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RESEARCH ARTICLE

Financial Stability, Monetary Stability and Growth: a PVAR Analysis

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Abstract This paper employs a panel vector autoregressive (PVAR) model to investigate the relationship among financial stress, inflation and growth in 19 advanced economies over the 1999–2016 period. To measure financial stress, we construct a financial stress index (FSI) that provides a signal of financial stress. We apply the PVAR approach along with impulse response functions (IRFs), variance decomposition, and Granger causality tests to FSI data on monetary stability, economic growth, housing markets and government policies. The analysis shows negative responses of the macroeconomic variables to financial stress shocks.

Keywords Impulse responses · Granger causality · Government deficit · Housing prices · Financial stress index

JEL Classification C32 · C43 · F30 · G15

1 Introduction

The impact of macroeconomic factors on finance as well as the channels that lead to financial imbalances have been well researched in the past. However, since the global financial crisis of 2007, the interest of scholars has concentrated on the impact of financial cycles on the real economy, sparking a debate over whether there is such an influence. Previous studies have demonstrated that credit plays a key role in the transmission of financial distress to the broader economy. Several studies indicate that the credit channel is the main channel for the transmission of financial distress

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(Jacobson et al. 2005; Gilchrist et al. 2009; Carlson et al. 2011). Empirical findings highlight credit growth as a predictor of financial stress in economies.

From a theoretical perspective, scholars argue that monetary policy impacts the real economy through the financial accelerator mechanism (Kiyotaki and Moore 1997; Bernanke et al. 1999). Recent theoretical developments have moved in the direction of incorporating the financial sector into a macroeconomic framework, thus relating financial frictions to economic activity (Cúrdia and Woodford 2009; Gertler and Kiyotaki 2010; Gertler and Karadi 2011). Limited research is available on the relationship between financial stability and growth (Hakkio and Keeton 2009; Hatzius et al. 2010; Cevik et al. 2013; Mallick and Sousa 2013a). Controlling for growth and inflation and using a financial soundness indicator, Hatzius et al. (2010) examined the predictive power of financial conditions with regard to future economic activity. (Mittnik and Semmler 2013) argue that in times of severe financial stress, large negative shocks to financial stress have sizeable positive effects on real activity. Afonso et al. (2017) found that a financial stress shock has a negative effect on output and worsens the fiscal situation. Creel et al. (2015), using a panel GMM approach, found supportive evidence that financial instability has a negative effect on economic growth.

Another strand of the literature investigates the linkages between financial stability and monetary stability. Schwartz (1995) found that achieving price stability over the medium-term is sufficient to prevent financial crises. Borio and Lowe (2002) argue that financial instability is possible even in conditions of low inflation and growth in the presence of a combination of supply shocks and asset price booms with overoptimistic assessments of risk. De Graeve et al. (2008) found evidence of a tradeoff between monetary stability and financial stability and suggest that an unexpected tightening of monetary policy increases the mean probability of distress. Thus, a key challenge for central banks is to maintain both monetary and financial stability simultaneously. However, Blot et al. (2015) examined the relationship between monetary stability and financial stability and did not find supportive evidence.

To date, the housing sector and its relationship with financial stability have received limited attention. Zhu (2005) argues that through banking channels and their profitability, property prices have important implications for financial stability. Helbling (2005) contends that housing price bubbles coincide with sharp slowdowns in economic activity and outright recessions. In a panel vector autoregressive analysis, Goodhart and Hofmann (2008) identified a multidirectional link between housing prices and the macroeconomy. Misina and Tkacz (2008) found that real estate prices are important predictors of financial stress. Reinhart and Rogoff (2009a) found that banking crisis episodes are usually related to a housing bust. (Vašíček et al. 2017) used housing prices to test their predictive power for financial stress using a financial stress index (FSI) for 25 OECD countries.

Finally, we examine government deficit as another factor that might lead to severe economic/financial disturbances, as in the recent example of Greece. Reinhart and Rogoff (2009b) argue that global economic factors, including commodity prices and center country interest rates, precipitate sovereign debt crises. They also posit that global debt crises are frequently emitted from the center through commodity prices, capital flows, interest rates, and shocks to investor confidence. Fischer (1993) found that growth is negatively associated with inflation, large budget deficits and distorted foreign exchange markets. Reinhart and Rogoff (2010) argue that an association exists between high debt-to-GDP ratios and low real GDP growth rates. Das et al. (2010) examined the channels and the linkages of public debt to financial stability. They argue that poor debt management can raise sovereign risks, deteriorating financial stability through a feedback loop. Taylor et al. (2012) examined the linkages among primary deficits, interest rates and economic growth. They found that low GDP growth rates are the cause of high debt-to-GDP ratios. Corsetti et al. (2013) examined how the sovereign risk channel affects macroeconomic dynamics and stabilization policy. They argue that the risk channel can become a critical determinant of macroeconomic outcomes in the case of an environment in which the monetary policy is constrained. Examining the relationships among growth, the level of debt, and the stress level, Proaño et al. (2014) found that debt impairs economic growth in the European Monetary Union during times of high financial stress.

