responses are less significant than for the euro area case, although they are slightly significant between the third and the fourth year following the shock on the euro area output (Figure 5) and the US output. The UK output does not seem to be significantly affected by the US credit shock. As above, pre-crisis and full samples do not yield large differences in the responses. To check this very strong result, we next consider stability tests.

3.2.2 Stability tests

The GVAR model based on the full sample could indeed face parameter stability issues. However, as country-specific models within the GVAR framework are specified conditional on foreign variables, such an issue could be alleviated somewhat, confirming the results obtained above when comparing impuse responses on two different samples. While the stability between the pre-crisis and the full samples could be surprising given the financial nature of the crisis, we could note that although univariate equations for financial variables (credit or asset prices) could be subject to breaks, they are likely to experience such breaks roughly around the same time in different economies, owing for strong spillover effects of shocks to the rest of the world (especially when they originate from a large country/region or are global in nature). This phenomenon is related to the concept of "co-breaking" introduced by Hendry and Mizon (1998). As the structure of the GVAR can accommodate co-breaking, the model is more robust to the possibility of structural breaks as compared to reduced-form single equation models.

As in Dees et al. (2007), we consider structural stability tests based on the residuals of the individual equations of the country-specific error correction models. Among the tests included in our analysis are Ploberger and Krämer's (1992) maximal OLS cumulative sum (CUSUM) statistic, denoted by $PK_{\sup}$, its mean square variant PK_{msq}, the tests for parameter constancy against non-stationary alternatives proposed by Nyblom (1989), denoted by $\mathfrak{N}$, as well as sequential Wald type tests of a one-time structural change at an unknown change point (including the Wald form of Quandt's (1960) likelihood ratio statistic (QLR), the mean Wald statistic (MW) of Hansen (1992) and the Andrews and Ploberger (1994) Wald statistic based on the exponential average (APW). The heteroskedasticity-robust version of the above tests is also presented.

Table 4 summarizes the results of the tests by variable at the 5% significance level. The critical values of the tests, computed under the null of parameter stability, are calculated using the sieve bootstrap samples obtained from the solution of the GVAR(p) model given by (5).

Table 4: Percentage of rejections of the null of parameter constancy per variable across the country-specific models at the 5 percent level

Test Stats	y	p	q	$e-p$	r	cr	hp	Nbs(%)
PK_{sup}	3.4	13.8	4.0	0.0	3.6	20.0	20.0	11(6.9)
PK_{msq}	0.0	6.9	4.0	7.1	3.6	20.0	0.0	8(5.0)
$\mathfrak{N}$	6.9	20.7	24.0	32.1	25.0	30.0	20.0	35(22.0)
robust-$\mathfrak{N}$	3.4	17.2	4.0	17.9	3.6	10.0	20.0	16(10.1)
QLR	31.0	41.4	36.0	39.3	64.3	40.0	30.0	66(41.5)
robust-QLR	6.9	17.2	0.0	25.0	25.0	20.0	40.0	27(17.0)
MW	13.8	27.6	20.0	46.4	35.7	30.0	30.0	46(28.9)
robust-MW	6.9	17.2	12.0	21.4	17.9	30.0	30.0	27(17.0)
APW	27.6	37.9	44.0	39.3	57.1	40.0	30.0	64(40.3)
robust-APW	10.3	17.2	0.0	21.4	25.0	20.0	40.0	27(17.0)

Note: The test statistics PK_{sup} and PK_{msq} are based on the cumulative sums of OLS residuals, $\mathfrak{N}$ is the Nyblom test for time-varying parameters and QLR, MW and APW are the sequential Wald statistics for a single break at an unknown change point. Statistics with the prefix robust denote the heteroskedasticity robust version of the tests. All tests are implemented at the 5% significance level.

The results vary across the tests and to a lesser extent across the variables. For example, using the PK tests (both versions) the null hypothesis of parameter stability is rejected at most 11 out of the possible maximum number of 159 cases, with the rejections higher for credit and house prices, which experienced strong movements over the recent years. This means that although the financial crisis may have changed the modelling of financial variable behaviours, the impact of financial variables on the real economy - which is at the core of our research - has remained broadly unchanged. Turning to the other three tests ($\mathfrak{N}$, QLR, and APW), the results for the robust version are in line with those of the PK tests, although the rate of rejections are now in the range 10-17% rather than the 5-7% obtained in the case of the PK tests. Once possible changes in error variances are allowed for, the parameter coefficients seem to have been reasonably stable. At least based on the available tests there is little statistical evidence with which to reject the hypothesis of coefficient stability in the case of 83% of the equations comprising the GVAR model. The non-robust versions of the $\mathfrak{N}$, QLR, and APW tests, however, show a relatively large number of rejections, particularly the latter two tests that lead to rejection of the joint null hypothesis (coefficient and error variance stability) in the case of 66 (QLR) and 64 (APW) out of the 159 cases. Although there is some evidence of structural instability, this seems to mainly concern error variances. The problem of possibly changing error variances is dealt with the use of impulse responses on the bootstrap means and confidence bounds rather than the point estimates.

3.2.3 Detailed results at the euro area county level

By disagregating the euro area into individual countries, our analysis can distinguish the impact of the shock on the various euro area countries. Figure 6 shows the reponses of individual country output to the shocks simulated above, i.e. respectively to euro area, global and US real credit. Although the responses are rather similar on impact and in the short term, the country results show large differences 2-3 years after the shock. It is interesting to note that Finland is the country where the shock has the lowest impact, while on the contrary credit shocks have sizeable effects on activity in Spain, Austria, Germany and, in the case of global and US shocks, in the Netherlands.

3.3 Generalised Forecast Error Variance Decomposition

Tables 5 and 6 show the Generalised Forecast Error Variance Decomposition of euro area and US real output in terms of their determinants accounting for more than 1%. In particular, each table shows the proportion of the forecast error variances of euro area and US real output explained by conditioning on contemporaneous and expected future values of the top variables (which are identified in terms of their relative contributions at the 12th quarterly horizon). The sums across the top determinants are also shown. Note that the sum across the total number of determinants can be greater than 100% because of the positive correlation that exists across the shocks from the various countries in the global economy.

