The Changing International Transmission of Financial Shocks: Evidence from a Classical Time-Varying FAVAR*

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Abstract

We study the changing international transmission of US financial shocks over the period 1971-2009. Financial shocks are defined as unexpected changes of a newly developed financial conditions index (FCI) for the US. We use a time-varying factor-augmented VAR (TV-FAVAR) to model the FCI jointly with a large set of macroeconomic, financial and trade variables for nine major advanced countries. We find that expansionary US financial shocks have a considerable positive impact on growth in the countries in our dataset, and *vice versa* for negative shocks. The transmission to GDP growth in the euro-area countries and in Japan has increased gradually since the 1980s, consistent with globalization. A more marked increase is detected in the early 1980s in the US itself and the UK, consistent with structural changes in financial markets. The size of US financial shocks varies strongly over time, with the 'global financial crisis shock' being larger than any other financial shock estimated over the sample under analysis and explaining 20-60 percent of the variation in GDP growth in 2008-2009 (compared to a little more than 10 percent on average over the 1971-2007 period). A large breakdown in exports contributed to the strong worldwide propagation of US financial shocks during the crisis. Differences in the real effects across countries are related to differences in openness, banks' capitalization, the fiscal and monetary policy stance, and general overheating of the economy prior to the crisis.

JEL classification: F1, F4, F15, C3, C5

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1 Introduction

In this paper, we study the temporal evolution in the dynamic international transmission of US financial shocks. We address the following questions.

(i) How large is the impact of US financial shocks on the major advanced countries, and have their size and transmission changed over time?

(ii) Through what channels are US financial shocks internationally transmitted, and can we identify changes in the transmission mechanism over time?

(iii) How strongly were the major advanced economies affected by the global financial crisis (which had its origin in the US and is represented here as a shock to US financial conditions), also in comparison with previous episodes of financial turmoil? Which channels played a major role in the transmission over the global crisis period? What country characteristics can explain differences in the transmission across countries?

We identify US financial shocks as unexpected changes in the financial conditions index (FCI) recently published by Hatzius et al. (2010). Since this FCI is a broad index summarizing 45 different financial variables, a shock to this index needs to be interpreted as surprises to overall 'financial conditions', possibly reflecting changes in credit conditions, stock prices, interest rates, oil prices, and/or exchange rates. The use of the FCI has advantages and disadvantages. It reflects, on the one hand, the close links among financial markets in the US, as the recent financial crisis has demonstrated, and FCI shocks (or shocks to overall financial conditions) may well reflect the sources of financial crises. A second advantage is that the use of the FCI is convenient since it does not require to impose too many identifying restrictions, which would be necessary in order to disentangle more narrowly defined shocks such as 'credit shocks', 'interest rate shocks' or 'stock price shocks'. Identification of such shocks is difficult and any identifying restrictions would probably be debatable. On the other hand, interpretation of results regarding the propagation of a broad 'FCI shock' is certainly more difficult than of more narrowly defined shocks. We carefully assess the properties of the FCI below to simplify interpretation.

We use a newly compiled quarterly dataset for nine major advanced countries (the US, Canada, the UK, France, Germany, Italy, Spain, Japan and Australia). The dataset contains 200 quarterly real variables, price variables, monetary and financial market variables, and trade variables, over the sample period 1971Q1-2009Q2.

The FCI and the common factors underlying the large set of international variables are jointly modeled in a factor-augmented vector autoregressive model (FAVAR). Each of the 200 international variables is then decomposed into a common component, which depends on the FCI and the (remaining) common factors, and an idiosyncratic component, which is related to variable-specific shocks. Shocks to the FCI are dynamically transmitted to the other variables/factors, and have therefore both a direct and an indirect impact on all the international variables.

The transmission mechanism is very complex. Financial shocks that occur in the US can affect consumption and investment in the US itself, e.g. through wealth effects, changes in funding costs and financial accelerator mechanisms.[1] A decline in real activity in the US can then lead, e.g., to lower import demand and via trade to negative economic effects abroad. Direct trade linkages with the US, but also trade linkages with US trading partners can be relevant. In addition, financial shocks can spill over to other countries via financial integration. Both fundamental linkages and nonfundamental contagion effects can play a role. Fundamental linkages such as the exposures to foreign assets might either result in a better risk sharing and help buffering shocks or rather reinforce the international spillovers.[2] Nonfundamental contagion might result in highly synchronized asset prices, e.g., via investors' reassessment of the outlook of countries with similar fundamentals, confidence effects or herd behavior. Changes in financial conditions abroad would then, through the channels presented above, affect the real sides of the foreign economies. By how much foreign activity is affected finally also depends on the foreign policy reactions to US financial shocks. We believe that our setup, which allows us to include many variables that can flexibly interact with each other, permits to appropriately capture the transmission mechanism. We should, however, acknowledge that it does not allow us to cleanly disentangle the different transmission channels, but only to assess how financial, trade and other variables capturing the different transmission channels respond to US financial shocks.

Our model allows for variation in the parameters of the VAR for the FCI and the factors (including changes in the variance-covariance matrix of the shocks), and in the loadings associated with the transmission of changes in the FCI and in the factors to the

[1] Cecchetti et al. (2010) give a useful overview on the channels through which negative financial (crisis) shocks or a worsening of financial conditions is effective: Higher interest rates, higher spreads and lower equity prices increase funding costs and reduce investment. Lower asset prices lead to negative wealth effects for households with negative consequences for household spending. Tighter financial conditions reduce financial institutions' willingness to lend. Higher risk aversion drive up risk premia and leads to a flight to quality. Lower asset prices drive down firms' and households' net worth, increasing the problems of adverse selection and moral hazard for firms and worsening the creditworthiness of households making borrowing more difficult. Changes in financial conditions may also go along with exchange rate movements. A worsening may lead to a flight to 'safe haven' currencies and reversals of capital flows which affect exchange rates and have trade effects. Finally, a worsening in financial conditions may lead to falling confidence and activity.

[2] As noted, we focus here on shocks to overall financial conditions in the US and hence on shocks that affect not only one but various financial markets. Risk sharing across different assets in the US after such shocks is therefore likely to be limited. The strength of the international propagation depends also on whether the identified shocks are truly shocks that first only hit the US or only very few economies or shocks that hit many countries simultaneously. After the latter types of shocks there will hardly be risk sharing across countries, but exposure to foreign assets is, instead, likely to lead to enhance international spillovers. We will assess below how strongly the identified shocks to the US FCI affect the US in comparison to the other countries.

international variables. Notwithstanding its complexity, all the model parameters can be estimated with classical Kalman filter based methods. This TV-FAVAR specification was suggested by Eickmeier, Lemke and Marcellino (2009) and extends the constant parameter FAVAR specification introduced by Bernanke, Boivin and Eliasz (2005). Allowing parameters to change over time when studying the international propagation of shocks is important since globalization, i.e. the increased integration via trade and financial markets, may have altered the shock transmission process, and this can be accounted for by our model. Also, accounting for parameter changes due to the development of the financial sector and its relation with the real sector is crucial for the analysis of the changing transmission of financial shocks and via financial markets. Our model is finally also capable of capturing possible changes in the size of financial (and other) shocks, and modifications in the transmission under different circumstances (for example, negative and positive shocks may be transmitted in a different way; moreover, imbalances on financial and asset markets may alter the transmission mechanism).

We should mention that estimation of our classical TV-FAVAR is computationally less burdensome than alternative Bayesian procedures, such as those adopted by Liu and Mumtaz (2009) (to be overviewed below).

With respect to the existing international transmission literature, we make four main contributions. First, we focus on the international transmission of financial shocks whereas previous studies mostly looked at the international propagation of real (supply, demand or (aggregate) output) shocks[3] or monetary policy shocks.[4]. There is relatively little (recent) empirical evidence on the international transmission of financial shocks, including papers by Bagliano and Morana (2010), Helbling et al. (2010) and Galesi and Sgherri (2009). All these studies also use large models. They focus, however, on specific financial shocks (shocks to house prices, stock prices, excess liquidity and financial fragility in the case of Bagliano and Morana 2010, credit shocks in the case of Helbling et al. 2010 and stock price shocks in the case of Galesi and Sgherri 2009) while we focus on shocks to overall financial conditions.[5] Also, all models employed in these three studies are based

[3] E.g. Canova and Marrinan (1998), Artis, Osborn and Perez (2006), Artis, Galvao and Marcellino (2007), Eickmeier (2007, 2010), Dées and Saint-Guilhem (2009), Dées and Vansteenkiste (2008), Dées et al. (2007), Mumtaz and Surico (2009), Liu and Mumtaz (2009), Maier and Vasishtha (2009), Canova and Ciccarelli (2009), Karagedikli and Thorsrud (2010).

[4] E.g. Kim (2001), Neri and Nobili (2010), Canova (2005), Liu and Mumtaz (2009), Mumtaz and Surico (2009), Eickmeier (2010), Maier and Vasishtha (2009), Karagedikli and Thorsrud (2010).

[5] Based on a FAVAR Bagliano and Morana (2010) identify four types of financial/asset price (as well as output) shocks in the US and assess their transmission to 50 countries over the sample 1980-2009. Helbling et al. (2010) fit a VAR to global factors extracted from panels of the G7 countries' output, inflation, productivity, interest rates, credit and credit spreads and examine the transmission of global and US credit shocks between 1988 and 2009. Galesi and Sgherri (2009) investigate the transmission of US equity price shocks to Europe (and look at results for five country groups including the euro area) between

on constant parameters.

This leads over to our second contribution. As noted, we use a fully time-varying model which allows us to assess to what extent there are changes in the size of US financial shocks and their transmission to the common international factors and, via them, to the entire set of variables. Our model permits very general patterns of parameter time variation. In this respect, our analysis is most closely related to Liu and Mumtaz (2009). This study, which analyzes the transmission of world (demand, supply and monetary) shocks to the United Kingdom, allows variances and covariances of the common shocks as well as factor loadings to vary over time. However, the VAR coefficients are kept constant unlike in our approach where these may change as well.[6]

Third, we look at the transmission not only via the traditional trade channel, but also via variables capturing financial and asset markets such as house prices, stock prices, credit, money and bond market interest rates. These different markets interact as shown, e.g., by Ehrmann et al. (2010), and this is allowed for in our setup.

Fourth, we analyze to what extent US financial shocks were transmitted to the nine countries over the global financial crisis years 2008-2009 and relate the impulse responses of GDP and its main components to FCI shocks to country characteristics in order to explain differences across countries. There is a growing recent empirical literature on why some countries experienced more negative growth than others during the global financial crisis (Rose and Spiegel 2010a, 2010b, 2010c, Frankel and Saravelos 2010, Giannone et al. 2010, Claessens et al. 2010, Lane and Milesi-Ferretti 2010). Based on cross-country regressions, these studies consider a wide range of possible determinants such as overall (trade and financial) openness, bilateral linkages with the US, macroeconomic and financial vulnerabilities, financial sector development, regulation as well as fiscal positions and the monetary policy stance prior to the crisis. Conclusions, however, widely vary as we will point out below. We contribute to this literature.

The main results we obtain can be summarized as follows. Expansionary US financial shocks have a considerable positive impact on growth in the countries in our dataset, and *vice versa* for negative shocks. The transmission to GDP growth in the euro-area countries and in Japan has increased gradually since the 1980s, consistent with globalization. A more marked increase is detected in the early 1980s in the US and the UK, consistent with structural changes in financial markets in this period. The size of US financial shocks

1999 and 2008 based on a Global VAR.

[6] Our paper is also closely related to Dées and Saint-Guilhem (2009) and Del Negro and Otrok (2006). The former paper assesses the changing transmission of US GDP shocks to the euro area, Japan, Canada and other major regions of the world based on a Global VAR estimated over 10-year rolling windows. The latter paper looks at the comovement between advanced economies' GDPs using a Bayesian approach where factor dynamics and the volatility of the idiosyncratic components vary over time, but loadings and the factor innovation volatility are kept constant over time.

also varies strongly over time, with the 'global financial crisis shock' being larger than any other financial shock estimated over the sample under analysis and explaining 20-60 percent of the variation in GDP growth during the crisis period (compared to a little more than 10 percent on average over the 1971-2007 period). We find that an exceptionally strong breakdown in exports (which was most pronounced in Japan, Germany, France and Italy) contributed to the strong worldwide propagation of US financial shocks during the crisis. House prices also have very strongly declined in all countries but Germany and Italy by historical standards in response to an adverse financial shock which may have contributed to exceptionally strong declines in consumption and investment in these countries during the crisis. Differences in the real effects across countries of the 'global financial crisis shock' are related to differences in openness, the degree of capitalization of the banking sector, the fiscal and monetary policy stance, and general overheating of the economy prior to the crisis.

The rest of the paper is structured as follows. The methodology is explained in Section 2. Section 3 describes the US FCI and the large international dataset. Section 4 studies the transmission of the FCI shock to GDP growth in the US and in the other countries in our panel, and its evolution over time. Section 5 explains the detected pattern of time variation in the consequences of the FCI shock on growth, and pins down the main transmission channels. Section 6 relates the transmission of US FCI shocks over the 2008-2009 period to pre-crisis country features, to explain why the global financial crisis affected some countries more than others. Finally, Section 7 summarizes the key results and concludes.

2 Methodology

The analysis departs from an N-dimensional vector X_t, which includes a large number of economic and financial variables for the nine countries under investigation, and is modeled with the aid of a time-invariant approximate dynamic factor model (Bai and Ng 2002, Stock and Watson 2002):

$$X_t = \Lambda' F_t + e_t \tag{2.1}$$

In equation (2.1), $F_t = (f_{1t}, \ldots, f_{rt})'$ and $e_t = (e_{1t}, \ldots, e_{Nt})'$ denote, respectively, a vector of common factors that have a major effect on all international variables and may thus be regarded as the main drivers of the international economies, and a vector of variable-specific (or idiosyncratic) components. F_t may contain dynamic factors and their lags. To that extent, equation (2.1) is non-restrictive. For the matrix of factor loadings $\Lambda = (\lambda_1, \ldots, \lambda_N)$, the number of common factors is generally well short of the number of variables contained in the dataset, i.e. $r << N$. Common and variable-specific components are orthogonal. The common factors are also assumed to be orthogonal to each other, and the variable-specific components can be weakly correlated with one another

and also serially correlated in the sense of Chamberlain and Rothschild (1983).

It is assumed that the dynamics of the factors can be described using a VAR(p) model:

$$F_t = B_1 F_{t-1} + \ldots + B_p F_{t-p} + w_t, \quad E(w_t) = 0,\ E(w_t w_t') = W. \tag{2.2}$$

Since the elements of X_t are assumed to be a zero-mean processes (and the respective data are demeaned), equations(2.1) and (2.2) do not contain intercepts.

Following Bernanke et al. (2005) we break down the r-dimensional vector of factors F_t into an M-dimensional vector of observed factors G_t and an $r - M$-dimensional vector of unobserved (or latent) factors H_t, i.e. $F_t = (G_t', H_t')'$. Let $G_t \equiv fci_t^{US}$ (and $M = 1$) where fci_t^{US} denotes the US FCI published by Hatzius et al. (2010). This FCI is an aggregate of 45 financial/asset variables. We provide a detailed explanation of how the FCI is constructed and of the underlying series in the next section. By including the FCI, we will be able to identify US financial shocks (or shocks to US financial conditions). The 'residual' common factors H_t consist of the other factors which drive our nine countries. These are most likely other global shocks or shocks that occur in one country (most likely in the US) and that spill over to all other countries.