In this paper, we examine the transmission of macroeconomic shocks to financial stability and vice versa using the PVAR model developed by Love and Zicchino (2006).

This model allows for fixed effects across countries, and to the best of our knowledge, this procedure has not been applied to financial stability before. PVAR models have been used by several scholars (Lof and Malinen 2014; Grossmann et al. 2014; Galariotis et al. 2016; Jawadi et al. 2016; Georgoutsos and Moratis 2017). Georgoutsos and Moratis (2017) examined default risk transmission at the bank and sovereign levels. Lof and Malinen (2014) studied the relationship between sovereign debt and economic growth. Jawadi et al. (2016) used a PVAR approach to examine fiscal and monetary policy shocks. Furthermore, Mallick and Sousa (2013b) examined the transmission of monetary policy and the impact of fluctuations in commodity prices on the real economy using a PVAR approach. Bénétrix and Lane (2010) measured the impact of fiscal shocks also using a PVAR model. In this study, we use a panel data set of 19 OECD advanced economies covering a period that includes the last 17 years.

The remainder of this paper is structured as follows: Section 2 presents the construction of the FSI and our dataset. Section 3 describes the PVAR framework. Section 4 presents the results of the empirical analyses. Finally, we conclude in Section 5.

2 Data

In this paper, we examine the effects of financial stress innovations on several macroeconomic variables. In a seminal work on financial index construction, Illing and Liu (2006) define financial stress "as a continuous variable with a spectrum of values, where extreme values are called a crisis." In the literature, different methods are available to construct FSIs (Hanschel and Monnin 2005; Illing and Liu 2006; Van den End 2006; Hakkio and Keeton 2009; Cardarelli et al. 2011; Vermeulen et al. 2015; Carlson et al. 2012; Hollo et al. 2012). For the purposes of this paper, we use methods similar to those of (Cardarelli et al. 2011) to construct an FSI, which is constructed by the equal variance-weighted average of 6 variables[1]:

[1] Following Vermeulen et al. (2015), we did not include the TED spread in our stress index.

i. The banking beta (the 12-month rolling beta), where r represents the month-on-month market returns computed over a 12-month rolling window. A beta greater than 1 represents a riskier banking sector, in line with the capital asset pricing model (CAPM).

$$\beta_{i,t} = \frac{\mathrm{cov}\left(r_{i,t}^{M}, r_{i,t}^{B}\right)}{\mathrm{var}\left(\mathrm{M}_{i,t}\right)}, \tag{1}$$

ii. The inverted term spread, measured as the difference between the short-term rate and long-term yields on government-issued securities.
iii. Stock market returns, measured as the inverted month-on-month change in the stock index.
iv. Stock market volatility, estimated by a GARCH(1,1) model using month-on-month returns.
v. A measure of sovereign risk, measured as the difference between the long-term interest rate and the US long-term interest rate.
vi. The foreign exchange market, estimated by a GARCH(1,1) model using month-on-month returns.

The FSI is given by adding the 6 standardized variables; a sum greater than 0 indicates stress, while a sum lower than 0 indicates stability:

$$\begin{aligned} FSI_{i,t} = {} & beta_{i,t} + inverterted\ term\ spread_{i,t} + stock\ market\ returns_{i,t} \\ & + stock\ market\ volatility_{i,t} + sovereign\ debt\ spreads_{i,t} \\ & + excange\ market\ volatility_{i,t} \end{aligned} \tag{2}$$

We empirically investigate the relationships between the FSI and macroeconomic fundamentals for 19 OECD advanced countries from 1999Q1 to 2016Q4, employing quarterly data panel vector autoregressive analysis. Our sample includes Australia (AS), Austria (AU), Belgium (BG), Canada (CN), Denmark (DK), Spain (ES), France (FR), Germany (GER), Greece (GR), Ireland (IR), Italy (IT), Japan (JP), the Netherlands (NL), Norway (NW), Portugal (PT), the United Kingdom (UK), Switzerland (SW), Sweden (SD), and the United States (US). The summary statistics of the input data, spanning the period from the end of 1999 to 2016, are presented in Table 1. On average, IT and ES indicate the highest financial stress levels, followed by FR. The Levin-Lin-Chu (LLC) unit root test for panel data indicates the stationarity of the series. In Panel C, we observe that the FSI and GDP have a significant negative correlation coefficient of −0.24 while the FSI and the CPI have a significantly positive correlation coefficient of 0.15.