In the case of the euro area (Table 5), the greatest proportion of real output forecast error variance at a 3 year horizon is explained by US variables (real output, equity and short-term interest rates). The domestic variables also explain altogether a large share of forecast error variance, notably financial and asset price variables (effective exchange rates, equity prices, house prices, and real credit). The contribution of oil prices is also relatively large. The presence of foreign variables among the top determinants shows the relatively high sensitiveness of the euro area economy to its international environment. Moreover, financial variables also contibute to the forecast error variance to a large extent, confirming the role of financial cycles on the business cycle. It is worth noting that the top determinants among the financial variables are related to the US economy, confirming the central role of the US in the global financial cycle.

Table 5: Forecast Error Variance Decomposition of euro area real output in terms of its top determinants together with the sum across the top variables

	Quarters						
Test Statistics	0	4	8	12	16	20	24
US GDP	4.5	14.1	20.0	21.1	21.2	21.2	20.9
US equity	3.4	14.7	13.1	12.1	11.5	11.4	11.3
US real int. rates	0.4	1.5	6.9	11.3	12.6	13.2	14.3
EA GDP	37.7	10.5	9.4	10.2	12.1	13.8	15.2
EA exch. rate	0.9	3.2	5.4	6.1	6.0	5.6	5.1
Oil prices	0.2	1.4	5.1	5.5	4.4	3.6	3.0
US house prices	0.4	1.4	2.2	3.9	5.9	7.3	8.2
US credit	0.0	0.1	0.8	2.6	3.8	4.2	4.3
EA equity	1.8	2.6	2.3	2.5	2.8	3.0	3.0
EA house prices	0.8	1.3	1.8	2.3	2.9	3.4	3.8
EA real int. rates	0.5	0.7	1.2	1.6	1.9	1.9	1.8
US prices	0.0	0.0	0.7	1.6	2.0	2.3	2.4
China GDP	3.6	0.4	0.4	1.5	2.9	4.1	5.4
EA prices	0.4	0.7	1.2	1.4	1.7	1.9	2.0
UK house prices	0.6	1.4	1.1	1.3	2.0	2.6	3.0
EA credit	1.2	0.8	1.0	1.3	1.5	1.6	1.6
Sum	56.2	54.8	72.6	86.2	95.3	101.2	105.3

Note: The results show the proportion of forecast error variances of euro area real output explained by conditioning on contemporaneous and expected future values of variables identified in terms of their relative contributions at the 12th quarterly horizon.

Contrary to the euro area case, the US real output variable explains the greatest proportion of US real output forecast error variance. Oil prices, US house prices, real equity prices and credit are also among the five main factors that help explain forecast error variance of US real output. Among the foreign variables, real output of the UK and other developed economies (ODC), that includes Canada, contribute the most together with Asian prices and Japanese interest rates. As for the euro area, financial variables contribute to a significant share to forecast error variance of output. However, in contrast to the euro area case, the financial variables are only domestic, pointing again to the central role of the US in the financial cycle movements.

Table 6: Forecast Error Variance Decomposition of US real output in terms of its top determinants together with the sum across the top variables

	Quarters						
Test Statistics	0	4	8	12	16	20	24
US GDP	77.3	54.5	52.9	54.2	55.7	56.7	57.5
Oil prices	0.1	11.1	15.3	15.3	14.1	13.1	12.3
US house prices	1.6	11.8	13.0	15.2	17.2	18.7	19.7
US equity	6.3	15.5	14.8	14.7	14.7	14.7	14.6
US credit	1.2	1.5	2.6	3.8	4.6	5.0	5.3
US real int. rates	0.2	0.3	1.5	2.4	2.7	2.9	3.3
US prices	0.1	0.9	1.6	2.0	2.1	2.2	2.2
Rest Asia prices	2.2	1.8	1.8	1.8	1.9	1.9	1.9
UK GDP	2.2	1.8	1.4	1.5	1.7	1.9	2.0
ODC GDP	1.4	1.3	1.3	1.5	1.6	1.6	1.7
Japan real int. rates	0.9	1.1	1.0	1.2	1.3	1.4	1.3
China prices	0.0	0.1	0.9	1.0	0.8	0.7	0.6
Sum	93.6	101.7	108.2	114.6	118.4	120.7	122.4

Note: The results show the proportion of forecast error variances of US real output explained by conditioning on contemporaneous and expected future values of variables identified in terms of their relative contributions at the 12th quarterly horizon.

Figure 7 shows the overall results, aggregating the contributions by type of determinants. To make the reading and the comparison easier, the sum of the contributions has been normalised to 100%. The contribution of foreign output is the largest in the case of the euro area, while the largest determinant is domestic output (own shock) in the US case. Among the financial variables, foreign equity prices contribute more to euro area forecast error variance than domestic equity prices, whereas the contrary holds for the US. Exchange rates seem to matter more for the euro area than for the US, together with foreign interest rates. House prices contribute to the forecast error variance both in the euro area and the US, although to a larger extent in the latter case. Credit contributes to a similar extent in both areas, while oil prices is a larger determinant for the US.

4 Identification of financial shocks and their impact on real economic fluctuations

The previous analysis was based on Generalised Impulse Response Functions and Generalised Forecast Error Variance Decomposition. Their computations considered shocks to individual errors and integrated out the effects of the other shocks using the observed distribution of all the shocks without any orthogonalization. The drawback of this approach is that it is difficult to give any structural interpretation of the shocks. To find evidence on the link between financial cycles and business cycles, we better identify financial shocks, notably those that create financial cycles. As it remains difficult to order variables and countries following the standard Orthogonalised Impulse Response approach, we chose here to use a sign restriction aproach. Following the seminal work by Faust (1998), Canova and De Nicoló (2002) and Uhlig (2005), the use of sign restrictions has become a popular way to identify structural shocks in the VAR literature. This approach identifies all shocks which are consistent with rather weak a priori restrictions, which could be derived for instance from economic theory. The shocks we are interested in relate to the financial cycle and can to some extent appear as credit supply shocks, as included in DSGE models with a banking sector (see Hristov et al., 2011). Eickmeier and Ng (2015) use a sign restriction approach to identify credit supply shocks in a GVAR. Their restrictions assume that after a negative credit supply shock, the volume of credit should to decline. GDP is also restricted to decline, but to a lesser extent. Moreover, 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. The shocks we would like to identify here differ to some extent from such credit supply shocks, as defined in Eickmeier and Ng (2015). First, our model does not include spreads and government bond yield. Second, we would like to link these shocks to the financial cycle, as defined by Borio (2012). The inclusion of property prices will allow us to impose restrictions on both credit development and on house price changes. In order not to impose any a priori link between the financial cycle and the real economy, we do not make any restriction on real output. A positive financial shock will then be defined as a shock that increase both real credit and real house prices. The sign restrictions on credit and house prices are imposed on the impulse response functions from impact to lag 8, in order to only select persistent shocks. The sign restriction approach used here follows Rubio-Ramirez et al. (2005).