The model we have described so far can be estimated in five steps. The first step is to determine the dimension of F_t , i.e. the number r of common (latent and observed) factors driving our large dataset. We set $r = 10$ as suggested by the PC_{p2} criterion of Bai and Ng (2002). Other criteria which are often used in practice (the IC_{p1} and IC_{p2}) suggest a relatively small number of factors (5 and 6 for the entire sample period). However, since the space spanned by the factors is estimated consistently when the number of factors is overestimated but not when it is underestimated (Stock and Watson 1998), we prefer to carry out the following analysis with 10 factors. These explain a considerable fraction - 55 percent - of the variation in X_t over the entire sample period.

In the second step, we estimate H_t by removing the observed factors from the space spanned by the r factors as follows. We extract the first r principal components from X_t and summarize them in $\hat{F}_t$. Next, we estimate a regression of the form $G_t = \gamma' \hat{F}_t + v_t$. H_t is then estimated as $\hat{H}_t = \hat{\gamma}_\perp^{'} \hat{F}_t$ where the $r \times (r - M)$ matrix $\hat{\gamma}_\perp$ denotes an orthogonal complement such that $\hat{\gamma}_\perp^{'} \hat{\gamma} = 0$. The matrix of factor loadings Λ is estimated by an OLS regression of X_t on $(G_t', \hat{H}_t')'$. We should note that this very easy and fast way of cleaning the factor space from the observed factor(s) yields latent factors which are mutually orthogonal and orthogonal to the observable factor(s).[7]

[7] We have, alternatively, assumed random walk processes for the elements of γ' when cleaning the latent from the observed factor(s). We have then re-estimated H_t based on an orthogonal complement of $\hat{\gamma}_t'$ for each t. These estimates are very similar to the constant parameter estimates of H_t. The trace R^2 of a regression of $\hat{H}_t$ when based on the time-varying cleaning on the constant counterpart is very high (0.94). Factors are not orthogonal anymore, but they are still only weakly correlated. Most (absolute) correlation coefficients are smaller than 0.05, and the largest (absolute) correlation is at 0.3. To preserve mutually

In the third step, we model the dynamics of $F_t = (G_t', \hat{H}_t')'$ with the aid of a VAR(1) model.

In a fourth step, we identify the US financial shocks by applying a Cholesky decomposition to the covariance matrix of the reduced-form VAR residuals where the FCI is ordered above the international factors. Using this identification scheme, we are as flexible as possible allowing all international factors/variables to react immediately to US financial shocks.

To assess robustness with respect to the identification scheme, we have repeated the analysis including in the VAR four US variables, i.e. GDP growth, GDP deflator inflation, the Federal Funds rate and the FCI, together with factors extracted from our dataset from which we have previously excluded US variables. The four US variables are modeled in the robustness analysis as block exogenous to the international latent factors, and for the identification we order the FCI below the other US observables but above the international factors. Otherwise we pursue as for our baseline. This alternative specification implies that FCI shocks are separated from other US macroeconomic shocks in a perhaps clearer manner than in our baseline model. The advantage of our baseline compared to this alternative specification obviously is that the US is modeled in the same way as the other countries, using as many variables for the US as for other countries (and being able to investigate the reactions of all these variables) and allowing for flexible interaction between US and other countries' variables. As we will show below, results from the two specifications are very similar, which is reassuring.

In order to trace possible changes in the way the US FCI shock effects the variables of interest in the various countries, we modify the baseline FAVAR model in (2.1) - (2.2) by allowing for time variation in the parameters. To introduce the approach, we first note that the VAR equation (2.2) can be represented as

$$PF_t = \mathcal{K}_1 F_{t-1} + \ldots \mathcal{K}_p F_{t-p} + u_t, \quad E(u_t) = 0, \; E(u_t u_t') = S, \tag{2.3}$$

where P is lower-triangular with ones on the main diagonal, and S is a diagonal matrix. The relation to the reduced-form parameters in (2.2) is $B_i = P^{-1}\mathcal{K}_i$ and $W = P^{-1}SP^{-1\prime}$.

We relax the assumption of parameter constancy in four dimensions by allowing for time variation in: (i) the autoregressive dynamics of the factors $(\mathcal{K}_1, \ldots, \mathcal{K}_p)$, (ii) the contemporaneous relations captured by the matrix P , (iii) the variances of factor innovations, i.e., the elements of S in (2.3), and (iv) the factor loadings in (2.1). Thus, we consider the following time-varying version of the single equations of (2.1),

$$x_{i,t} = \Lambda_{i,t}' F_t + e_{i,t}, \quad i = 1, \ldots, N \tag{2.4}$$

uncorrelated factors and given that the latent factor estimates are very similar in both cases, we stick in the remainder of the paper to the (faster) constant parameter approach.

and the VAR (2.3),

$$P_t F_t = \mathcal{K}_{1,t} F_{t-1} + \ldots + \mathcal{K}_{p,t} F_{t-p} + u_t, \quad E(u_t) = 0,\ E(u_t u_t') = S_t, \tag{2.5}$$

where again P_t is lower-triangular with ones on the main diagonal, and S_t is diagonal. In addition, we specify the idiosyncratic components in (2.4) to follow a first-order autoregressive process:

$$e_{i,t} = \rho_i e_{i,t-1} + \xi_{i,t}, \quad E(\xi_{i,t}) = 0,\ E(\xi_{i,t}^2) = \sigma_i^2, \quad i = 1, \ldots, N \tag{2.6}$$

The elements of $\xi_t \equiv (\xi_{1,t}, \ldots, \xi_{N,t})'$ are assumed to be contemporaneously uncorrelated.

Let the time-varying parameters $\{P_t, \mathcal{K}_{1,t}, \ldots, \mathcal{K}_{p,t}, \Lambda_{1,t}, \ldots, \Lambda_{N,t}\}$ be collected in a vector α_t. Note that the dimension of this vector is $r \cdot (r-1) \cdot 0.5 + p \cdot r^2 + N \cdot r$, which can be fairly large. As is common in time-varying parameter regression models, see e.g. Nyblom (1989), we assume the parameters to vary slowly over time, as independent random walks

$$\alpha_t = \alpha_{t-1} + \epsilon_t, \quad \epsilon_t \sim N(0, Q), \tag{2.7}$$

where Q is a diagonal matrix. Finally, all elements of (ξ_t, u_t, ϵ_t) are assumed to be uncorrelated contemporaneously and over time.

We estimate the VAR and the factor loading relations equation by equation. As discussed in Eickmeier et al. (2009), this is possible as each of these equations with time-varying parameters can be cast into a linear Gaussian state space model. The crucial point is how to model time-variation in factor innovation volatility: if it were assumed to be governed by another latent process, say q_t, such that e.g. $S_{t,gg} = \exp(q_t)$ and $q_t = a_i + \phi_i q_{t-1} + \zeta_{i,t}$, this would make the model nonlinear in the state vector, preventing estimation based on linear Gaussian state space models. To circumvent such problems, while at the same time allowing for different sizes of shocks over time, we assume that the variance of each structural shock is a linear function of three contemporaneous observed factors: realized US stock market volatility based on daily data, the realized volatility of the BAA spread based on daily data, and the dispersion of GDP forecasts across forecasters. Following Adrian and Rosenberg (2005) we apply an HP filter to the volatility measures and ultimately use the HP trends.[8] The forecast dispersion is computed as the standard deviation of 6-months ahead forecasts of GDP across individual forecasters (published in the Livingston survey and provided on the Fed of Philadelphia's website). Hence, the volatility specification of the structural shock in the gth equation has the form

$$S_{t,gg} = c_g + b_g' Z_t, \tag{2.8}$$

where the scalar c_g and the vector b_g are equation-specific, and Z_t contains the three described observed volatility measures. Obviously, the specification nests the homoscedastic case, that would arise from $b_g = 0$.

[8] Results are very similar if we use unsmoothed versions of the volatility measures.

The elements of F_t are estimated as in the case of the constant-parameter version. We then treat them as observable and estimate the time-varying-parameter factor VAR and the loading equations. Note that, as argued by Stock and Watson (2002, 2008), the factors are still estimated consistently even if there is some time variation in the loading parameters.[9] The intuition underlying this result is that factor estimates at time t are weighted averages of the N x_i variables at time t only.

Regarding the cross-sectional relations, we put each of the N equations (2.4) into state space form. For the ith equation the state vector is $\tilde{\alpha}_t^{(i)} = (\Lambda_{it}', e_{it})'$. Because the idiosyncratic component in (2.4) follows an AR(1) process, rather than being white noise, it becomes part of the state vector besides the time-varying loading parameters. The transition equation is given by

$$\tilde{\alpha}_t^{(i)} = \Phi_i \tilde{\alpha}_{t-1}^{(i)} + \tilde{\epsilon}_t^{(i)},$$

where $\Phi_i = \text{diag}(1_r, \rho_i)$, $\tilde{\epsilon}_t^{(i)} = (\epsilon_t^{(i)}, \xi_{it})$, where $\epsilon_t^{(i)}$ are the respective elements of ϵ_t in (2.7), hence, $E(\tilde{\epsilon}_t^{(i)}) = 0$, and $E(\tilde{\epsilon}_t^{(i)} \tilde{\epsilon}_t^{(i)'}) = \text{diag}(q^{(i)}, \sigma_i^2)$. That is, $q^{(i)}$ contains the random-walk innovation variances of the time-varying parameters (i.e. the respective elements of Q in (2.7)) and σ_i^2 is the innovation variance of the idiosyncratic component process. The measurement equation is

$$x_{i,t} = Z_t^{(i)} \tilde{\alpha}_t^{(i)}$$

where $Z_t^{(i)} = (F_t', 1)$. We estimate the $r + 2$ hyperparameters $(\rho_i, q^{(i)}, \sigma_i)$ of the ith loading equation by maximum likelihood. We then back out the path of time-varying loading parameters using the Kalman smoother.

Since our assumptions imply independence between the r equations of the VAR representation (2.5), we can likewise estimate the time-varying parameters contained in the P_t and $\mathcal{K}_{i,t}$ matrices equation by equation. For the g^{th} equation in state space form, the state vector containing the time-varying parameters is given by

$$\alpha_t^{g\prime} = (-P_{g\,1,t}, \ldots, -P_{g\,g-1,t}, \mathcal{K}_{g\,1,1,t}, \ldots \mathcal{K}_{g,r,1,t}, \mathcal{K}_{g\,1,2,t}, \ldots \mathcal{K}_{g,r,2,t}, \ldots, \mathcal{K}_{g\,1,p,t}, \ldots \mathcal{K}_{g,r,p,t}),$$

where for $g = 1$, there are no P parameters showing up. Note that due to the different number of elements coming from the triangular P matrix, the dimensions of the state vectors are different for each of the r equations.

The state equation is the random walk for α_t^g,

$$\alpha_t^g = \alpha_{t-1}^g + \epsilon_t^g, \quad \epsilon_t^g \sim N(0, Q_g), \quad Q_g = \text{diag}(q_g) \tag{2.9}$$

The measurement equation is given by

$$f_{g,t} = f_t^{g\prime} \alpha_t^g + u_{g,t}, \quad u_{g,t} \sim N(0, S_{gg,t}) \tag{2.10}$$

[9] See also Banerjee et al. (2008) for finite sample simulation evidence.

where

$$f_t^{g\prime} = (f_{1,t}, \ldots, f_{g-1,t}, f_{1,t-1}, \ldots f_{r,t-1}, f_{1,t-2}, \ldots f_{r,t-2}, \ldots, f_{1,t-p}, \ldots f_{r,t-p})$$

and $S_{gg,t}$ is given by (2).

In a first step, we estimate for each equation the 'hyper-parameters' (q_g, c_g, b_g) by maximum likelihood. In a second step, we filter out the time-varying parameters of each equation by the Kalman Filter. However, when taking the filtered states $a^1_{t|t}, \ldots, a^r_{t|t}$ from each equation and reconstructing the respective VAR matrices, $P_t, \mathcal{K}_{1,t|t}, \ldots, \mathcal{K}_{p,t|t}$, the resulting local VAR dynamics at time t may imply explosive behavior. In order to avoid this, we ensure that at each point in time, all eigenvalues of the autoregressive matrix corresponding to the reduced-form VAR representation in companion form are inside the unit circle. To achieve this, instead of running r independent and unrestricted Kalman filters, we use an algorithm that runs the r Kalman filters and performs an updating step only if the SVAR structure implied by the filtered states jointly satisfies the stationarity condition, see Eickmeier et al. (2009) for details.

Given the estimated time-varying FAVAR, impulse response functions and forecast error variance decompositions provided in this paper are based on the (smoothed) parameter structure prevailing at the respective point in time. That is, they are computed in the standard way as with constant-parameter FAVARs but with a new parameter structure at each time t.[10]

3 Data description

3.1 US financial conditions index

We use in our analysis the FCI for the US which has been recently constructed by Hatzius et al. (2010) and published on Mark W. Watson's webpage. This FCI summarizes a broad set of 45 quarterly financial variables including interest rates and spreads, exchange rates, oil prices, credit aggregates, survey measures on credit conditions and asset prices. The index is based on an unbalanced dataset and therefore goes beyond other, existing, indices in two respects. First, it starts in 1970 whereas previous FCIs generally start a decade or more later (see Hatzius et al. 2010 and references therein for details). And second, the underlying dataset includes more series (existing indexes use up to a dozen financial series).

In their paper Hatzius et al. (2010) mainly focus on an FCI constructed as follows. They first purge each series in the large financial dataset by contemporaneous and lagged influences of GDP growth and inflation and then estimate the FCI as the first PC from

[10] Eickmeier et al. (2009) also show a bootstrap method to provide confidence intervals for the time-varying impulse responses, these may be added in the next version of this paper.

the residuals. We use instead as our FCI the first PC of the unpurged data (which they also publish) and remove other influences later when modeling the FCI together with international factors and, further below, as a robustness check, with both international factors and a few observable US macroeconomic variables in the VAR.

The FCI we use in our analysis is shown in Figure 1(a). An increase in the FCI can be interpreted as an improvement of overall financial conditions, while a decline reflects a worsening. The evolution of the index matches with anecdotal evidence on major financial turmoils such as the financial headwinds period in the early 1990s, the stock market crash in 1987, the burst of the dotcom bubble in 2001 and the global financial crisis in 2008-2009. It is also clear from the chart that other influences such as the business cycle are still reflected in the FCI.

As noted in the introduction, a shock to this FCI index needs to be interpreted as surprises to overall 'financial conditions'. The use of the FCI to identify 'financial shocks' has advantages and disadvantages. It reflects, on the one hand, that financial markets in the US are strongly linked, as the recent financial crisis has demonstrated. Moreover, the use of the FCI is convenient since it frees us from imposing identifying restrictions which would be necessary in order to disentangle more narrowly defined shocks such as 'credit shocks', 'interest rate shocks' or 'stock price shocks'. Any identifying restrictions would be debatable.[11] On the other hand, interpretation of results regarding the propagation of a broad 'FCI shock' is certainly more difficult than that of more narrowly defined shocks.