The FSI thus captures the major episodes of financial distress during the last two decades, with higher values indicating more stressful periods. In Fig. 1, we plot the FSI for every country together with GDP growth and the change in CPI. From the plot, we distinguish one period of increased financial stress for all countries in 2008 during the global financial crisis. The USA reaches a maximum level of financial stress in

Table 1 Descriptive statistics: advanced countries

Panel A $N=72$	Mean	Median	MAX	MIN	Std.	Mean	Median	Max	Min	Std.	Mean	Median	MAX	MIN	Std.
	FSI					CPI					GDP				
AS	−0.186	−0.548	11.528	−3.0734	2.29802	1.853972	1.772833	3.772333	0.202667	0.875792	1.6431	1.6505	5.57	−5.842	1.976094
AU	−0.487	−0.759	10.318	−3.3555	2.20889	2.713037	2.613833	6.096333	1.051667	1.094287	3.0339	2.876	5.167	1.158	0.983906
BG	−0.369	−1.081	7.1665	−4.2711	2.45773	1.937514	1.913667	5.693333	−1.14133	1.216017	1.6684	1.6035	5.121	−3.811	1.669722
CN	−0.639	−1.123	11.439	−4.3384	2.53761	1.917537	1.9275	4.478667	−0.81867	0.876593	2.3172	2.4755	5.892	−4.048	1.843587
DK	−0.777	−1.171	5.8629	−4.7618	2.27457	1.840093	2.0855	4.209667	0.117	0.937295	1.2457	1.468	4.732	−6.168	2.123439
ES	−1.238	−1.634	3.0275	−3.6286	1.66877	2.220343	2.645833	4.922	−1.113	1.589416	1.929	3.081	5.586	−4.263	2.684996
FR	−1.094	−1.496	4.5033	−3.8324	1.76741	1.389356	1.633167	3.289667	−0.402	0.849332	1.4165	1.322	4.439	−3.824	1.555222
GER	0.2962	−0.333	8.2702	−3.1577	2.31778	1.378968	1.387333	3.118667	−0.20667	0.744946	1.3636	1.6095	5.569	−6.926	2.31334
GR	−0.385	−0.382	2.5128	−3.2221	1.36229	2.167181	2.822167	5.55	−2.44733	2.055831	0.3327	0.8435	6.778	−10.277	4.66284
IR	−0.57	−1.293	8.652	−3.4491	2.55677	2.055935	2.292833	6.675	−6.06367	2.620584	5.324	5.385	27.717	−9.055	6.598652
IT	−1.462	−1.653	3.3221	−5.1878	1.7596	1.838986	2.139	3.967	−0.431	1.061835	0.3823	0.8695	4.19	−7.209	2.239414
JP	0.2107	−0.312	10.699	−3.3176	2.58863	−0.02283	−0.20333	3.606	−2.17233	1.038817	0.8429	1.07	5.527	−8.67	2.223669
NL	0.311	−0.602	11.209	−4.6259	2.9525	1.882222	1.837333	4.402333	−0.00933	0.994615	1.6013	1.803	5.661	−4.52	2.122766
NW	−0.089	−0.456	12.935	−4.171	2.7408	2.085069	2.056667	4.856	−1.299	1.089211	1.7202	1.8365	5.393	−1.567	1.666516
PT	−0.499	−0.694	4.0452	−3.1014	1.83494	2.071343	2.419833	4.748	−1.404	1.496686	0.6968	1.2695	4.809	−4.466	2.282493
SD	−0.065	−0.304	5.6287	−3.4654	1.83883	1.169963	1.038167	4.424	−1.127	1.157613	2.4732	2.992	7.872	−6.301	2.706271
SW	−0.02	−0.564	7.2556	−2.8198	2.0704	0.48775	0.469833	3.003333	−1.39133	0.920821	1.8763	1.9805	4.63	−3.185	1.705113
UK	−0.706	−1.214	8.7131	−4.2246	2.40782	1.951569	1.713333	4.848667	−0.052	1.153338	1.9318	2.194	4.906	−5.922	1.96749
US	−0.034	−0.545	11.084	−4.286	2.74659	2.180787	2.079667	5.253	−1.607	1.25477	2.1035	2.277	5.266	−4.062	1.810935

Table 1 (continued)