Figure 8 reports the result of such a financial shock originating from the euro area. As expected, the shock has significant and persistent effects on credit and house prices. Although no restriction was imposed on any other variable, real output react positively to the shock. The diffusion of the shock to the real economy is gradual and persistent. The transmission of the euro area shock abroad is strong and significant for the UK variables, while it does not affect credit and house prices in the US. Trade spillovers matter nevertheless, since the impact of higher GDP in the euro area leads to positive, significant impacts on US activity.

Similarly, Figure 9 reports a financial shock originating from the US. By imposing that the shock only affects real credit and property prices in the US, we may however neglect the global nature of the US shocks. We will see this point next. When the shock is restricted to affect only US variables, both the euro area and the UK do not show significant impulse responses. The impact of the shock on the US economy is strong and persistent on house prices and start having significant effect on real output after a year, pointing to a possible lag in the transmission of financial shocks to the real economy.

Finally, to capture the global nature of financial shocks, we consider a global shock by imposing the restrictions on credit and house prices for all countries where these variables are available. Contrary to the US shock, the global shock affects significantly all variables in all countries (Figure 10). When comparing the global shock and the domestic shocks, it is interesting to note that, while the impact on credit and house prices are relatively similar in size (compare Figures 10 and 8 for both the euro area and for the US), their impact is much larger on real output, pointing to important spillover effects through other channels.

5 Concluding remarks

This paper investigates the transmission of financial shocks to the real economy, domestically and cross border, in order to assess the role of the financial cycle on the business cycle. By extending the GVAR model of Dees et al. (2007)

through the inclusion of credit and property price variables, the model shows first that such financial-cycle related variables change the dynamic properties of the model, making the responses of real variables to financial shocks more persistent. There are however strong cross-country differences in terms of responses, notably within the euro area. Second, the 2007-8 global financial crisis is shown not to lead to strong, significant changes in the model properties. The transmission of financial shocks remain similar whether we consider a sample including or excluding the crisis period. At the same time, the stability tests point however to possible changes in the reaction of financial variables to other variables. The paper also confirms the role of the US economy in the global financial cycle and shows that global financial shocks, although leading to similar responses on credit and asset prices, have stronger impacts on real variables. Finally, the paper shows that imposing restrictions on both credit and property prices in the identification of financial shocks is key to investigate the link between financial and business cycles.

Although this paper seeks to model in a global context the link between financial and business cycles, further research on this interaction are necessary, as additional features should be included in the analysis like the presence of stock variables (debt and capital stock), the use of commercial property prices[9] or the inclusion of non-linearities in the model specifications. These features remains however challenging in such a global modelling approach and are left for future research.

[9] As shown by Kan et al. (2004), commercial property market are found to be more reactive to business cycles than residential property, hence more subject to asset price bubbles.

Appendix: Countries included in the GVAR model, composition of regional groups and weighting matrix

Table 7 presents the countries included in the GVAR. The version of the GVAR model covers 33 countries. Compared to the model of Dees et al. (2007), this version treats the 8 of the 11 countries that originally joined the euro area on January 1, 1999 individually. By contrast, the 5 Latin American countries are grouped together. All the remaining countries are modeled individually. Therefore, the present GVAR model contains 29 economic areas.

Table 7: Countries and Regions in the GVAR Model

Unites States	**Euro Area**	**Latin America**
China	Germany	Brazil
Japan	France	Mexico
United Kingdom	Italy	Argentina
	Spain	Chile
Other Developed Economies	Netherlands	Peru
Canada	Belgium	
Australia	Austria	
New Zealand	Finland	
Rest of Asia	**Rest of W. Europe**	**Rest of the World**
Korea	Sweden	India
Indonesia	Switzerland	South Africa
Thailand	Norway	Turkey
Philippines		Saudi Arabia
Malaysia		
Singapore		

Table 8: Trade Weights Based on Direction of Trade Statistics

Country/ Region	U.S.	E.A.	Japan	U.K.	Rest of W. Europe Sweden	Switz.	Norway	Rest*
U.S.	0.000	0.155	0.124	0.052	0.008	0.012	0.004	0.644
E.A.	0.227	0.000	0.072	0.238	0.057	0.090	0.028	0.288
China	0.236	0.164	0.248	0.029	0.010	0.007	0.003	0.304
Japan	0.319	0.132	0.000	0.032	0.007	0.009	0.003	0.499
U.K.	0.180	0.537	0.042	0.000	0.027	0.028	0.023	0.163
Sweden	0.104	0.517	0.035	0.115	0.000	0.017	0.099	0.113
Switz.	0.113	0.670	0.039	0.066	0.015	0.000	0.004	0.094
Norway	0.090	0.449	0.030	0.181	0.132	0.008	0.000	0.109

Note: Trade weights are computed as shares of exports and imports displayed in rows by region such that a row, but not a column, sums to one.
*"Rest" gathers the remaining countries. The complete trade matrix used in the GVAR model can be obtained from the author on request. Source: Direction of Trade Statistics, IMF.

The trade shares used to construct the country-specific foreign variables (the "starred" variables) are given in the 29×29 trade-share matrix available on request. Table 8 presents the trade shares for the eight largest economies (seven countries plus the euro area), with the "Rest" category showing the trade shares for the remaining countries.