To facilitate interpretation it is useful to report the variables with the largest positive and negative loadings with respect to the FCI (which are proportional to the weights). The loadings were computed based on an OLS regression of each series on the FCI where the residuals were modeled as AR(1) processes using the Cochrane Orcutt procedure. We sort the variables according to their loadings and present variables and loadings in Figure A.1. (blue line).[12] The FCI is most highly positively correlated with a number of credit variables and the Loan Performance National House Price Index. Largest negative loadings are found for various risk spreads, bank stock market volatility and a tightening of lending

[11] The papers on the international transmission of financial shocks overviewed above either identify them using sign restrictions (Helbling et al. 2010) or generalized impulse responses (Galesi and Sgherri 2009); in both cases financial shocks are not orthogonal to other shocks. Bagliano and Morana (2010) use a Cholesky decomposition to identify simultaneously a number of different financial/asset price shocks assuming a specific ordering for the variables in the model. Other (closed economy) papers employ long-run restrictions (e.g. Bjørnland and Leitemo 2009) or identification through heteroscedasticity (e.g. Rigobon 2003). From this brief overview, it has become clear that identification is difficult and a consensus has not yet been reached.

[12] The loadings we report differ from the loadings provided in Hatzius et al. (2010) which are based on data from which growth and inflation influences were removed prior to estimating the FCI. Note also that not all variables are publically available, and we only show loadings for the (37) variables which are available (although the FCI used in our paper was constructed based on all 45 variables).

conditions by banks. It is also important to notice that the FCI increases with both an increase in oil prices and a real effective appreciation of the US dollar. Of all variables, the exchange rate exhibits, however, the smallest loading in absolute terms. They are hardly distinguishable from zero and, hence, movements in exchange rates should only have a very limited influence on the FCI. The positive oil price loading can be explained with oil prices being mainly determined by demand shocks rather than by exogenous oil supply disruptions as recent work by Kilian (2009) has illustrated. Hatzius et al. (2010) indeed find a small negative loading of the oil price for the purged FCI, and we can also expect exogenous increases in oil prices to worsen overall financial conditions once other influences are accounted for.

A legitimate question is whether weights of individual variables in the FCI are constant over time. The argument brought forward by Stock and Watson (2002, 2008) (and used in the previous section to justify our approach) can also justify the PC approach for the construction of the FCI: Even if the weights of the various financial indicators in the index change over time, 'financial conditions' can be consistently estimated by PC. The PC estimate of the FCI would therefore, according to this argument, be consistent with both constant and time-varying weights. To assess whether loadings might have changed and further facilitate interpretation of the FCI (and the FCI shocks to be identified below), we implement the approach of the previous section and estimate time-varying loadings also for the financial variables. Results are presented in Figure A.1. Averages of the time-varying loadings (green lines) and of the constant loadings (blue lines) are very similar. More importantly, the red lines in Figure A.1 reveal that the loadings of most variables are fairly stable over time. There are only a few exceptions. Loadings change relatively strongly for the Wilshire 5000 stock price. They are large around the major stock market turmoils (they peak around 1987 and are also large and positive in the late 1990s/early 2000s). A similar pattern (with the opposite sign) is observed for bank stock market volatility and the VIX. We also find some variation in the TED spread with troughs during the recessions. In addition, we observe a declining trend in the weight of bank credit (with the exception of a peak in the early 1990s) and an increasing trend in the weights of other forms of finance (i.e. of ABS issuances (mortgage) since the early 1990s and commercial paper outstanding over the entire period). Also, the weight of the 10-year government bond yield has declined since the early 1980s. Interestingly, we find relatively large absolute loadings for stock prices, house prices, ABS issuance (mortgages), bank stock market volatility and the TED spread over the recent crisis period suggesting that the most recent worsening of US financial conditions was indeed broad-based and concerned various financial markets.

We refer to Hatzius et al. (2010) for more details on the underlying data and a careful analysis of the statistical properties of the FCI.

3.2 Large international dataset

The vector comprises quarterly variables over the period 1971Q1-2009Q2. The dataset covers nine major advanced countries, i.e. the US, Canada, the UK, France, Italy, Germany, Spain, Japan as well as Australia. We include for each country 23 variables (if available). These variables comprise several measures of real economic activity (GDP, personal consumption, total fixed investment, residential and non-residential investment, government consumption, government debt-to-GDP ratio, total factor productivity (TFP), industrial production, unemployment rate), aggregate price variables (GDP deflator, CPI), trade (activity and price) variables (real exports, real imports, export prices, import prices, the real effective exchange rate, the bilateral nominal exchange rate with the US Dollar) as well as monetary and financial variables (equity prices, residential property prices, domestic credit, short-term and long-term interest rates). Overall, the dataset contains $N = 200$ series.

Asset prices and credit were converted to real variables by division by the GDP deflator. Exchange rates are defined such that increases reflect an appreciation of the respective currency.

Data are taken from various international institutions, including the BIS, the IMF, the OECD and the EU commission. These data are, in some cases, complemented with data from national sources. It is notoriously difficult to construct a comprehensive set of quarterly house prices. House prices are often not available and/or only at a biannual or annual basis. We take residential property prices from Goodhart and Hofmann (2008), who very carefully constructed a quarterly dataset for 17 OECD countries for the period 1971-2006, and updated the dataset with recent data taken from the BIS.[13] Other series such as TFP and the government debt-to-GDP ratios were also available only on an annual basis. We converted annual to quarterly data using a cubic spline interpolation.

We believe that it is particularly interesting to look at the international transmission of financial shocks to financial and asset variables, in the light of the recent crisis. As noted in the introduction, there exists, however, not yet much work on the international shock transmission via asset prices, credit and other monetary and financial variables. We also believe that looking at the transmission of financial shocks, especially in the crisis period, to TFP is particularly interesting. There is currently a lively debate on whether the global crisis has affected potential (or trend) growth which is strongly determined by TFP (e.g. European Commission 2009, ECB 2008, Deutsche Bundesbank 2009).[14] Finally, including

[13] We are grateful to Boris Hofmann for providing us with his house price data.

[14] Financial crises can have an impact on capital accumulation and, hence, on potential growth, e.g. through their effects on credit spreads and, hence, on capital costs (ECB 2008) or the obsolescence of some capital vintages due to economic restructuring (European Commission 2009). Besides this most obvious effect, crises can affect potential growth also through their effects on TFP. The European Commission (2009) argues that "[a] slow process of industrial restructuring, caused for example by credit constraints,

government consumption and government debt-to-GDP ratios will help to assess to what extent the reaction of fiscal policy to the international financial crisis has been unusual. Our choice of the data is otherwise driven by data availability. Some series or observations are missing for some countries. We exclude these series from the dataset and work with a balanced panel.

As is common practice in factor analysis, the series are transformed in a multiplicity of ways. Stationarity, where required, is created by differencing; all variables are entered as differences or logarithmized differences, with the exception of interest rates, which are entered in levels. The series are standardized and subsequently have a zero mean and a unit variance. Finally, we remove outliers - defined here as observations of the (stationary) series with absolute deviations from the median which exceed six times the interquartile range. Following Stock and Watson (2005), we replace them with the median of the preceding five observations. Table A.1 of the appendix contains a more detailed description of the series, sources and treatment of the data.

The analysis covers the 1971Q1-2009Q2 period. The choice of the sample period is mainly driven by data availability. Such a long period is needed to assess whether and to what extent globalization and financial deepening has changed the way US financial shocks are transmitted internationally. Another advantage is that we can compare the recent downturn with earlier recessions and periods of financial turmoil, reaching back up to the beginning of the 1970s.

4 The evolution of the transmission of US financial shocks to the FCI and international GDP growth

In this Section we discuss the evolution of the size of US financial shocks and their transmission to the FCI and to real activity (summarized by GDP) growth in the nine countries under study. We also study the sources of time variation by assessing to what extent it is present in the loadings of the latent and observed factors on the variables, in the coefficients of the VAR for the factors, and in their contemporaneous correlation or shock volatility.

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an impaired system of capital allocation or by entrenched structural rigidities, can [...] hurt the level and growth of TFP in the medium to long term by locking resources in (relatively) unproductive activities." and "TFP growth in the medium to long run could also be curtailed by depressed investments in private Research and Development (R&D) [...]. TFP drivers, such as physical investment, R&D and innovation, may also suffer from a prolonged recession and from the shifts in attidues towards risk which are resulting in a tightening of credit conditions and an increase in the cost of capital."

4.1 The changing reaction of the FCI to its own shock

Figure 2 shows the temporal evolution of the impulse responses of the FCI to its own shock, obtained as the Cholesky residual associated with the FCI equation in the TV-FAVAR. The impulse responses are shown for different horizons (contemporaneous, i.e. zero quarters, four quarters and eight quarters) (left panel) and different points in time (the first quarters of 1972, 1978, 1984, 1990, 1996, 2002 and 2008) (middle panel). In the right panel we also present the forecast error variance share of the FCI explained by the FCI shock itself.

For the impulse response analysis we have normalized the shock to raise the US FCI by one unit. This normalization allows us to compare the transmission of shocks of the same size over time.

To get a sense of the magnitude of such a shock to the FCI we need to multiply the loadings of the financial variables underlying the FCI with respect to the FCI (provided as the blue line in Figure A.1) by their standard deviations (computed from the original data that are provided on Mark W. Watson's homepage). For example, a one unit rise of the FCI reflects impact increases of the Wilshire 5000 stock price index, the Loan Performance National House Price, bank credit, the oil price, the exchange rate and the 10-year government bond yield by, respectively, 1.7 percent, 1.3 percent, 0.5 percent, 7.2 percent, 0.02 percent, and 0.3 percentage points. It also reflects impact declines of the spread between the 10-year government bond over the 3-month Treasury bill, the monetary aggregate MZM, and the TED spread by 0.5 percentage points, 0.6 percent and 0.2 percentage points, respectively.

The charts reveal that the effect of the shock to the FCI itself peaks on impact and has come back to zero after three to five years. The shock seems to have a somewhat more persistent impact on the FCI over the more recent periods. The explanatory power of the FCI shock for movements in the FCI is large and strongly fluctuates over time. The FCI shock explains between 40 percent and more than 80 percent at medium-term forecast horizons (five years). These numbers are even higher and range from 70 to 90 percent at shorter horizons (one year). The variance shares are particularly high in periods where the FCI shock also exhibited a relatively high volatility.

Figure 3 reports the estimated FCI shock series (not scaled (divided) by their (time-varying) standard deviations) and Figure 4 the volatility of the FCI shock. Troughs of the shocks and peaks of the volatility reflect the major oil market disruptions in the early 1970s and early 1980s, structural changes in financial markets (regulatory changes and financial innovation) in the late 1970s and the 1980s[15], the stockmarket crash in 1987, the

[15] Structural changes in financial markets are, e.g., the phasing out of regulation Q, the spreading of securitization, the creation of an interstate banking system, the introduction of risk-oriented capital adequacy requirements and the promotion of fair-value accounting and increased competition in the interbank

Asian and Russian crisis at the end of the 1990s, the build-up and subsequent burst of the dotcom bubble around 2001, and the global financial crisis at the end of the sample period. As shown above estimated weights of oil prices in the FCI were not particularly large around the first two oil price shocks in the 1970s and 1980s. Increased volatility during these episodes was therefore probably due to a rather general worsening in financial conditions. By contrast the peaks in the volatility around 1987 and 2001 possibly went along with an increased weight of the stock price around these years. In the latest period we finally observe a sequence of negative shocks during the crisis probably responsible for exceptionally persistent negative effects. We also find that during the crisis the variance of the shock is larger compared to previous episodes.

Finally, the relevant panel of Figure 6(b) indicates that there is very limited temporal variation in the parameters of the FCI VAR equation, once changes in variances are taken into consideration.

4.2 The changing transmission of US financial shocks to international GDP growth

Figure 5 shows impulse response functions of GDP growth of the nine countries to the US financial shock (upper and middle panels). The FCI shock is positively transmitted on impact to all countries and over the whole sample period. There is, however, considerable heterogeneity in the magnitude of the effect. While the immediate impact on GDP growth is similar across countries (between 0.2 and 0.4 percentage points), the impact at intermediate and longer horizons is relatively high for the euro-area countries and Japan and lower (or even negative) for the other countries, including the US. It is also striking that Australian growth is less affected than growth in the other countries by US financial shocks. The next Section will shed light on these relative magnitudes.

In terms of variation over time, we find that the peak effect (which occurs at very short horizons) rises over time only in France, Germany, Spain and Japan. There is more time variation in the reactions at longer horizons. In the euro-area countries and in Japan, the medium-term transmission of the FCI shock has increased since the 1980s (meaning also that the shock impact has become more persistent). The timing and the finding that changes occurred relatively smoothly would be consistent with a gradual structural change in the economies such as that implied by globalization. In the US and the UK, we observe a more marked increase in the early 1980s which could rather be related to structural changes in financial markets discussed above.

Over the global crisis period, peak increases in the reaction of GDP growth were at 0.2-0.6 percentage points. In the euro area and in Japan the peak impact even reaches

market. See, e.g., Boivin et al. (2010). These changes might be reflected in financial shocks but might also have led to a changing transmission.

its maximum in this episode, whereas, interestingly, the impact during the crisis is not extraordinarily high by historical standards in the other countries.

It is appealing to investigate the sources of the detected time-variation in the impulse responses of GDP growth to a (constant-size) US FCI shock (Figure 6). Time-variation can in principle stem from different sources. First, there is the direct contemporaneous impact of the FCI shock that is channeled via the relevant entry in the factor loading matrix. Figure 6(a) shows the evolution of the loadings of GDP growth associated with the FCI (red solid line) and the nine latent factors (black dotted lines). It highlights that there is time variation in two to three of the ten loadings. The impact of the FCI only increases for Japan and Spain (since the early 1980s) and for Germany (since the early 1990s), consistent with our previous finding of rising impact effects in these countries. The impact is broadly constant over time for the other countries.

Second, there can be changes in the parameters of the VAR for the FCI and the international factors. Specifically, the contemporaneous relations between variables and the autoregressive matrices constitute additional sources of potential time variation in the shock response. The estimation results show that for the autoregressive matrices there are about zero to two parameters per equation that vary markedly over time, while the others turn out to be stable or only very mildly time-varying (Figure 6(b)). The coefficient on the lagged FCI varies in only one of the ten equations. A similar pattern results for the estimated paths of contemporaneous correlation parameters (Figure 6(c)).

Grouping these findings, we can conclude that the observed time variation in shock propagation from the US FCI shocks to GDP growth is stemming not so much from an evolving dynamics of the FCI but rather from the FCI's and other factors' direct impact on growth as well as a more general and scattered pattern of time variation in the VAR coefficients for the latent factors.