Panel B												
	Mean	Median	Max	Min	Std.	N	Mean	Median	Max	Min	Std.	N
	DEF	HP										
AS	−0.05646	0.059833	5.294333	−3.852	1.21783	52	0.008841	0.008326	0.08284	−0.07483	0.024321	67
AU	−0.98636	−0.65383	7.763	−7.93633	3.03832	72	0.018678	0.018943	0.059506	−0.02222	0.019817	72
BG	NA	NA	NA	NA	NA	0	0.008631	0.009304	0.035654	−0.02385	0.013308	47
CN	−0.09948	0.008833	2.139	−4.85067	1.235289	72	0.016746	0.016504	0.061637	−0.03446	0.018397	72
DK	0.06563	0.028333	3.041667	−3.258	1.182537	72	0.010697	0.01153	0.077626	−0.07787	0.026184	72
ES	−0.17164	0.364833	10.26333	−10.2097	3.78227	52	0.010467	0.012213	0.065068	−0.05195	0.027672	72
FR	−0.17511	0.008667	11.92867	−10.5	3.866514	72	0.012486	0.010595	0.052279	−0.03726	0.019527	72
GER	0.258176	0.8835	12.77233	−14.899	4.925162	72	0.003247	0.001398	0.02224	−0.01022	0.007384	72
GR	−0.05328	−0.01933	6.988333	−6.298	1.630064	72	−0.00965	−0.01174	0.041988	−0.03951	0.017836	43
IR	−0.00669	0.075	0.995	−1.84967	0.493769	72	0.008151	0.01253	0.097731	−0.07775	0.037643	72
IT	−0.04936	−0.1455	11.83267	−15.4547	5.701025	72	0.005053	0.005437	0.057372	−0.02207	0.013306	72
JP	0.30995	3.186333	26.11633	−45.531	13.4552	43	−0.00482	−0.00757	0.027407	−0.01868	0.009924	72
NL	0.033471	0.0465	4.004	−7.452	1.606759	68	0.008254	0.008745	0.052992	−0.03889	0.017758	72
NW	−0.06375	0.021333	4.108	−6.79833	1.786578	72	0.018055	0.019423	0.080997	−0.0704	0.02791	72
PT	−0.02223	0.018167	1.923333	−2.097	0.597187	72	0.000213	0.000795	0.037446	−0.03192	0.015991	35
SD	0.044009	0.198167	5.016333	−6.67433	1.94668	72	0.018406	0.019079	0.061293	−0.05187	0.017753	72
SW	0.021972	−0.00717	0.635667	−0.53967	0.280575	72	0.007682	0.007602	0.02569	−0.01025	0.006772	72
UK	−0.33398	−0.01467	8.696667	−13.2437	3.681925	72	0.015298	0.018297	0.082	−0.06616	0.025713	72
US	−2.94444	0.224833	71.97267	−110.597	29.28226	72	0.009837	0.015788	0.041659	−0.05137	0.021817	72

Table 1 (continued)

Panel B: Panel data descriptive statistics					
	FSI	CPI	GDP	DEF	HP
Mean	−0.411	1.7431	1.7843	−0.2527	0.00942
Median	−0.811	1.7893	1.906	0.05333	0.00874
Max	12.935	6.675	27.717	71.9727	0.09773
Min	−5.188	−6.064	−10.28	−110.6	−0.07787
Std. Dev.	2.3073	1.4252	2.8628	7.97651	0.02212/row>
Skewness	1.6823	−0.245	1.0567	−3.4851	−0.09406
Kurtosis	7.9049	4.2899	18.667	63.4139	4.31852
JB	2016.541***	108.5279***	14,246.28***	188,465.3***	94.01567***
LLC	−12.4079***	−3.65513***	−5.91240***	−13.1835***	−5.84545***
N	1368	1368	1368	1223	1272
Panel C: Pairwise correlations among variables	1	2	3	4	5
FSI	1				
CPI	0.14333***	1			
GDP	−0.24329***	0.10241***	1		
DEF	−0.16682***	0.05910**	0.18201***	1	
HP	−0.28362***	0.04940*	0.38994***	0.09591***	1

J-B denotes the Jarque-Bera test for normality. LLC is the panel unit root test (with just a constant using the Akaike information criterion (AIC) to select the lag length and the Newey-West automatic bandwidth selection and the Bartlett kernel) of Levin, Lin and Chu (2002), Ho: Panels contain unit roots vs. Ha: Panels are stationary. *** denotes significance at the 1% level. ** denotes significance at the 5% level

March 2008. The financial distress of several other countries peaks during 2008, e.g., CN, the NL, and the UK. In the case of GC, the FSI reaches a maximum level of 2.51 in February 2010 during this nation's sovereign debt crisis.