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Figures

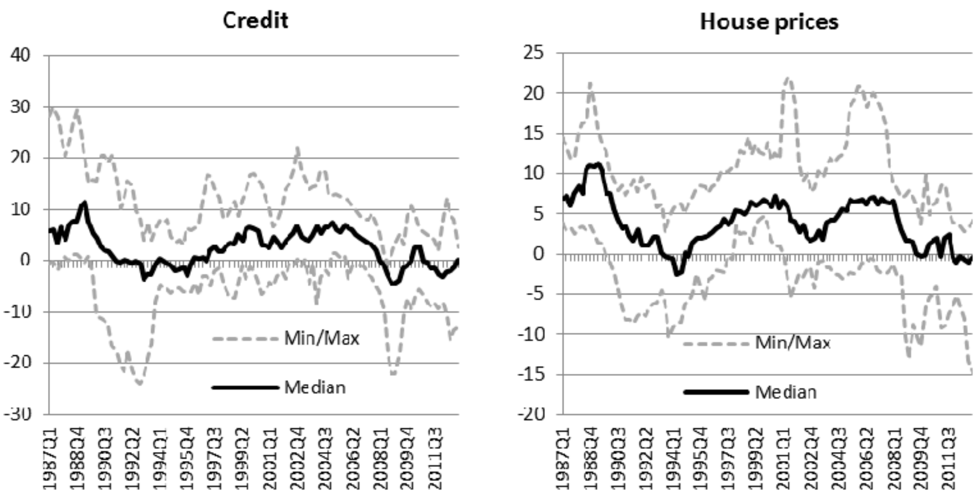


Fig. 1. Year-on-year changes in credit and house prices for a sample of 38 countries (in %)

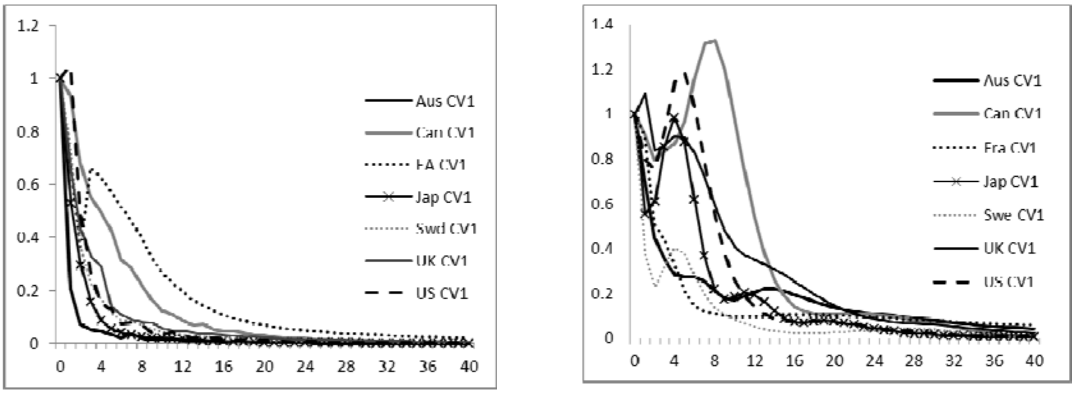


Fig. 2. Selected Persistence Profiles of the Effect of a System-wide Shock to the Cointegrating Relations - comparison between Dees et al., 2007 (re-estimated with data up to 2013) – *left panel* – and the current paper's specification – *right panel* –

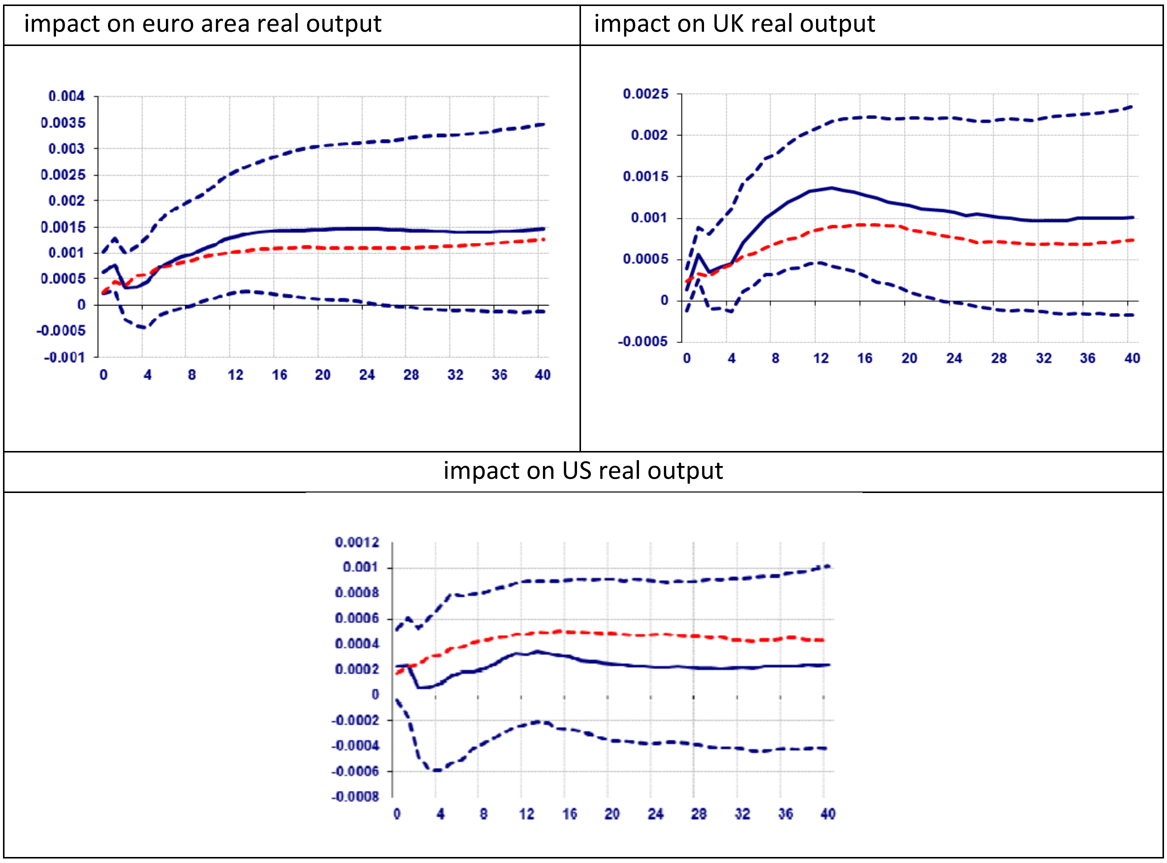


Fig. 3. GIRFs of a one standard-deviation credit shock in the euro area

Notes: Solid line: full sample; dotted lines: confidence interval; red dotted-line: pre-crisis sample.