Another interesting issue to consider is the contribution of the financial shock in explaining the forecast error variance for GDP growth in the different countries. The relevant information is provided in the lower panel of Figure 5, which plots the time-varying variance decompositions of GDP growth for horizons one and five years. It turns out that the variance share explained by FCI shocks varies notably over time, from negligible to up to 60 percent at the end of the sample period. Contributions were large around the second oil price shock episode in the early 1980s, with shares of 15-60 percent, around the stock market peak in 1987 (15-40 percent), and the dotcom bubble (10-40 percent) for all countries except for Australia where the variance share explained by the FCI shock never exceeded 10 percent in the pre-crisis period. On average over all the countries and over the 1971-2007 (pre-crisis) period, the fraction of growth variability explained by FCI shocks is slightly above 10 percent at the five-year horizon. The contribution of the shock rises strongly during the recent financial crisis, to more than 10 percent in Australia and 20-60 percent in the other countries. The magnitudes are roughly consistent with Helbling et al.

(2010) for a US credit shock. Helbling et al. (2010) also find that US credit shocks explain a slightly smaller forecast error variance share of US GDP than of a global aggregate of GDPs. The time-varying pattern of the variance decompositions thus resembles closely the FCI shock volatility pattern, graphed in Figure 3, suggesting that, for the variance decompositions, the variation in the size of the shocks dominates the changes in their transmission. The broad nature of the 'global financial crisis shock' (which was shown in Section 3.1) possibly contributed to the increased transmission to most countries at the end of the sample.

As mentioned in Section 2, we have also carried out a robustness check where we have included a few observable US variables (among them the FCI) in the VAR together with factors extracted from data covering the remaining eight countries. The main results of this analysis are presented in Figure A.2, and overall they are very similar to our baseline.[16] This provides further evidence in favor of our baseline specification and robustness of our shock identification.

In summary, we find substantial changes over time in the size of US financial shocks, with the 'financial crisis shock' larger than any other shock previously experienced over the sample. Our results further show gradual increases in the transmission to euro-area countries' and Japanese GDP growth since the 1980s, consistent with the ongoing globalization process, and more marked increases in the early 1980s in the US and the UK, consistent with structural changes in financial markets. During the crisis the contribution of US financial shocks to the variation in GDP growth rises to 20-60 percent from negligible in some episodes and slightly above 10 percent (at the five-year horizon) on average over all countries over the 1971-2007 (pre-crisis) period. The exceptionally deep recent worldwide recession was therefore a large negative US financial shock combined with a stronger propagation of that shock to the euro-area countries and Japan.

5 Understanding the changing transmission of US financial shocks

We now try to explain the detected pattern of time variation in the consequences of the FCI shock on growth, and to pin down its main transmission channels by looking at the effects of the FCI shock on a variety of other variables.

Table 1 presents impulse responses of selected variables (in levels) to the US financial

[16] The FCI shock explains, in the robustness analysis, a larger fraction of the movements in the FCI than in the baseline. The local peak in the early 1980s in the volatility of the FCI shocks is less pronounced, and hence, the forecast error variance shares of GDP growth explained by FCI shocks are smaller in this episode. Finally, the impulse responses are somewhat more persistent. Otherwise, the shapes and magnitudes of impulse responses and shock volatility are very similar. The correlation between the two shock estimates is at 0.96.

shocks. To save space, we do not present results for all horizons and all points in time, but focus on the effect after one year and averages over the 1971-1986, the 1987-2007 and the 2008-2009 periods. 1987 is often seen as the begin of financial globalization (see, e.g., Kose et al. 2007), and 2008 broadly marks the start of the most recent recession in most countries. Our periods therefore represent the 'pre-financial globalization period', the 'financial globalization period'[17] and the 'global financial crisis period'. We will assess in what follows to what extent the transmission also to other variables than GDP growth has changed with financial globalization and with the global financial crisis.

5.1 Effects in the US

US FCI shocks broadly display the expected effects in the US. They raise equity and house prices and, e.g. via wealth effects and changes in funding costs, investment and consumption. Financial accelerator mechanisms probably also played a role in the first two subsamples when domestic credit increased after expansionary financial shocks, but not over the crisis years when the credit reaction was negative. One interpretation of the credit response over the 2008-2009 period is that our credit aggregate includes, besides claims on the private sector, claims on the public sector which probably have increased over the crisis period due to large government programs (such as the Troubled Asset Relief Program (TARP)) which were established to counteract the negative effects of the crisis.

Interestingly, investment increases by more than consumption. The positive reaction of TFP may have contributed to the positive investment reaction. A decline in the unemployment rate may have improved the income outlook and contributed to the positive consumption response. Positive demand reactions trigger price and interest rate increases. Finally, we find a countercyclical reaction of fiscal policy reflected in an increase in government consumption and government debt relative to GDP.

In terms of variation over time, we find that with financial globalization (and financial sector development) the effects of financial shocks on US equity and house prices and on credit have increased, and so have the effects on consumption, investment, the unemployment rate and GDP. Smaller price and interest rate responses in 1987-2007 may have contributed to these changes. Over the crisis period, the effects on US consumption and investment are larger than over the pre-crisis period, possibly because of exceptionally strong increases in house prices and TFP and a very strong decline in the unemployment rate and despite relatively weak equity price and even negative credit reactions, relatively strong price and interest rate increases and a large countercyclical fiscal policy response.

[17] The financial globalization period was also a period when the financial sector and its relation with the real economy grew and when the Great Moderation (i.e. a decline in the variation of output and inflation) took place. This needs to be kept in mind when interpreting results.

5.2 Through which channels are financial shocks transmitted internationally, and what explains differences in the transmission across countries?

To start with the trade channel, a positive reaction in US import demand can explain export increases in other countries (the negative signs for US imports in the two periods before the crisis are misleading; we find positive reactions for shorter horizons which are just very short-lived). Exchange rates seem to play an important role for the transmission of US financial shocks on trade. We find appreciations in most countries in at least two of the three periods, but depreciations in Japan and Germany, which explains the relatively strong export performance after positive FCI shocks in these two countries. Imports, however, have risen as well in most countries. Exports rose by more than imports in the North American and the euro-area countries (except for Spain), having positively contributed to positive GDP responses. Terms of trade, defined as export relative to import prices, improved only in Canada and Australia in all three periods, while they worsened in at least two of the three periods in the other countries. Apparently, the resulting positive income effects in Canada and Australia were, however, not sufficient to lead to consumption responses that were systematically larger than in the other countries. Hence, terms of trade movements do not seem to matter much for the international financial shock transmission.

As concerns financial and monetary linkages, equity prices and capital rates move in line with their US counterparts and increase after expansionary financial shocks. Responses of house prices and credit are more scattered. They are generally positive, but house prices decline in Germany and Italy, and credit declines in these two countries as well as Australia and Canada in at least two of the three periods. Similar reactions of credit and house prices in the euro-area countries and Japan confirm the view that house price booms (busts) and an increase (a decrease) in leverage often coincide, which was particularly apparent before and during the crisis (e.g. Eickmeier and Hofmann 2010).

Positive developments of equity prices have probably contributed to positive consumption and investment responses in all countries. Consumption and investment were possibly also influenced by improvements of the labor market situation and positive TFP reactions. We also find positive price and short-term interest rate responses which, together with countercyclical fiscal policies in most countries counteracted the shocks' impact on GDP.

In the previous Section, Australia stood out with the smallest GDP growth responses to the FCI shocks. Table 1 shows that Australian investment and exports barely move in response to the shocks while imports increase relatively strongly which can explain our findings of Australia being relatively little affected.

5.3 How has the transmission mechanism changed over time, and is the global crisis unusual?

There is not clear pattern of time variation in the export and import responses between 1971-1986 and 1987-2007. With the global crisis, however, the effect on exports has risen compared to the globalization (and generally also the pre-globalization) period in all countries but Australia. The effect on imports has also risen over the crisis period in most countries. Our findings are therefore in line with the observation of a particularly strong worldwide breakdown of trade during the crisis. The effects on both export and import prices have declined for most countries in the financial globalization period compared to the pre-globalization period, but they have generally risen in the crisis period back to levels observed in 1971-1986. As concerns exchange rates, while the US Dollar appreciated in real effective terms after positive financial shocks before the global crisis, probably because interest rates in the US increased by more than in most other countries, it depreciated over the 2008-2009 period. The latter finding can probably be explained by the fact that the US was still considered as a 'safe haven' by investors despite the fact that the crisis originated in the US, leading to capital inflows in the US and an appreciation after adverse financial shocks (and, hence, a depreciation after positive shocks) (see Cecchetti et al. 2010 who describe this mechanism). The US exchange rate responses over the three subsamples can also explain why the (positive) export reaction in the US was larger during the crisis than before.

In terms of financial and monetary linkages, the impact of US financial shocks on stock prices has increased in all countries between the first and the second subsample. During the crisis, stock price reactions in some countries have risen compared to before while others have declined. The pattern is much clearer for house prices. The impact has increased for most countries over time and is largest at the end of the sample period (not counting the countries for which negative house price reactions were found). During the crisis, long-term rates reacted relatively little in Japan and Germany which explains perhaps also why the FCI shock impact on demand was relatively large in these countries. The long-term rate response was also weak in the UK over the crisis period. Over time, the pass-through of financial shocks to interest rates has declined in almost all countries in the 1987-2007 period compared to the 1971-1986 period but has risen in the crisis period to levels similar to the pre-globalization period.

The impact on investment and consumption are generally larger in the financial globalization period compared to the pre-globalization period (with the exception of consumption responses in Germany and Italy and investment responses in Germany and Australia). During the global crisis, the effects on consumption and investment have risen further in the majority of countries. An increase in the responsiveness of TFP over the crisis period in all countries probably also contributed to investment reaction increases. The result for

TFP is also interesting in the light of recent discussions on whether the global financial crisis had an impact on potential (or trend) growth which tends to be strongly influenced by TFP (e.g. European Commission 2009, ECB 2008, Deutsche Bundesbank 2009). Our results, at least, do not stand against this hypothesis. The sensitivity of government consumption to GDP seems to have increased in Japan and the euro-area countries (without Italy), but clear patterns of time variation for fiscal policy responses in the other countries are not apparent. Over the crisis period strongest responses are found for the European countries and Japan. For government debt to GDP ratios (not available for all countries and all points in time), responses were strongest during the crisis for the US, the UK, Spain and Japan. All together this suggests that most governments have reacted strongly to fight the negative impact of the global crisis.

Overall, this section has helped us to understand the complex and changing transmission mechanism. Trade tends to be more affected in the US and in other countries than investment, and investment to be more affected than consumption. Hence, trade seems to be an important international transmission channel of financial shocks, which is consistent with Bagliano and Morana (2010). Trade reactions were probably shaped by exchange rate movements. While stock prices increased in all countries and periods after expansionary US financial shocks and are likely to have enhanced positive domestic demand responses, the impact on house prices and credit varies across countries and over time. Finally, the impact of FCI shocks was probably dampened by price increases and consequent interest rate increases and countercyclical fiscal policy. Therefore we can conclude that trade, financial linkages and policy responses all have played a role.

We do not find a clear pattern of time variation for trade variables when comparing the globalization to the earlier period. We find, however, an increase in the reactions of consumption and investment in most countries probably due to increased reactions of stock and - in general also - house prices and decreased reactions of interest rates between the two periods.

We have also assessed to what extent the crisis was unusual. We find that, over the crisis years, the US experienced exceptionally large negative investment and consumption reactions after adverse financial shocks to which exceptionally large negative TFP and house price reactions probably contributed. Despite the fact that the crisis originated in the US, the US was probably still seen as a 'safe haven' which attracted capital, led to an appreciation of the US dollar and probably contributed to the exceptionally strong worsening of the export performance. A similar pattern for domestic demand, TFP, house prices and exports is found for the other countries. An exception is the negative transmission to house prices in Germany and Italy. We should also emphasize the very strong appreciation of the Japanese currency after adverse financial shocks is striking (and larger than in previous episodes) and can probably explain Japan's strong export response dur-

ing the crisis. Other countries experienced a depreciation which probably dampened the effects. In all countries, countercyclical fiscal policy and interest rate increases which were, however, not exceptional by historical standards counteracted the shocks' effects during the crisis.

6 Can country features explain differences in the transmission of the global financial crisis?

In this Section we relate country characteristics to the propagation of US financial shocks over the global crisis period. There is a growing literature which examines why some countries were affected more strongly than others by the global financial crisis (e.g. Rose and Spiegel 2010a, 2010b, 2010c, Frankel and Saravelos 2010, Giannone et al. 2010, Claessens et al. 2010, Lane and Milesi-Ferretti 2010). This literature relates changes in real activity (in general in GDP)[18] in advanced and developing economies during the crisis to country features related to trade and financial market openness (overall and with the US), macroeconomic and financial vulnerabilities, financial development, institutional factors as well as fiscal positions prior to the crisis.

While, according to all these studies, relatively rich countries were more strongly affected by the crisis, a consensus on other possible determinants has, however, not yet been reached. Rose and Spiegel (2010a) find that countries which experienced a sharper rise in stock prices in the years before the crisis were relatively strongly hit and (weaker) evidence for countries with closer trade linkages with and assets in the US being relatively little affected by the crisis. According to Claessens et al. (2010) current account deficits, asset price bubbles, rapid credit growth, high leverage, financial integration with the US and exposure to asset backed securities have worsened economic performance during the crisis. By contrast, countries which had more room for policy intervention were less affected. Giannone et al. (2010) find that countries with liberalized credit markets experienced stronger declines in economic activity during the crisis period; credit market regulation is, however, not found to be a significant determinant in a high-income countries-only sample. Lane and Milesi-Ferretti (2010) highlight that current account deficits, credit growth and growth relative to trend before the crisis as well as trade integration are important in explaining the strong impact of the crisis on certain countries. Frankel and Saravelos (2010) find low reserves, national savings and real interest rates to be important indicators of the global crisis (for GDP) and that countries with a more developed financial sector and with low external debt were relatively little affected.

[18] Frankel and Saravelos (2010), e.g., also consider other dependent variables such as changes in stock prices, industrial production, exchange rates, reserve losses and participation in an IMF program. Rose and Spiegel (2009a) also consider stock prices, exchange rates and institutional country rating.

We contribute to this literature by correlating average impulse response functions of the levels of GDP and its main components to FCI shocks over 2008-2009 with pre-crisis countries' characteristics which have also been considered in the studies listed above and which we believe might be also relevant for our advanced countries-only sample. We include various variables capturing international integration (i.e. overall trade, trade with the US, FDI, assets and debt in the US and claims vis-à-vis US banks), financial sector development (or size) (proxied, e.g., by the bank credit-to-GDP ratio and market capitalization), the health of the banking sector (capital and liquidity ratios and the non-performing loans ratio), external vulnerabilities (the current account balance, national savings and the net external position relative to GDP), fiscal positions (government debt and expenditure and the government balance relative to GDP), the monetary policy stance measured as the real interest rate, overheating before the crisis (the output gap and average growth over 2004-2007 relative to growth over 1990-2007) and increases in asset prices and credit, the share of manufacturing in GDP and exports, measures of regulatory quality and barriers in credit and labor markets and business, and a (Euromoney) country rating.[19] The pre-crises variables, in general, refer to 2006 or, in the case of asset price and credit growth to 2004-2006. They are mostly taken from the World Bank (World Development Indicators database and Financial Development and Structure database) and from the papers by Rose and Spiegel (provided on Andrew Rose's website). For details, see Table A.2.