3 Methodology

This paper is built on the PVAR framework as an attempt to examine the dynamic relationship among financial stability, monetary stability and growth. Using the VAR methodology, we can treat our variables of interest as endogenous and therefore examine the effects of financial stress on financial stability and growth, as well as the reverse effects. Following Love and Zicchino (2006), we exploit a PVAR generalized method of moments (GMM) estimator to explore the stress dynamics and macroeconomic variables of 19 OECD advanced countries. Our panel VAR model can be written as follows:

$$Y_{\mathrm{it}} = \Gamma_0 + \Gamma(L)Y_{\mathrm{it-1}} + \mathrm{f_i} + d_t + \mathrm{e_{it}}, \quad \mathrm{i} = 1, \ldots, \mathrm{N} \quad \mathrm{t} = 1, \ldots, \mathrm{T} \tag{3}$$

where $\mathrm{Y_{it}}$ is a vector of three endogenous variables: GDP (real GDP growth), CPI (change in the CPI) and the FSI; Γ_0 is a vector of constants; $\Gamma(\mathrm{L})$ is a matrix polynomial in the lag operator, $\mathrm{f_i}$ denotes fixed effects, capturing unobservable time-invariant factors at a country level; $\mathrm{d_t}$ denotes the forward mean-differencing; and $\mathrm{e_{it}}$ is a vector of independently and identically distributed errors. The data were time demeaned and forward mean-differenced using the Helmert procedure and following Arellano and Bover (1995) as fixed effects are usually correlated with the regressors. Model 3 was estimated using GMM-style instruments, as proposed by Holtz-Eakin et al. (1988). First, we present the results of the PVAR model, and then, we proceed to Granger causality Wald tests for each equation of the underlying PVAR model. Finally, we present the impulse response functions (IRFs) using Monte Carlo (MC) simulations for the confidence intervals. For computation of the impulse-response functions (IRFs) and the forecast-error variance decompositions (FEVDs), we follow the Choleski decomposition of variance–covariance matrix residuals, transforming our system in a recursive VAR for identification purposes (Hamilton 1994).

4 Empirical Results

First, we test for the stability of our PVAR model by checking whether all eigenvalues lie within the inner circle. Usually, variables that are introduced first in VAR models are assumed to be the most exogenous and affect subsequent variables both contemporaneously and with a lag, whereas variables that are ordered later are less exogenous and affect previous variables only with a lag in such a recursive VAR, indicating that the GDP and CPI react to the FSI with a lag. Following these general directions, we introduce macroeconomic variables first in the system and estimate our baseline model: GDP → CPI → FSI. Next, we introduce our augmented model of five variables including a measure of government deficit (deficit/surplus, DEF) and a measure of the real estate

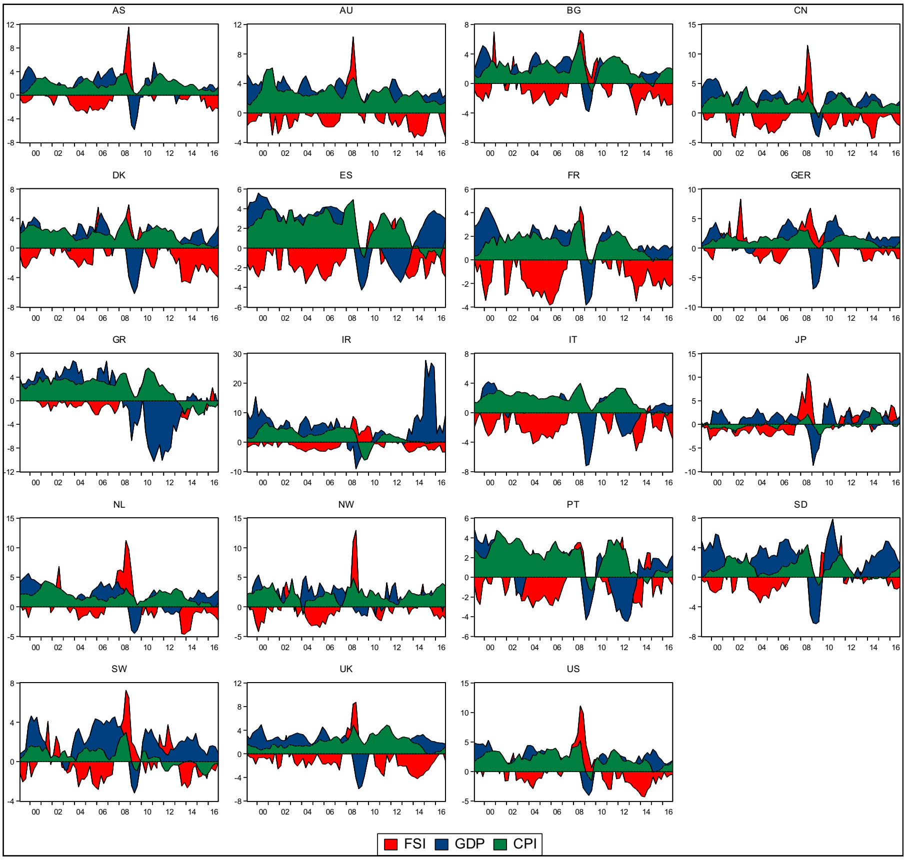

Fig. 1 FSI, GDP, and CPI

markets (housing prices, HPs): GDP → DEF → HP → CPI → FSI. Our ordering indicates that shocks commonly originate in the real sector, while financial stress is likely a reaction to various shocks rather than their immediate source. In other words, our ordering implies that a lag exists between financial stress and its impact on the economy.