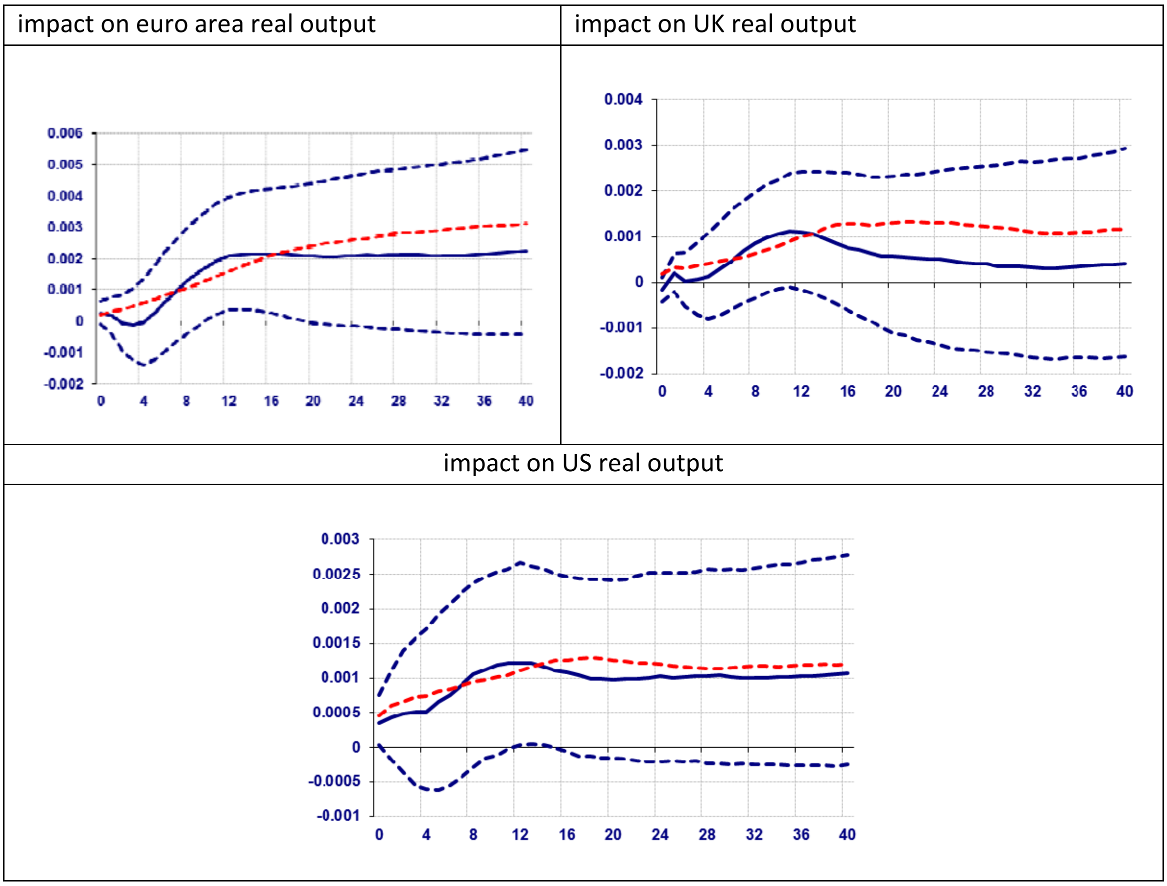
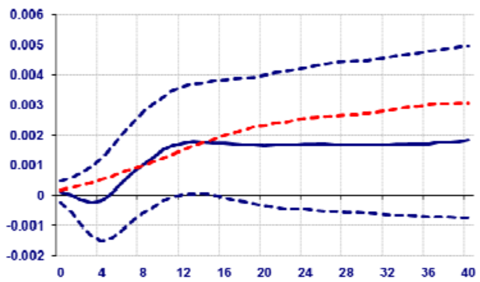


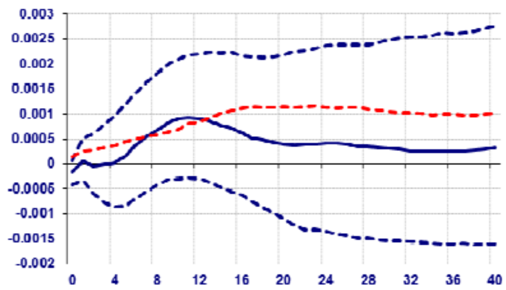
Fig. 4. GIRFs of a one standard-deviation global credit shock

Notes: Solid line: full sample; dotted lines: confidence interval; red dotted-line: pre-crisis sample.

impact on euro area real output



impact on UK real output



impact on US real output

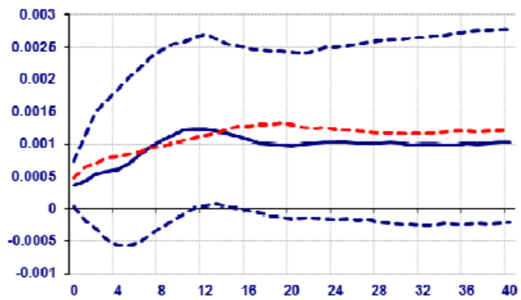


Fig.5. GIRFs of a one standard-deviation credit shock in the US

Notes: Solid line: full sample; dotted lines: confidence interval; red dotted-line: pre-crisis sample.