Since the number of observations is very small (nine or, when bilateral linkages with the US are considered, eight) we only carry out bivariate analyses. We should also emphasize that the results only hold for the countries under consideration here, but may not be representative for a larger set of countries. We focus on average impulse responses over the crisis period 2008-2009 and are therefore able to condition on US financial shocks. Previous studies, by contrast, focus on cross-country differences in GDP growth which can, in principle, stem from differences in the transmission of US financial shocks but also other shocks such as country-specific shocks that have occurred in the period under evaluation as well. We note, however, that our average GDPs' impulse responses (to negative FCI shocks) are significantly and highly correlated with changes in GDP over 2008-2009 (the correlation coefficient is at 0.7). This does not come as a surprise since GDP growth in this episode was, according to our analysis in the preceding section, to a very large extent driven by FCI shocks.

Table 2 presents the correlation coefficients for impulse response functions of (the levels of) GDP, consumption, investment and exports (at the one-year horizon[20]) to expansionary

[19] Following previous work we have also considered GDP per capita. Correlations with GDPs' impulse responses are, however, not significant, and GDP per capita is likely to be rather relevant in a sample which includes developing countries.

[20] Wer have, alternatively, considered impact responses and responses at the two-year horizon. Our main findings are robust with respect to the horizon.

FCI shocks. Figure A.3 shows scatterplots for GDP impulse responses (which remains our main focus). Scatterplots allow us to assess whether results are driven by outliers, which cannot be excluded given the small number of observations. They show that results derived from simply looking a the correlation coefficients would probably not be reversed if we dropped outliers from the analysis.

Table 2 shows that only a few pre-crisis country features are systematically related to GDPs' impulse responses (which is also reflected in the scatterplots which rarely display systematic relationships). Focusing on international linkages and external balances first, we find no significant relation with overall trade and FDI exposure and trade with the US. By contrast, we find negative correlations for the shares of assets and debt in the US in total foreign assets and debt, suggesting that countries with stronger linkages with the US via assets and debt were less affected by FCI shocks over the crisis period. This result seems surprising at first sight, given that the shock initiated in the US and one might have expected that strong linkages with the US would aggravate the crisis' impact. However, given that the US were not among the countries which were most affected by the crisis, it is perhaps not too surprising. Moreover, results for the impulse responses of the GDP components show that this finding is due to exports, while corresponding linkages with the US do not seem to have significantly altered the consumption and investment responses. These results are broadly consistent with Rose and Spiegel (2010c) who find that linkages with the US via assets markets or trade have, if anything, attenuated negative responses to the crisis.

Interestingly, we find positive correlations for the share of claims vis-à-vis US banks to total claims. They are not significant for GDP but are very high and significant for consumption, supporting the view that the banking sector played an important role for the propagation of the crisis.

External balances were introduced by previous studies as measures of external vulnerabilities. From this point of view, the positive significant correlations we find between GDPs' impulse response and the current account balance are perhaps surprising. They suggest that countries with larger current account surpluses were relatively strongly affected. We have found in Section 4.3. that US financial shocks were to a large extent transmitted through trade. Hence, export-dependent countries (i.e. current account surplus countries) probably suffered particularly strongly, which can explain our findings for external balances. This interpretation is supported by the positive correlation between GDPs' impulse responses and overall trade openness (which is, however, not statistically significant), and it is also supported by large significant positive correlations between the export responses and the current account. Hence, in our sample, external positions seem to reflect openness rather than vulnerabilities which may be more important in samples including developing countries used in previous studies and which may explain differences between our and previous results.

Another (new) finding is that countries with a highly capitalized banking system were less strongly affected, as is apparent from the negative correlation between GDPs' impulse responses and bank capitalization. This finding is interesting also in the light of recent regulatory proposals of higher capital ratios which aim at avoiding collapses of entire banking systems in the future and which would, according to our results, also help alleviating negative economic reactions to adverse external financial shocks.

Fiscal positions also seem to have mattered. The fiscal indicators all have the expected sign, i.e. relatively high government deficits/debt before the crisis probably left less room for fiscal policy intervention in response to the crisis and undermined confidence. The government expenditure-to-GDP ratio is even significantly (positively) correlated with the impulse response functions of GDPs and investment. Similarly, the impact of US financial shocks during the crisis was smaller in countries with an expansionary monetary policy stance (low real interest rates) before the crisis; correlations are very high and significant for GDPs and all components shown here. This finding is in line with Frankel and Saravelos (2010).

Another interesting finding is that investment in economies which were overheated prior to the crisis (measured as high growth in 2004-2007 relative to 1990-2007) was more affected by US financial shocks during the crisis.

Neither credit growth nor asset price growth is found to be significantly correlated with impulse response functions of GDPs and most components. Exceptions are the negative significant correlations between export impulse responses and pre-crisis credit growth as well as real effective exchange rate movements. The negative correlation between exchange rate appreciation and export responses (which also explains the negative (although not significant) correlation between exchange rate appreciation and GDP responses) can probably be explained as follows. A relatively large appreciation prior to the crisis is typically followed by a correction (a depreciation) in the course of crisis. Consequently, exports decline by less than without this exchange rate channel. We have indeed found in Section 4.3. that effective exchange rates appreciate in real terms after expansionary FCI shocks (and therefore depreciate after adverse shocks) in most countries, and the described pattern was particularly apparent for Canada, Spain and - to a lesser extent - Germany and France. The negative sign for credit growth is difficult to explain and perhaps due to credit growth being highly correlated with some other variable not controlled for.

Other potential determinants such as the development of the financial sector, the relevance of the manufacturing sector, regulation and a country rating do not seem to matter significantly. If anything, a larger manufacturing sector has led to larger effects of US financial shocks on GDPs during the crisis, more liberalized markets and a larger (or more developed) financial sector have helped absorbing these shocks. The latter two results are consistent with Giannone et al. (2010) for the high income countries sample-only and with Frankel and Saravelos (2010), respectively.

Let us summarize our main results. First, more open countries have suffered more from US financial shocks from the crisis, but direct linkages with the US seem to have rather attenuated responses (with the exception of claims vis-à-vis US banks which aggravated the impact of the crisis). This finding is consistent with our finding from the previous Section, that a break-down in trade was probably one culprit for the world-wide scope of the crisis. The correlation analysis suggests that direct trade with the US was perhaps less important than indirect trade linkages (via other countries).[21] Second, countries with a strongly capitalized banking sector suffered relatively little. Third, expansionary fiscal and monetary policy before the crisis (which possibly left less room for policy intervention in response to the crisis) has contributed to greater vulnerability during the crisis. Fourth, we find some evidence that growth which was high by historical standards prior to the crisis led to stronger negative investment reactions. Fifth, strong real effective appreciations before the crisis led - probably via corrections (depreciations) during the crisis - to less negative export responses to adverse financial shocks over the crisis years.

We should finally also note that looking not only at GDP but also at its components provided us with additional insights and helped us making sense of our results. In some cases, results for exports and domestic demand components differ, and results for GDP which, at first sight, perhaps came as a surprise could be reconciled.

7 Concluding remarks

In this paper we derive and explain a number of interesting stylized facts about how US financial shocks are transmitted internationally, and how the transmission has changed over time.

The US shock is defined as an unexpected change in the Hatzius et al. (2010) Financial Condition Index. We combine the US FCI with a newly compiled dataset of 200 variables from nine large advanced countries: US, Canada, UK, Germany, France, Italy, Spain, Japan and Australia. The large dataset is modeled by means of a FAVAR specification, enabling us to comprehensively analyze the (virtually) entire transmission mechanism. We exploit this feature and study not only the final effects of the financial shock on the GDP growth of the nine countries but also the various transmission channels, mostly through trade and financial variables.

In order to allow for and assess the extent of time variation in the transmission mechanism, we adopt the time-varying FAVAR specification introduced by Eickmeier, Lemke and Marcellino (2009), which allows for smoothly time-varying loadings, VAR coefficients and factor innovation variances and covariance. This econometric methodology therefore

[21] This would be consistent with Dées and Vansteenkiste (2008) who find, for Europe, that indirect trade is more important for the transmission of US (output) shocks than direct trade with the US.

permits a thorough evaluation of the temporal evolution of the international transmission of the US financial shocks.

We are now in the position to answer the three main questions that we raised in the introduction.

(i) How large is the impact of US financial shocks on major advanced countries, and have the shock size and its transmission changed over time?

We find that expansionary US financial shocks have a considerable positive impact on the nine countries (with Australia being less affected), and *vice versa* for negative shocks. The transmission to GDP growth in the euro-area countries and in Japan has increased gradually since the 1980s, consistent with globalization. We also detect a more marked increase in the early 1980s in the US and the UK, consistent with structural changes in financial markets in this period. The size of US financial shocks also varies strongly over time, with the 'global financial crisis shock' being larger than any other financial shock estimated over the sample under analysis.

(ii) Through what channels are US financial shocks internationally transmitted, and can we identify changes in the transmission mechanism over time?

According to our results, trade is more affected than investment and consumption and seems to be an important international transmission channel of financial shocks. Trade reactions were probably shaped by exchange rate movements. While stock prices increased in all countries and periods after expansionary US financial shocks and are likely to have enhanced positive domestic demand responses, the impact on house prices and credit varies across countries and over time. Finally, the impact of FCI shocks was probably dampened by price and interest rate increases and countercyclical fiscal policy. In terms of time variation, we do not find that trade variables were systematically more affected by US financial shocks in the globalization period compared to the pre-globalization period. We find, however, an increase in the reactions of consumption and investment in most countries probably due to increased reactions of stock and - in general also - house prices and decreased reactions of interest rates between the two periods.

(iii) How strongly were the major advanced countries affected by the global financial crisis, also in comparison with previous episodes of financial turmoil? Which channels played a major role in the transmission over the global crisis period? What country characteristics can explain differences in the transmission across countries?

We find that the exceptionally deep recent worldwide recession was mostly due to a large negative US financial shock combined with a strong propagation of that shock. US financial shocks explain 20-60 percent of the variation in GDP growth during the crisis period, which is very large compared to a little more than 10 percent on average over the 1971-2007 period, and also larger compared to other turmoil episodes.

We confirm the widely held view that an exceptionally strong breakdown in exports (which was most pronounced in Japan, Germany, Italy and the US) contributed to the

strong worldwide propagation of the global financial crisis. House prices also have very strongly declined by historical standards in response to the adverse financial shock in all countries but Germany and Japan which may also have contributed to an exceptionally strong decline in consumption and investment in these countries.

Correlation analysis of impulse responses over the crisis period with a large number of country characteristics prior to the crisis helped us to gain a better understanding on the determinants of the international propagation of financial shocks during the crisis. We found that more open countries have suffered more from the crisis, but direct linkages with the US seem to have rather attenuated responses (with the exception of claims vis-à-vis US banks which aggravated the impact of the crisis). Another result is that countries with a strongly capitalized banking sector suffered relatively little. Moreover, expansionary fiscal and monetary policy before the crisis (which possibly left less room for policy intervention in response to the crisis) seems to have contributed to greater vulnerability during the crisis. We also find some evidence that growth which was high by historical standards prior to the crisis led to stronger negative investment reactions. Finally, strong real effective appreciations before the crisis led - probably via corrections (depreciations) during the crisis - to less negative export responses to adverse financial shocks over the crisis years. Focusing not only at responses of GDPs but also of its components significantly helped us making sense of our results.

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Table 1: IRFs to the FCI shock (averages over subsamples)

	1971-1986	1987-2007	2008-2009	1971-1986	1987-2007	2008-2009	1971-1986	1987-2007	2008-2009
	GDP			Consumption			Investment		
US	0.19	0.57	0.56	-0.24	0.33	0.54	0.35	0.90	2.69
CA	0.94	0.89	0.98	0.28	0.82	1.04	2.17	3.19	3.69
UK	0.77	1.20	1.14	0.32	0.45	0.49	3.05	4.37	3.77
FR	1.20	1.24	1.51	0.48	1.04	0.79	2.14	2.49	2.86
DE	1.33	0.60	2.47	0.87	0.63	1.15	1.44	0.98	1.93
IT	1.72	1.41	1.71	1.51	1.50	1.93	1.58	1.89	2.42
ES	0.67	1.71	2.00	0.67	1.83	2.53	3.33	6.53	5.83
JP	1.01	1.03	2.55	0.91	0.99	1.21	1.79	2.62	4.23
AUS	0.45	0.22	0.25	0.61	0.91	0.90	0.54	-1.17	-0.54
	Unemployment rate			Total factor productivity			Government consumption/GDP		
US	-0.37	-0.47	-0.57	0.04	0.12	0.24	-0.14	-0.10	-0.42
CA	-0.39	-0.30	-0.36	0.13	0.24	0.42	-0.57	-0.55	-0.52
UK	-0.32	-0.51	-0.50	0.11	0.28	1.00	-0.96	-0.96	-0.98
FR	-0.25	-0.45	-0.42	0.42	0.41	0.55	-0.58	-0.68	-0.79
DE	-0.13	-0.13	-0.15	0.21	0.39	1.05	-1.01	-0.60	-2.18
IT	-0.27	-0.38	-0.38	0.77	0.64	0.82	-1.59	-0.73	-1.03
ES	-0.31	-1.26	-2.19	0.31	0.21	0.22	-0.33	-1.22	-1.40
JP	-0.21	-0.10	-0.17	0.45	0.66	1.04	-0.52	-0.03	-1.36
AUS	-0.37	-0.19	-0.26				-0.15	0.46	0.08
	Government debt/GDP			GDP deflator			Exports		
US	-0.79	-0.94	-2.35	1.40	1.20	1.54	3.67	2.69	4.05
CA				1.83	1.75	2.97	0.43	-0.82	3.11
UK	-0.28	-0.75	-2.99	2.15	1.81	2.78	2.36	1.78	1.97
FR				1.74	1.60	1.97	2.87	2.55	3.91
DE	-0.49	-0.63	-0.83	3.02	3.39	3.93	3.62	5.17	5.94
IT	-0.64	-0.76	-0.85	2.77	2.51	2.81	4.06	4.04	5.12
ES	-0.26	-0.93	-2.24	2.56	2.78	3.18	1.21	1.20	3.85
JP	-0.71	0.28	2.03	1.11	0.99	0.39	2.69	1.39	5.46
AUS	-0.15	0.46	0.08	2.23	2.32	2.46	0.32	-0.45	-0.75
	Imports			Real effective exchange rate			Export price		
US	-2.05	-0.97	2.17	1.20	1.27	-3.00	3.52	2.74	3.75
CA	-2.71	-2.35	3.38	-0.07	1.44	3.26	4.46	3.32	6.77
UK	3.17	3.64	3.51	2.29	1.82	2.38	1.81	0.70	1.06
FR	3.03	2.89	3.18	0.06	-0.16	0.69	2.43	2.31	2.89
DE	1.86	2.29	4.19	-0.54	-0.60	1.14	1.62	1.38	1.75
IT	4.35	3.90	4.46	0.25	1.79	0.86	3.92	2.17	2.98
ES	2.86	4.31	10.91	3.13	1.68	0.97	2.03	2.34	3.56
JP	3.38	1.74	2.18	-4.49	-8.07	-11.74	4.97	5.47	6.14
AUS	4.32	1.05	2.50	0.18	-0.96	1.90	5.42	6.25	6.00
	Import price			Short-term interest rate			Long-term interest rate		
US	5.08	1.16	3.94	1.59	0.74	1.20	0.79	0.48	0.64
CA	3.09	0.17	-0.12	1.46	0.86	1.60	0.87	0.49	0.65
UK	2.40	0.99	1.53	0.70	0.37	0.62	0.35	0.21	0.29
FR	4.14	2.69	3.99	1.24	0.11	1.17	0.69	0.32	0.41
DE	4.10	3.90	4.71	0.71	0.25	0.30	0.52	0.24	0.31
IT	3.77	2.30	5.56	1.16	0.43	1.26	0.66	0.30	0.86
ES	5.15	2.81	3.80	1.22	0.53	0.60	0.66	0.39	0.61
JP	9.92	8.51	10.21	0.64	0.07	0.02	0.50	0.10	0.15
AUS	3.11	3.31	1.60	1.35	0.91	1.04	0.53	0.48	0.54
	Equity price			House price			Credit		
US	11.29	20.59	5.06	1.89	2.39	5.09	0.74	1.49	-1.09
CA	1.83	6.88	7.99	1.71	2.68	4.31	1.49	-0.12	-2.74
UK	-0.31	5.67	4.73	3.45	6.12	20.25	1.19	4.48	-0.80
FR	4.93	12.52	12.61	1.50	3.32	10.12	0.89	1.41	1.33
DE	1.62	23.79	6.65	-2.11	-2.35	-2.51	-2.25	-3.52	-4.02
IT	7.95	16.98	14.24	0.13	-0.60	-0.09	-1.79	-2.73	-1.42
ES	9.70	20.14	3.73	2.74	4.51	5.24	-1.54	1.34	0.56
JP	6.13	10.82	12.29	2.08	2.49	4.52	0.99	1.39	1.34
AUS	1.02	8.60	11.09	0.38	0.19	0.36	-1.16	-1.24	-1.11

Notes: IRFs refer to the levels of the variables and the 1-year horizon. In percentage points (interest rates, unemployment rate, government consumption/GDP), in percent (all other variables).