4.1 PVAR Results

First, we present the results from the estimated PVAR (2) and the GMM coefficients. Table 2 shows that GDP growth has a negative effect on FSI concurrently and after a lag but that it has an effect on CPI only after a lag. Taking the FSI as the dependent variable, we observe that most of the GMM coefficients of the CPI and GDP growth are significant.

4.2 Granger Causality

Next, we examine the Granger causation of financial stress among countries. In Table 3, we report the chi-square Wald statistics for the null hypothesis that the FSI does not Granger cause CPI or GDP growth and vice versa. The final row reports the

Table 2 PVAR (2) coefficient estimates

Dependent variable	GDP	CPI	FSI
GDP (1)	0.9078***	0.0521***	−0.0793***
	(20.3150)	(3.8067)	(−2.9741)
GDP (2)	−0.0654	−0.0192	0.0619**
	(−1.3885)	(−1.4808)	(2.4341)
CPI (1)	−0.0840	1.1815***	0.4958***
	(−0.8846)	(30.9535)	(6.0965)
CPI (2)	−0.1843***	−0.3268***	−0.5130***
	(−2.6380)	(−9.0485)	(−6.3024)
FSI (1)	−0.0749***	−0.0039	0.8013***
	(−3.0657)	(−0.2746)	(20.1501)
FSI (2)	−0.0741***	0.0050	−0.0615*
	(−3.1194)	(0.4114)	(−1.8021)

No. of obs. = 1311, No. of panels = 19, Instruments: l(1/4). Robust standard errors, Z statistics in parentheses. The VAR model estimated 2 lags according to the modified Bayesian information criterion (mBIC). *** denotes significance at the 1% level. ** denotes significance at the 5% level. * denotes significance at the 10% level

joint probability of all lagged variables in the equation, in which we test the null hypothesis that all lags of all variables can be excluded from each equation in the VAR system. We can characterize Granger causalities from the FSI to GDP growth and from the CPI to GDP growth as bidirectional. However, Granger causation from the FSI to the CPI is found to be unidirectional. In that case, we argue that the causality runs one way only – from financial stress to inflation. The joint significance chi-square statistics in the last row indicate all variables are Granger caused by all lagged variables.

4.3 Impulse Response Functions

The same ordering used in the PVAR was used in the estimation of the IRFs and FEVDs. Figure 2 plots the responses to a one-standard deviation shock for a 10-

Table 3 Granger causality tests among the advanced economies

	GDP	CPI	FSI
GDP		25.019***	9.047**
CPI	17.863***		44.769***
FSI	40.620***	0.155	
All	81.777***	25.669***	47.056***

The tests are based on the PVAR(2) model. The entries in the table are the chi-square statistics for the null hypothesis that the excluded variable does not Granger cause the equation variable vs. the alternative hypothesis that the excluded variable Granger causes the equation variable. *** denotes significance at the 1% level. ** denotes significance at the 5% level. * denotes significance at the 10% level

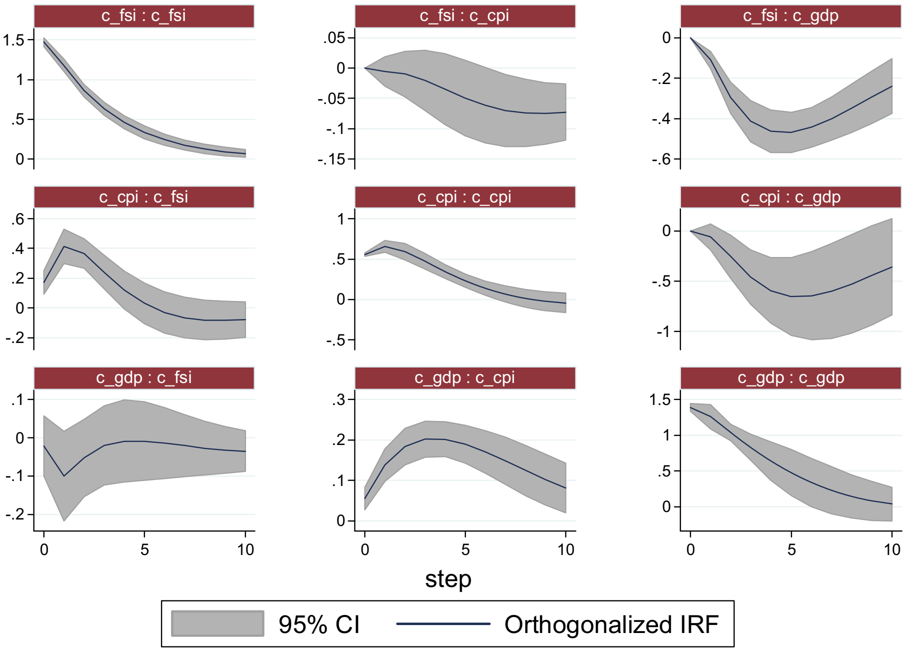

Fig. 2 IRFs of shocks, baseline model. Note: Impulse: Response, PVAR(2), error bands were drawn from 500 MC repetitions