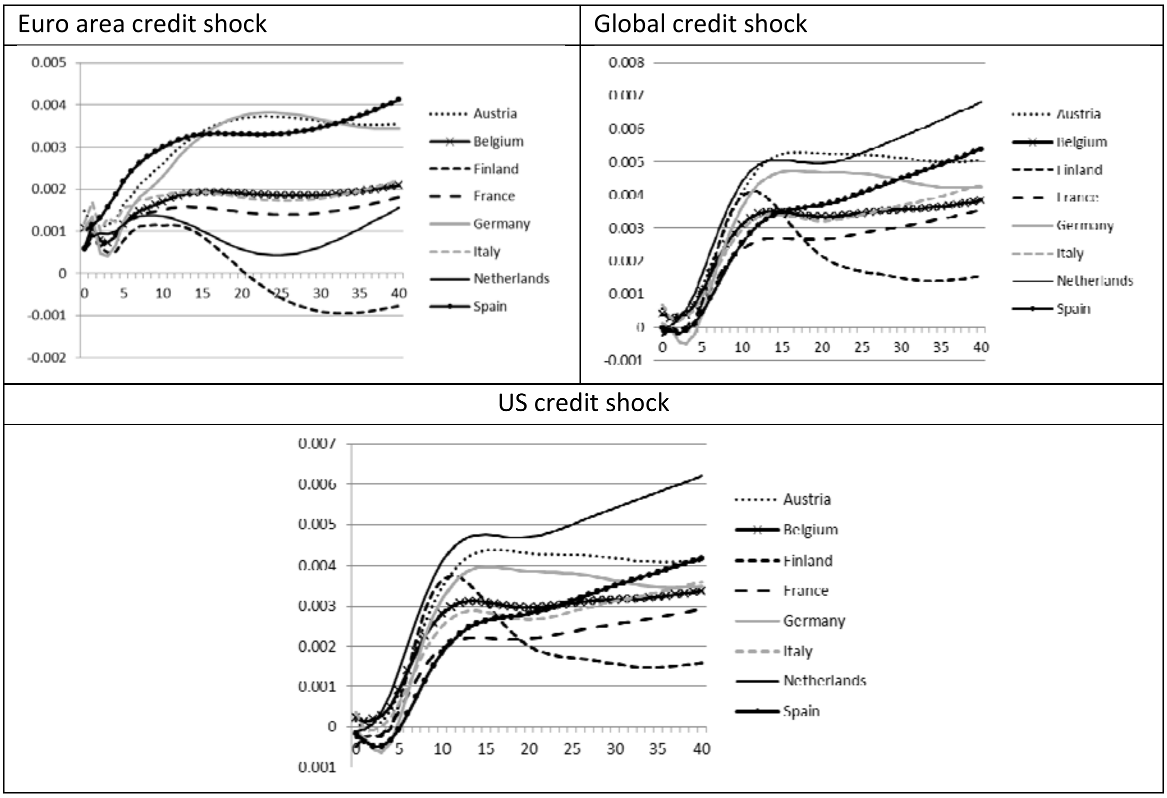
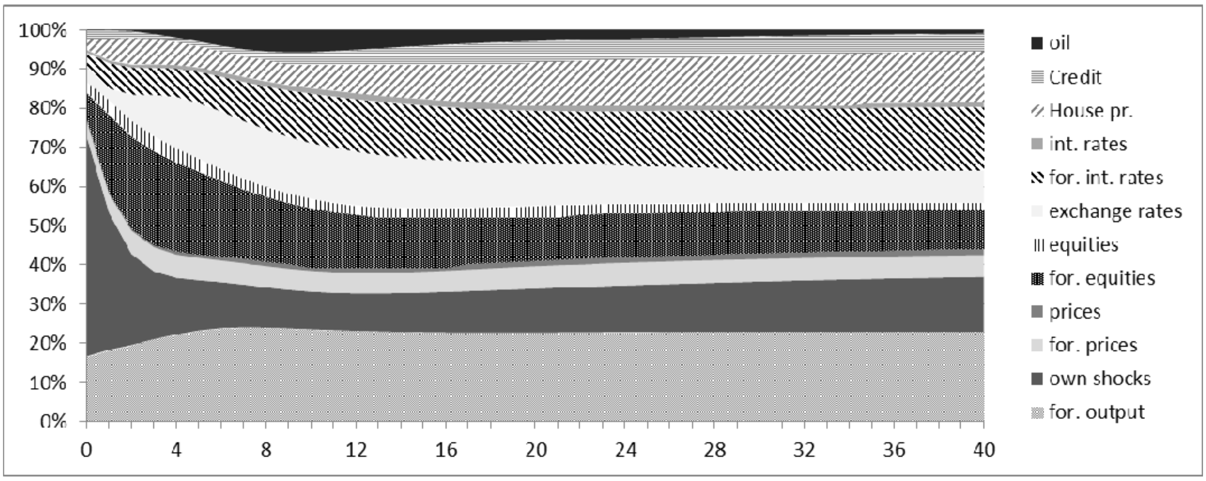


Fig. 6. Selected GIRFs on euro area countries real output

Euro area



United States

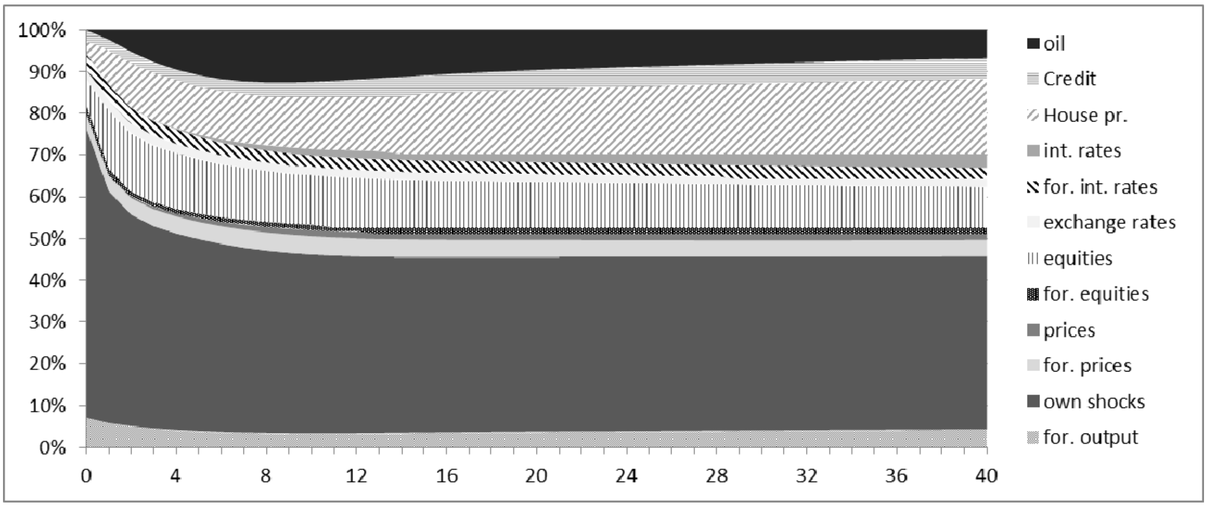


Fig. 7. Generalised Forecast Error Variance Decomposition

Note: As the sum of the contributions exceed 100%, the decomposition has been normalised to ease the reading.