Table 2: Correlation coefficients between average impulse responses of (the levels of) GDPs and components during the global crisis and pre-crisis country characteristics

	GDP	Consumption	Investment	Exports
Openness and linkages with the US				
Trade/GDP	0.49	0.06	0.42	0.22
Trade with the US/total trade	-0.51	-0.19	0.04	-0.48
Exports to the US/total exports	-0.46	-0.14	0.10	-0.45
FDI/GDP	0.40	0.22	0.54	0.08
Assets in US/total foreign assets	-0.72 **	-0.12	-0.36	-0.63 *
Debt in US/total debt	-0.76 **	-0.19	-0.27	-0.72 **
LT debt in US/total LT debt	-0.73 **	-0.14	-0.25	-0.68 **
Claims vis-a-vis US banks	0.41	0.79 **	0.58	0.23
External balances				
Current account/GDP	0.75 **	0.53	0.48	0.67 **
Domestic savings/GDP	0.05	-0.15	-0.05	-0.22
Savings/GDP	0.18	0.10	-0.12	0.05
Net ext. position/GDP	0.56	0.50	0.50	0.52
Health of the banking system				
Bank capital/assets	-0.62 *	-0.45	-0.38	-0.16
Bank liquid assets/assets	0.39	0.49	0.18	0.24
Bank NPL/loans	0.49	0.11	0.15	0.44
Financial sector development				
Domestic bank credit/GDP	-0.13	0.21	0.08	0.10
Domestic credit to priv. sector/GDP	-0.19	0.04	0.21	0.00
Market capitalization/GDP	-0.45	0.02	-0.11	-0.29
Fiscal position and monetary policy stance				
Gov. expenditure/GDP	0.75 **	0.55	0.63 *	0.47
Gov. bal./GDP	-0.28	-0.34	-0.28	-0.43
Government debt/GDP	0.42	0.18	0.48	0.52
Real interest rate	-0.89 ***	-0.77 **	-0.93 ***	-0.58 *
Measures of overheating of the economy				
Output gap	0.15	0.05	0.42	-0.04
GDP growth 2004-07/1990-2007	0.54	0.39	0.67 **	0.34
Asset price and credit increases				
Stock price chge 2004-2006	0.17	0.25	0.03	0.51
House price chge 2004-2006	-0.28	-0.09	0.19	-0.30
Credit growth 2004-2006	-0.40	0.13	0.13	-0.69 **
Chge in REER 2004-2006	-0.54	-0.12	-0.14	-0.81 ***
Importance of the manufacturing sector				
Manuf. val. added/GDP	0.31	0.34	0.29	0.11
Manuf./merch. exports	0.40	0.21	0.41	0.42
Regulation				
Regulatory quality (WGI)	0.02	0.08	0.18	-0.16
Credit mkt regulation (EFW)	-0.33	-0.07	0.06	-0.30
Labor mkt regulation (EFW)	-0.56	-0.08	-0.16	-0.32
Bus. regulation (EFW)	-0.49	-0.31	-0.06	-0.76 **
Others				
Euromoney country rating	-0.01	-0.30	0.13	0.29

Notes: '***', '**','*' denote significance at the 1, 5 and 10% level, respectively. Correlation between pre-crisis country features and IRFs of the levels of GDP and GDP components after an expansionary FCI shock. The IRFs refer to the 1-year horizon and averages over 2008Q1-2009Q2. See Table A.2. for details on the pre-crisis country features.

Figure 1: US financial conditions index (FCI)

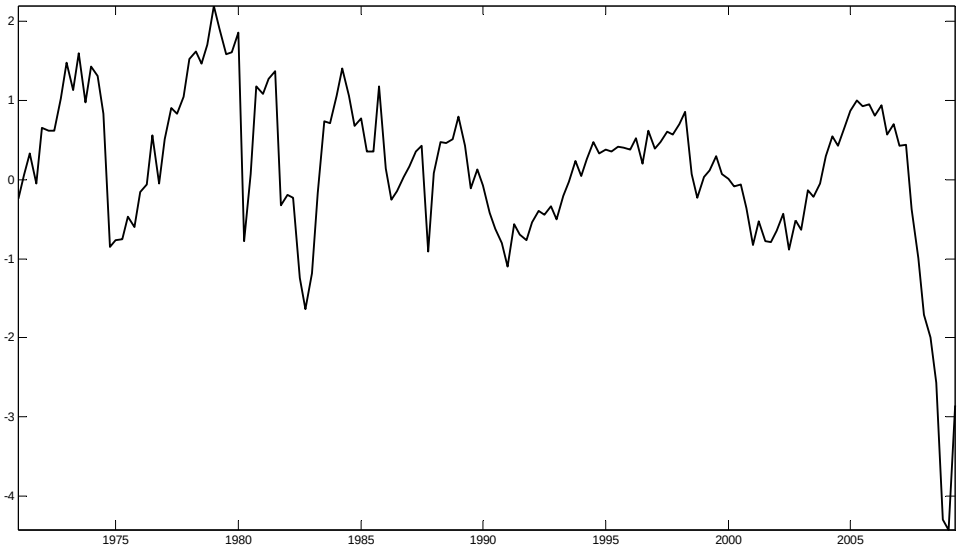
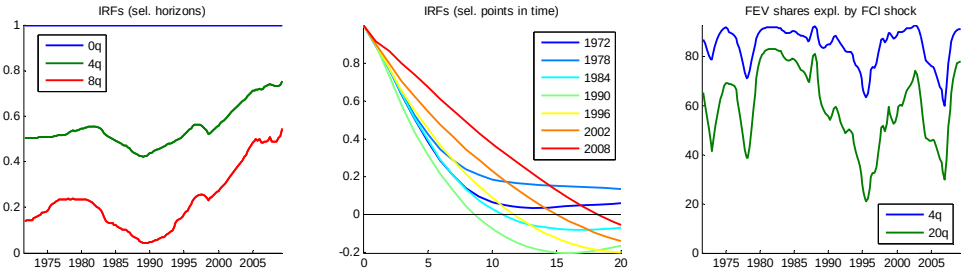
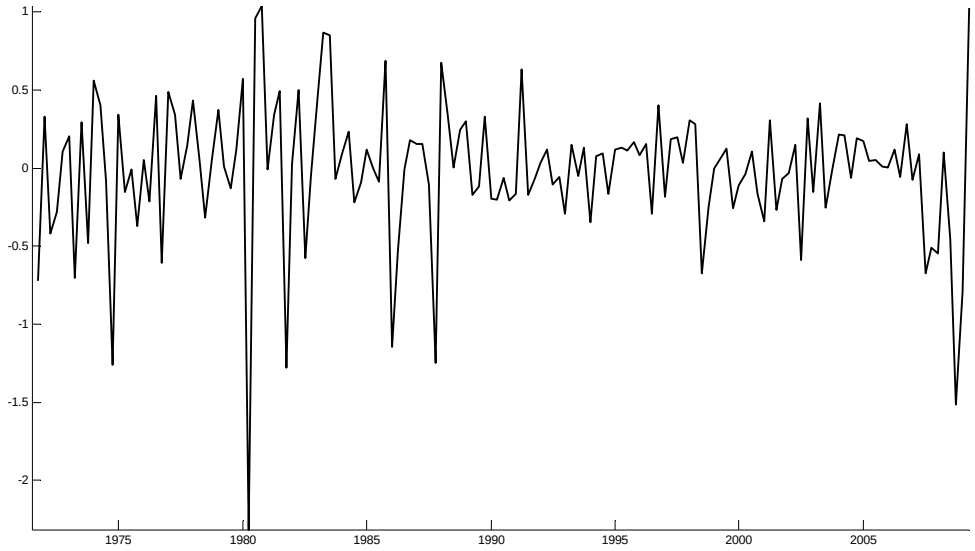


Figure 2: Time-varying impulse responses of the FCI to and the forecast error variance share explained by FCI shocks



Notes: The years/points in time for the IRFs refer to the first quarter of the year, i.e. the IRF in 2008 is the IRF in 2008Q1. The FEV shares are in percent.

Figure 3: FCI shock estimates



Notes: The shocks are unscaled (not divided by their (time-varying) standard deviations).

Figure 4: Time-varying FCI shock volatility

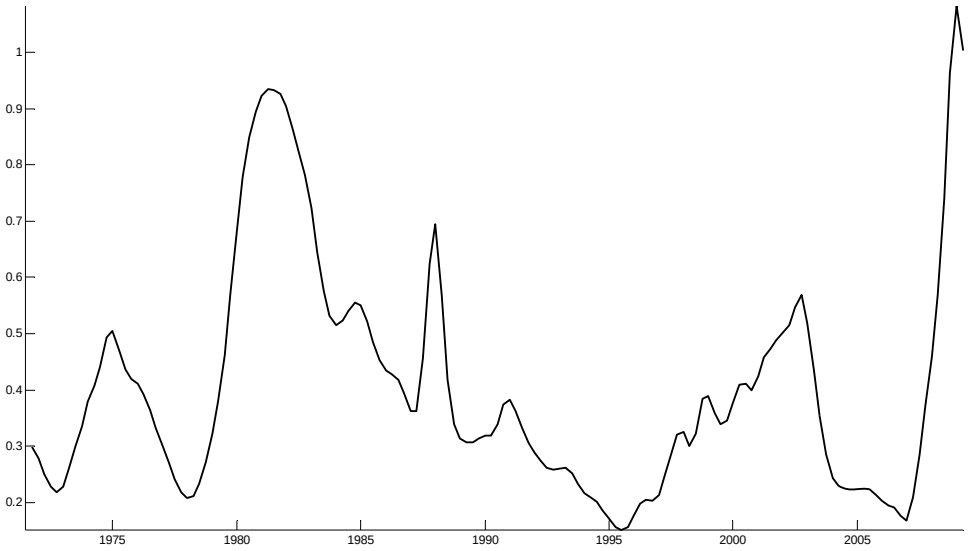
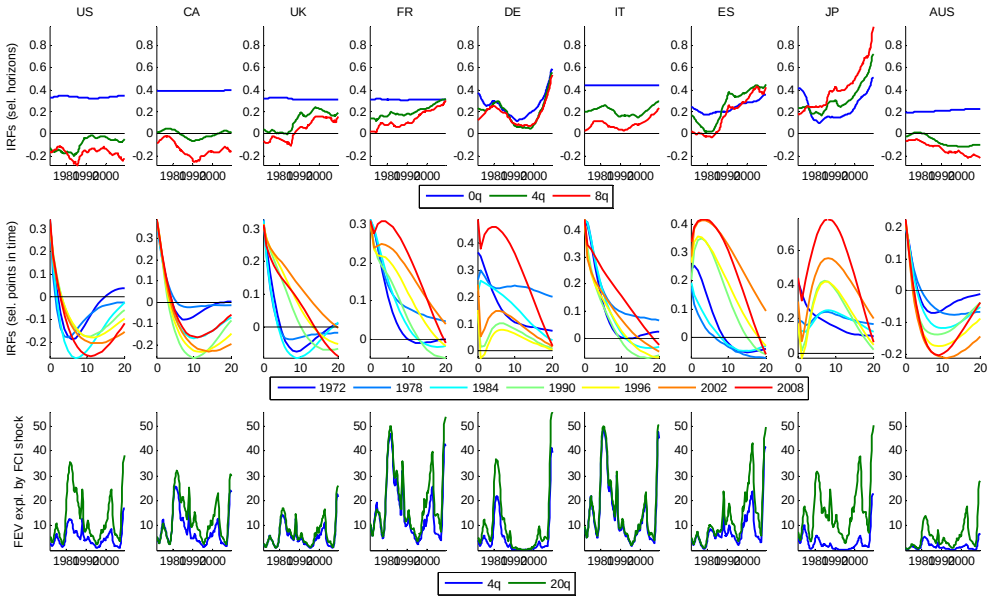


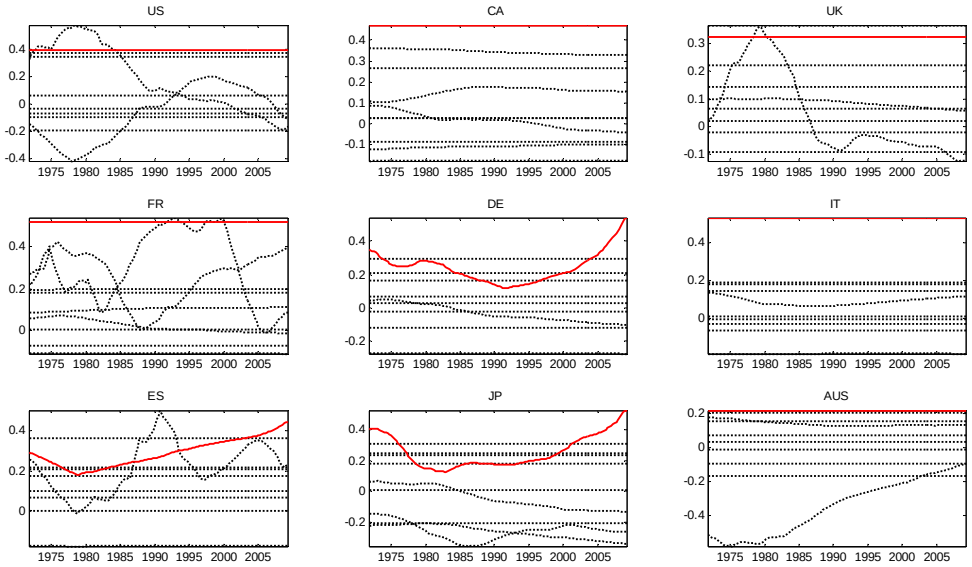
Figure 5: Time-varying impulse response functions and forecast error variance decompositions of GDP growth



Notes: The years/points in time for the IRFs refer to the first quarter of the year, i.e. the IRFs in 2008 are the IRFs in 2008Q1. Impulse responses are in percentage points, FEV shares in percent.