quarter period. GDP growth responds negatively and significantly to a shock to the FSI. Our findings are consistent with those of other scholars who examine the relationship between financial stress and growth (Hakkio and Keeton 2009; Bloom 2009; Cevik et al. 2013; Mallick and Sousa 2013a, b; Apostolakis and Papadopoulos 2015; Creel et al. 2015). In the first lags, the FSI responds negatively but not significantly to a shock to GDP growth and responds positively to an inflation shock, indicating that a positive shock to the general level of prices increases financial stress in the short-term. Regarding inflationary responses to a GDP growth shock or an FSI shock, we observe a positive and significant impact from a GDP growth shock; however, inflation responds negatively but not significantly to a shock to the FSI. Finally, GDP growth responds negatively to an inflation shock, which is consistent with the findings of Apostolakis and Papadopoulos (2015).

4.4 Variance Decompositions

Table 4 reports the FEVDs of the baseline PVAR model after 10 and 20 periods. We observe that the CPI explains approximately 14% of the total variance in GDP and that GDP growth and FSI explain approximately 25% and approximately 28% of the total variance in the CPI, respectively. GDP growth has the largest explanatory power for financial stress, explaining approximately 14%, which indicates a somewhat large influence. The CPI explains only a small portion of the variance in the FSI (2%).

Table 4 Forecast-error variance decomposition (FEVD)

Response variable & Forecast horizon	Impulse variable		
	GDP	CPI	FSI
GDP			
10	0.6323	0.2373	0.1304
20	0.6063	0.2549	0.1387
CPI			
10	0.1403	0.8463	0.0134
20	0.1443	0.8302	0.0255
FSI			
10	0.0029	0.0767	0.9204
20	0.0043	0.0790	0.9167

*** denotes significance at the 1% level. ** denotes significance at the 5% level. * denotes significance at the 10% level

4.5 Augmented PVAR Model Including Housing Prices and Government Deficit

Tables 5, 6 and 7 show the results of the PVAR analysis with 5 variables. Table 6 shows that there is a bidirectional relationship between the FSI and housing prices. Table 7 indicates that housing prices can explain approximately 10% of the variance in the FSI while the deficit can explain only 1%. Approximately 10% of the variation of GDP growth is explained by the macroeconomic variables. Financial stress and GDP growth explain a large portion of the variation in

Table 5 PVAR (1) estimates

Variables	GDP	DEF	HP	CPI	FSI
GDP	0.7150***	0.2371***	0.0004*	0.0159*	−0.0129
	(20.3570)	(4.0316)	(1.9140)	(1.7649)	(−0.6760)
DEF	0.0073*	0.5081***	−0.0001**	0.0102***	0.0034
	(1.8396)	(6.8000)	(−2.1457)	(4.2280)	(0.6437)
HP	37.2332***	−0.0848	0.6276***	7.2232***	13.0846***
	(11.7641)	(−0.0137)	(16.0910)	(6.3049)	(5.0680)
CPI	−0.3275***	0.2610*	0.0007	0.8369***	0.0595
	(−5.3635)	(1.7750)	(1.3526)	(35.2268)	(1.2780)
FSI	−0.1301***	−0.1766*	−0.0016***	0.0116	0.8111***
	(−5.3783)	(−1.6757)	(−5.3601)	(1.1494)	(22.6450)
Observations	1121	1121	1121	1121	1121

No. of obs. = 1121, No. of panels = 19, Instruments: l(1/4). Robust standard errors, Z statistics in parentheses. The VAR model estimated 1 lag according to the mBIC. *** denotes significance at the 1% level. ** denotes significance at the 5% level. * denotes significance at the 10% level

Table 6 Granger causality tests among the advanced economies

Lags (1)	GDP	DEF	HP	CPI	FSI
GDP		16.254***	3.663*	3.115*	0.457
DEF	3.384*		4.604**	17.876***	0.414
HP	138.393***	0		39.751***	25.684***
CPI	28.768***	3.151*	1.829		1.633
FSI	28.926***	2.808*	28.73***	1.321	
All	271.364***	28.825***	38.871***	70.823***	30.367***