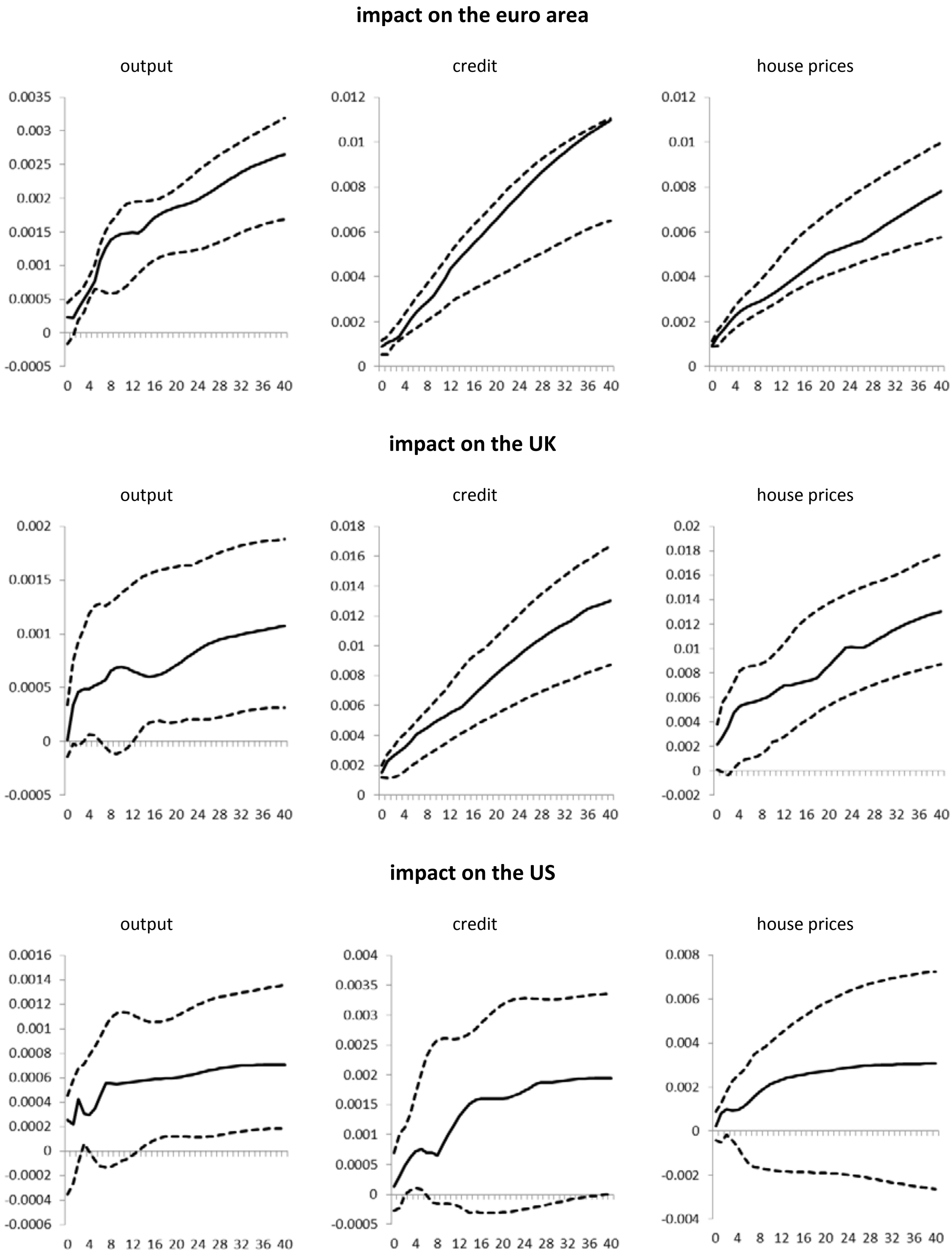


Fig. 8. Euro area financial shock – identified with sign restrictions –

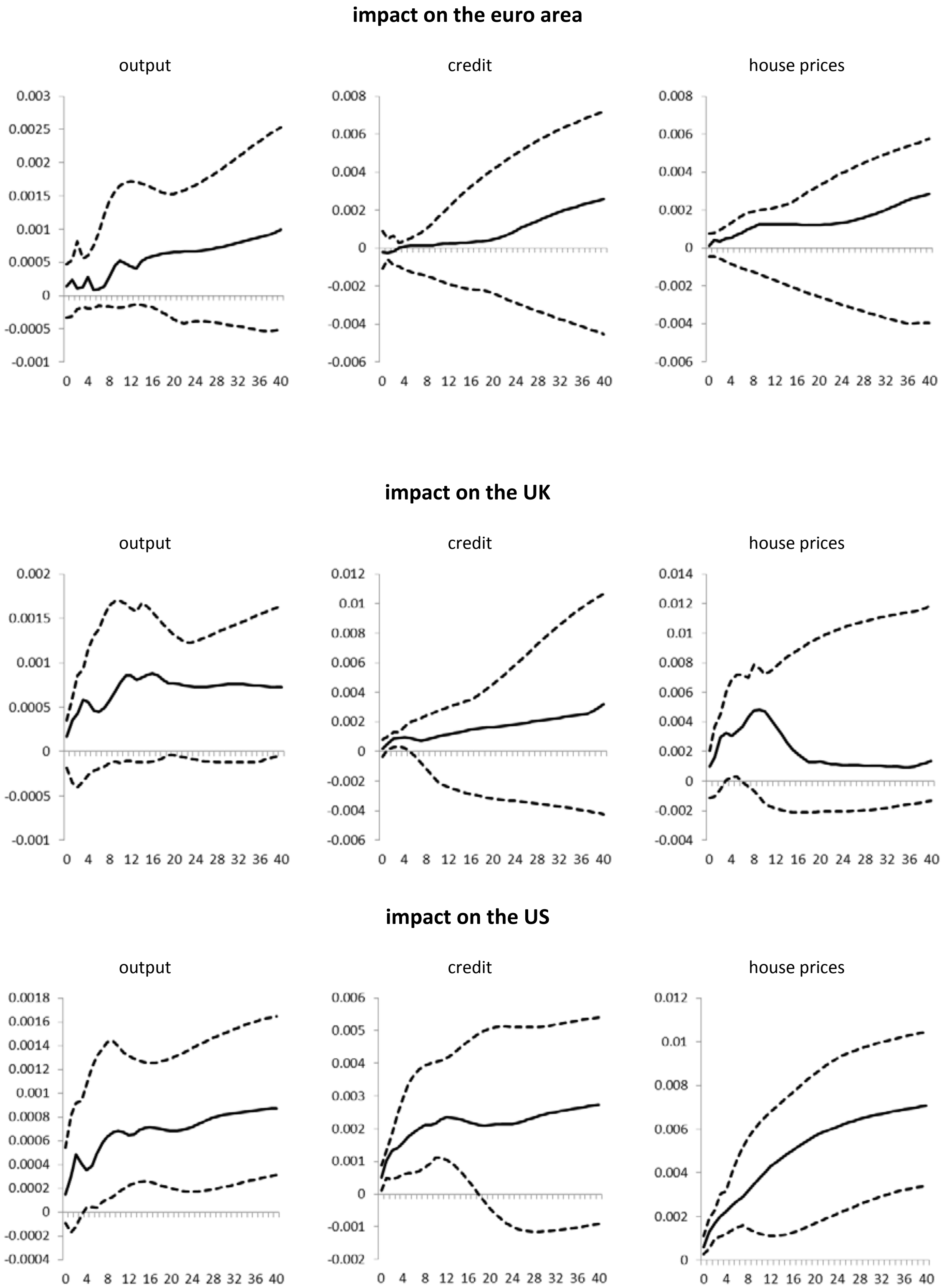


Fig. 9. US financial shock – identified with sign restrictions –