Figure 6: Sources of time variation

(a) Loadings of GDP growth



(b) Autoregressive VAR matrices (K)

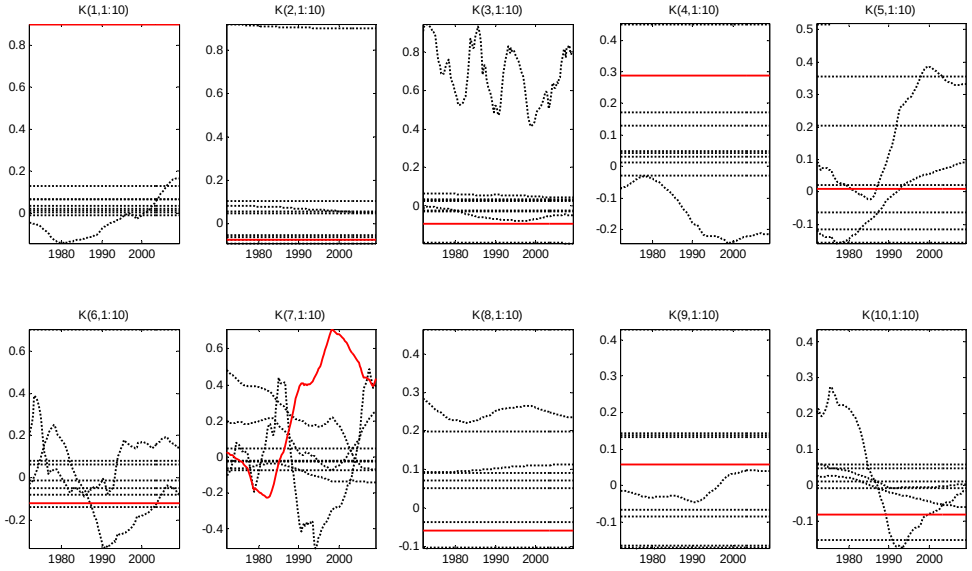
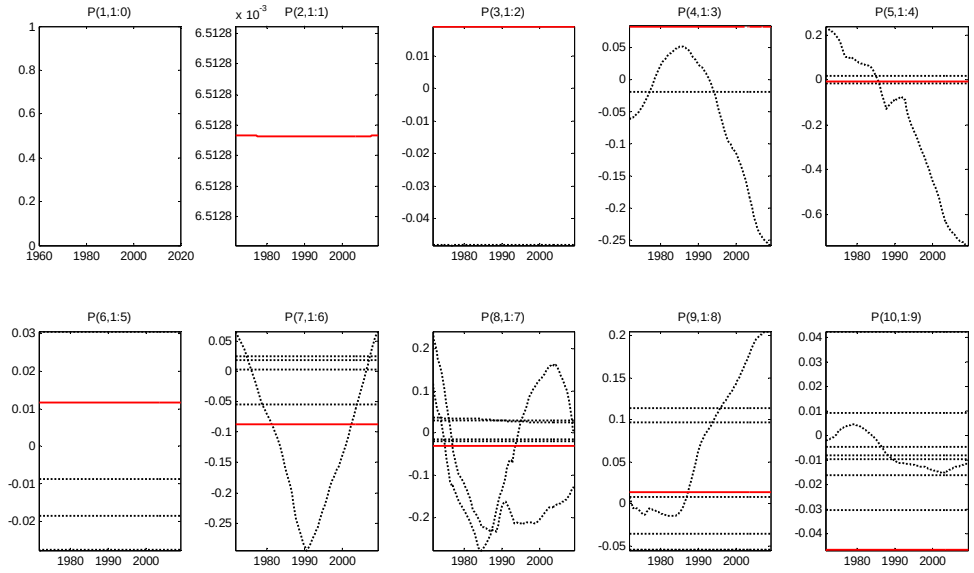


Figure 6 cont.

(c) Contemporaneous correlation matrices (P)



Notes: The red solid lines refer to the FCI, black dotted lines refer to the other 9 (unidentified) factors.

Table A.1: Data included in the factor model

Variable	Source	Treatment
GDP	OECD, ECO	2
Private final consumption	OECD, ECO	2
Gross fixed capital formation	OECD, ECO	2
Residential gross fixed capital formation	OECD, ECO	2
Non-residential gross fixed capital formation	OECD, ECO	2
Government consumption	OECD, ECO	2
Government debt/GDP	EU Commission, AMECO	1
Industrial production	IMF, IFS	2
Unemployment rate	OECD, ECO	2
Exports of goods and services	OECD, ECO	2
Imports of goods and services	OECD, ECO	2
Total factor productivity	EU Commission, AMECO	2
GDP deflator	OECD, ECO	2
Consumer price index	OECD, MEI	2
Export prices	OECD, ECO	2
Import prices	OECD, ECO	2
Equity price (real)	BIS	2
Residential property price (real)	Hofmann/Goodhart (2008) and BIS	2
Domestic credit (real)	IMF, IFS	2
Short-term interest rate	OECD, ECO and IMF, IFS	0
Long-term interest rate	OECD, ECO and IMF, IFS	0
Real effective exchange rate	BIS	2
Bilateral exchange rate with US Dollar	Federal Reserve Board	2

Notes: 0: levels, 1: difference, 2: log difference; equity prices, residential property prices and domestic credit were converted into real variables by division by the GDP deflator.

Table A.2: Data on pre-crisis country-level characteristics

Abbreviation	Description	Year(s)	Source
Openness and linkages with the US			
Trade/GDP	Trade relative to GDP	2006	Worldbank
Trade with the US/total trade	Trade with the US relative to total trade	2006	Rose/Spiegel
Exports to the US/total exports	Exports to the US relative to total exports	2006	Rose/Spiegel
FDI/GDP	Foreign direct investment (net inflows+outflows) relative to GDP	2006	Worldbank
Assets in US/total foreign assets	Assets in US relative to total foreign assets	2006	Rose/Spiegel
Debt in US/total debt	Debt in US relative to total debt	2006	Rose/Spiegel
LT debt in US/total LT debt	LT debt in US relative to total LT debt	2006	Rose/Spiegel
Claims vis-a-vis US banks	Consolidated claims vis-a-vis US banks	2006	Rose/Spiegel
External balances			
Current account/GDP	Current account balance relative to GDP	2006	Worldbank
Domestic savings/GDP	Gross domestic savings relative to GDP	2006	Worldbank
Savings/GDP	Gross savings relative to GDP	2006	Worldbank
Net ext. position/GDP	Net external position relative to GDP	2006	Rose/Spiegel
Health of the banking system			
Bank capital/assets	Bank capital relative to bank assets	2006	Worldbank
Bank liquid assets/assets	Bank liquid reserves relative to bank assets	2006	Worldbank
Bank NPL/loans	Bank nonperfoming loans relative to total gross loans	2006	Worldbank
Financial sector development			
Domestic bank credit/GDP	Domestic credit provided by banking sector relative toGDP	2006	Worldbank
Domestic credit to priv. sector/GDP	Domestic credit to private sector relative to GDP	2006	Worldbank
Market capitalization/GDP	Market capitalization of listed companies relative to GDP	2006	Worldbank
Fiscal position and monetary stance			
Gov. expenditure/GDP	Government expenditure relative to GDP	2006	Rose/Spiegel
Gov. bal./GDP	Cyclically adjusted government final balance relative to GDP	2006	Rose/Spiegel
Government debt/GDP	Central government debt relative to GDP	2006	Worldbank
Real interest rate	Short-term interest rate/future GDP deflator inflation (yoy)	2006	See Table A.1
Measures of overheating of the economy			
Output gap	Output gap	2006	Rose/Spiegel
GDP growth 2004-07/1990-2007	GDP growth 2004-07 relative to GDP growth 1990-2007	1990-2007	See Table A.1
Asset price and credit increases			
Stock price chge 2004-2006	Stock price changes	2004-2006	See Table A.1
House price chge 2004-2006	House price changes	2004-2006	See Table A.1
Credit growth 2004-2006	Domestic credit growth	2004-2006	See Table A.1
Chge in REER 2004-2006	Real effective exchange rate appreciation	2004-2006	See Table A.1
Importance of the manufacturing sector			
Manuf. val. added/GDP	Manufacturing value added relative to GDP	2006	Worldbank
Manuf./merch. exports	Manufactures exports relative to merchandise exports	2006	Worldbank
Regulation			
Regulatory quality (WGI)	WGI (Worldwide Governance Index) regulatory quality	2006	Worldbank
Credit mkt regulation (EFW)	EFW (Economic Freedom of the World), (liberal) credit market regulation	2006	Frazer Institute (EFM)
Labor mkt regulation (EFW)	EFW (Economic Freedom of the World), (liberal) labor market regulation	2006	Frazer Institute (EFM)
Bus. regulation (EFW)	EFW (Economic Freedom of the World), (liberal) business sector regulation	2006	Frazer Institute (EFM)
Others			
Euromoney country rating	Euromoney index, incl. market indicators (measuring access to bond markets, trade finance, etc.), credit indicators (measuring credit records and rescheduling difficulties), analytical indicators (incl. political risk, economic performance).	2007	Giannone et al. (2010)

Figure A.1: Loadings of financial variables with respect to the FCI

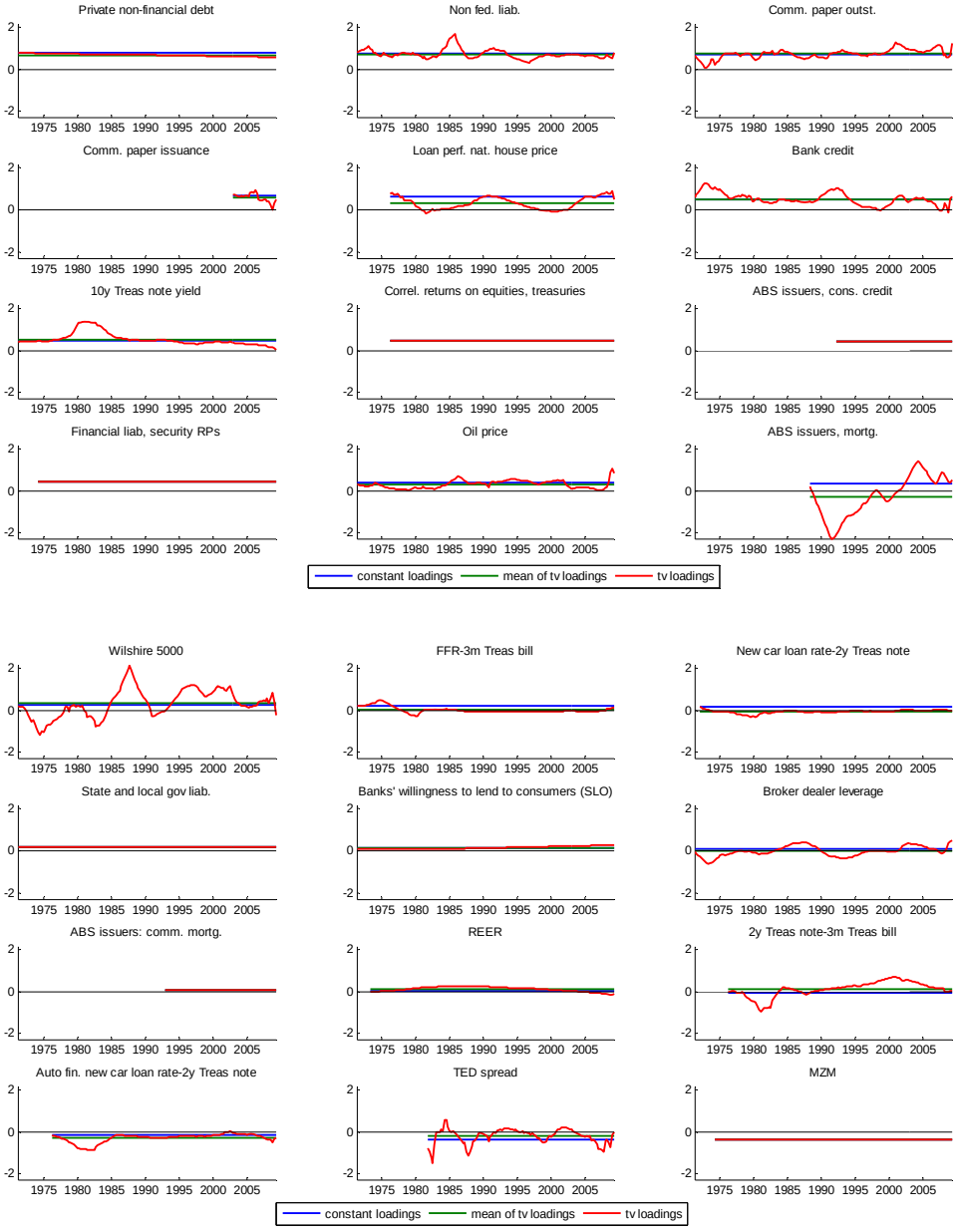
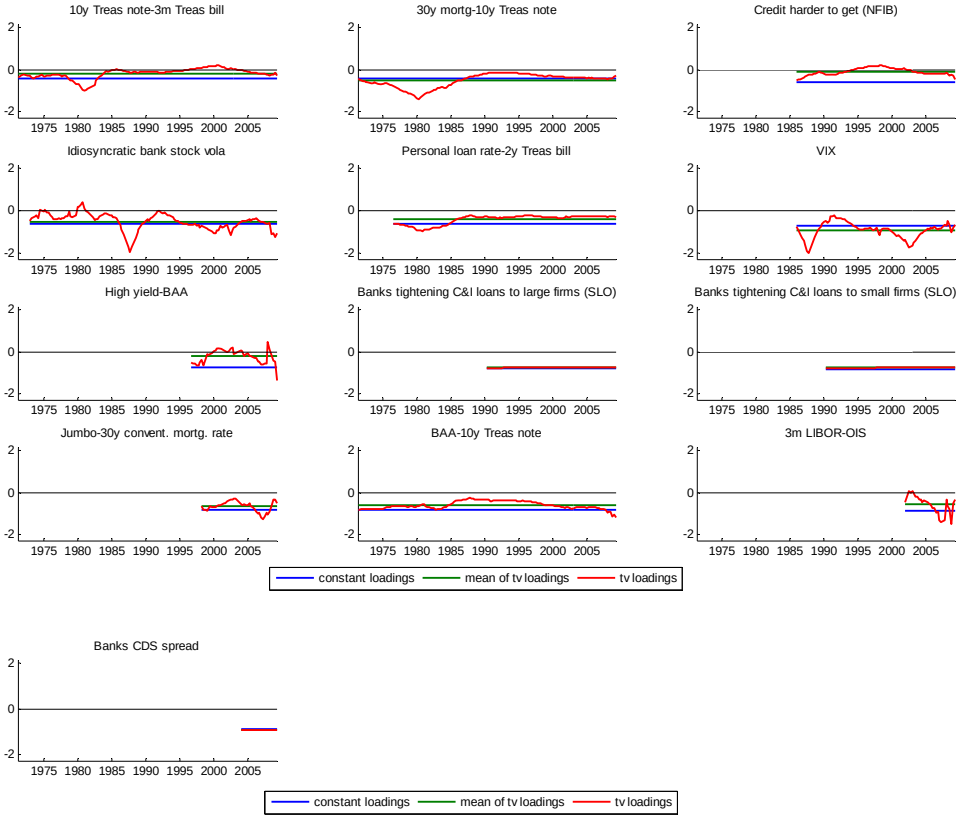