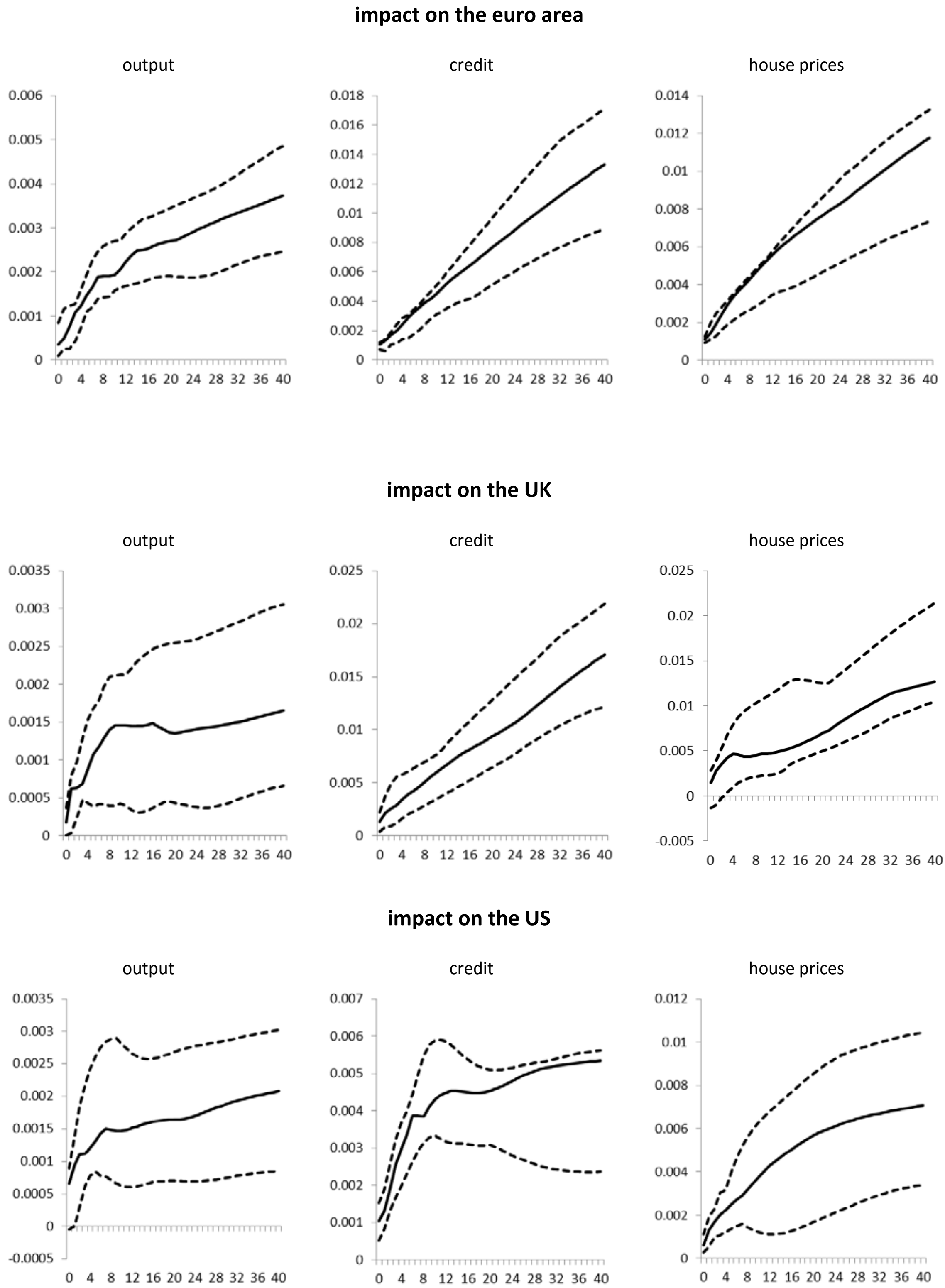


Fig. 10. Global financial shock – identified with sign restrictions –

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