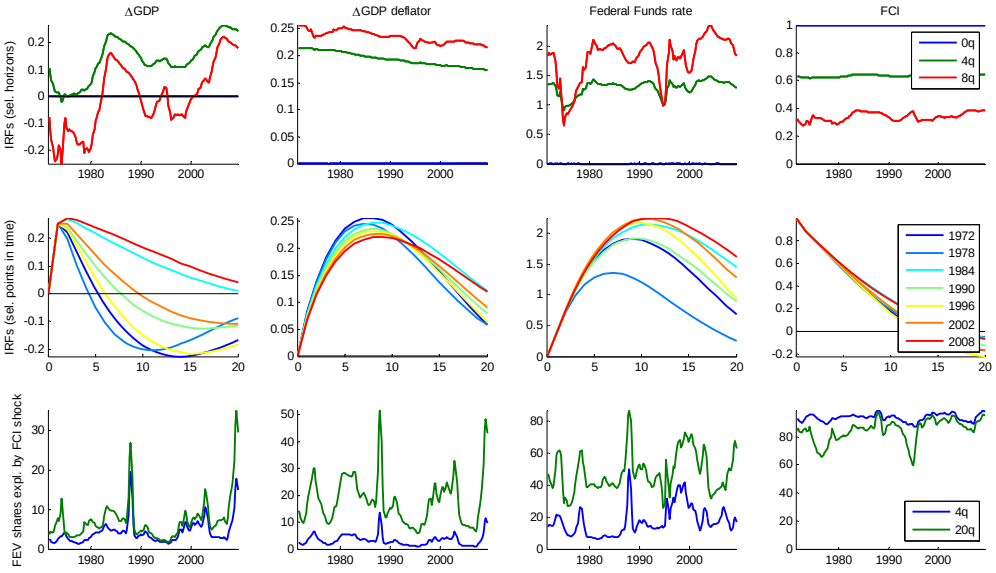
Figure A.1 cont.



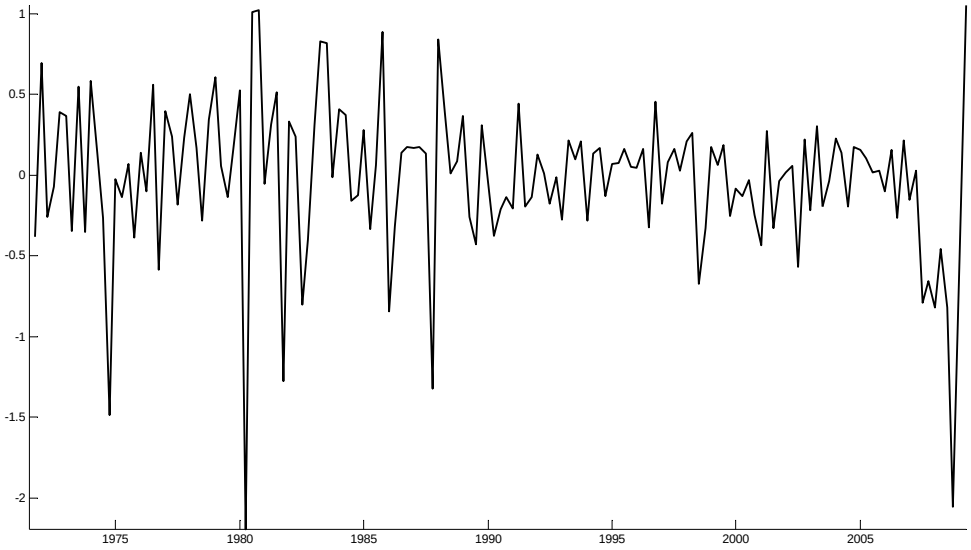
Notes: The estimates of the loadings are based on a one-factor model where the factor is the first PC (our FCI) extracted from the 45 financial variables. This FCI is provided on Mark. W. Watson's webpage. AR(1) processes for the residuals are allowed for, in the constant parameter case using the Cochrane-Orcutt procedure and in the time-varying parameter case using the estimation procedure described in the methodological section of the paper. Some of the 45 variables are not available publically, and we only provide results for the available variables. For the presentation of the results, variables are ordered with respect to their (constant) loadings.

Figure A.2: Robustness analysis: US observables block exogenous to factors estimated from data from 8 countries

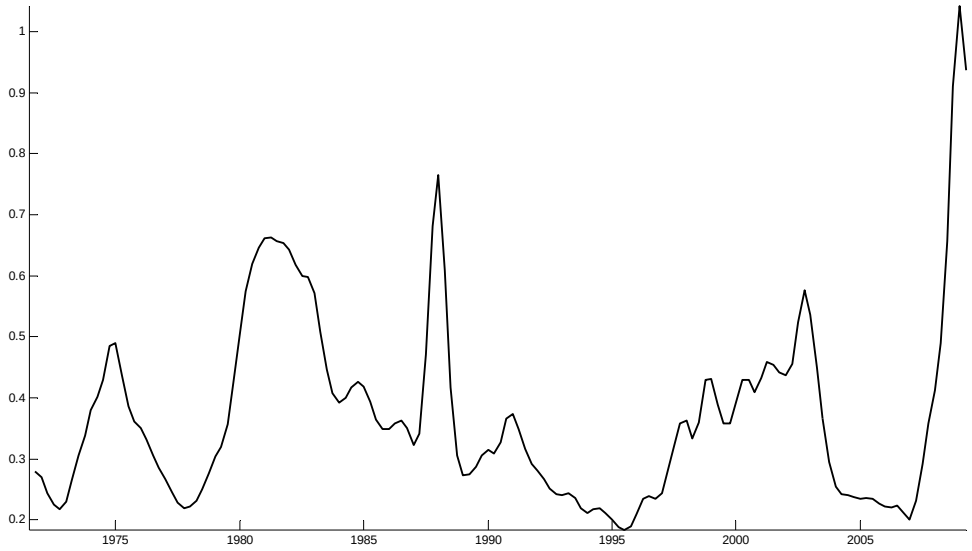
(a) Time-varying impulse responses of US variables to and the forecast error variance share explained by FCI shocks



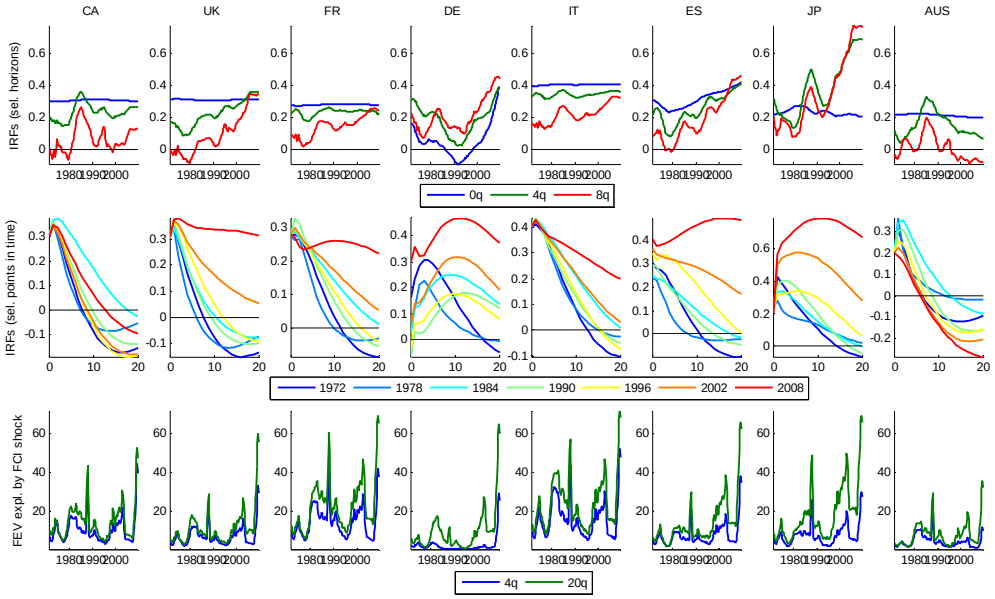
(b) FCI shock estimates



(c) Time-varying FCI shock volatility



(d) Time-varying impulse response functions and forecast error variance decompositions of GDP growth



Notes: The years/points in time for the IRFs refer to the first quarter of the year, i.e. the IRFs in 2008 are the IRFs in 2008Q1. Impulse responses of GDP growth, inflation and the Federal Funds rate are in percentage points, FEV shares are in percent. Shocks are unscaled (not divided by their (time-varying) standard deviations).

Figure A.3: Relation between impulse responses of the level of GDP in 2008-2009 and country-features

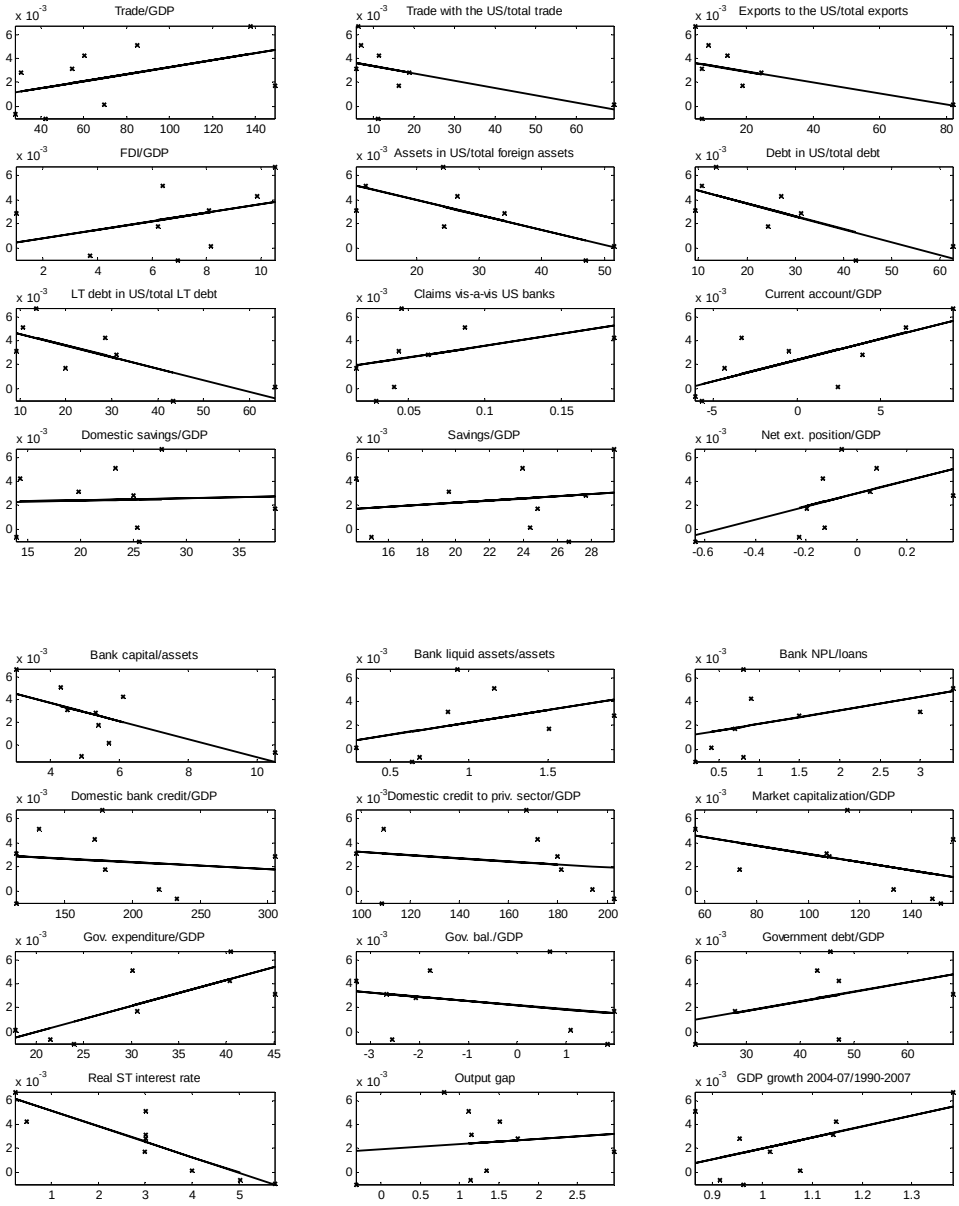
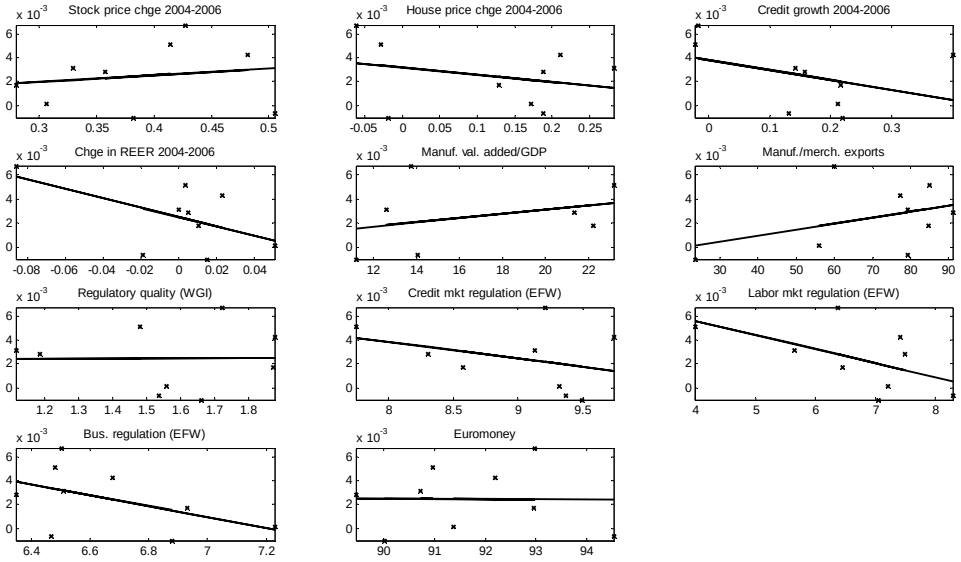


Figure A.3 cont.



Notes: IRFs are on the vertical axis, country features on the horizontal axis. IRFs refer to the 1-year horizon. For details on the country features, see Table A.2.