The tests are based on the PVAR(1) model. The entries in the table are chi-square statistics for the null hypothesis that the excluded variable does not Granger cause the equation variable vs. the alternative hypothesis that the excluded variable Granger causes the equation variable. *** denotes significance at the 1% level. ** denotes significance at the 5% level. * denotes significance at the 10% level

inflation. The variation in housing prices is explained by the deficit (33%) and GDP growth (18%). Figure 3 illustrates the impulse responses of the augmented model: GDP → DEF → HP → CPI → FSI. The response of GDP growth to FSI shocks remains negative and significant, as in our three-variable model. (Afonso et al. 2017) found that a financial stress shock has a negative effect on output and worsens the fiscal situation. Additionally, we observe no significant response by financial stress to a positive growth shock. A positive shock to the FSI has a negative but small effect on housing prices. A shock to housing prices significantly increases financial stress for the first periods. A larger negative response to deficit from a positive shock to the FSI is observed.

Table 7 Forecast-error variance decomposition (FEVD)

Response variable & Forecast horizon	GDP	DEF	HP	CPI	FSI
GDP					
10	0.4979	0.0158	0.1793	0.1289	0.1781
20	0.4852	0.0173	0.1779	0.1274	0.1922
DEF					
10	0.0282	0.6082	0.3313	0.0216	0.0106
20	0.0286	0.6005	0.3352	0.0250	0.0108
HP					
10	0.0298	0.0071	0.8610	0.0113	0.0908
20	0.0315	0.0073	0.8521	0.0115	0.0977
CPI					
10	0.0390	0.0347	0.0283	0.8976	0.0005
20	0.0389	0.0348	0.0311	0.8948	0.0005
FSI					
10	0.0061	0.0082	0.0177	0.0828	0.8853
20	0.0060	0.0090	0.0177	0.0876	0.8797

*** denotes significance at the 1% level. ** denotes significance at the 5% level. * denotes significance at the 10% level

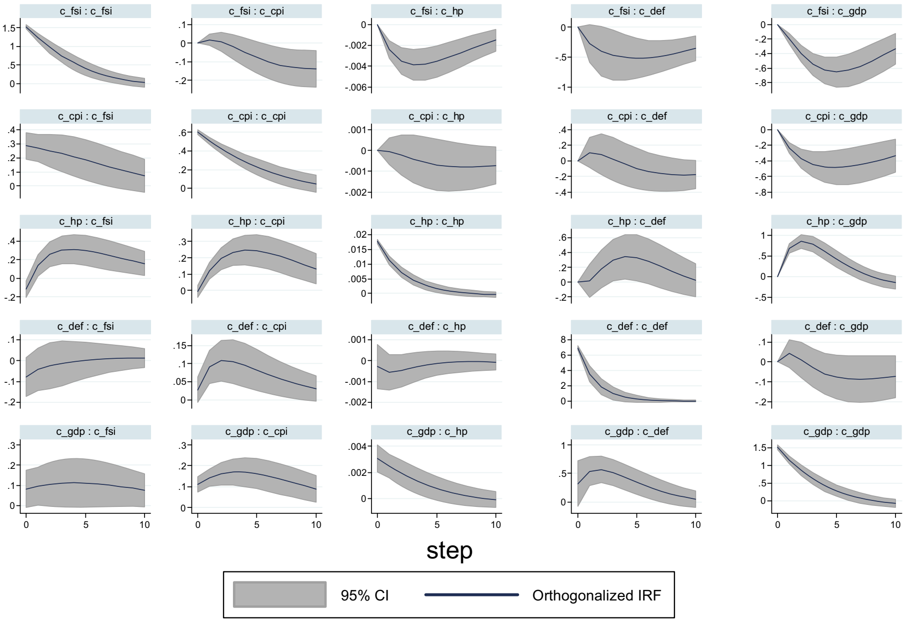

Fig. 3 IRFs of shocks, 5-variable model. Note: VAR(1), error bands were drawn from 500 repetitions

Furthermore, we observe that a positive impact on housing prices increases GDP growth. This outcome is consistent with the findings of Goodhart and Hofmann (2008). Notably, the IRF of GDP growth on the deficit shows that when there is a positive shock to GDP growth, the deficit shows a strong positive response for the first 2 periods (bottom row). Reversely, the response of GDP growth to a deficit shock, although positive in the short run before becoming negative, is not significant. Our findings contradict those of Taylor et al. (2012), who found a negative response of the real primary deficit to a shock to GDP growth. Proaño et al. (2014) found that financial stress affects the relationship between debt and economic growth via its impact on risk premia, particularly bond spreads. Debt impairs economic growth primarily during times of high financial stress. Furthermore, Lof and Malinen (2014) found a significant negative effect of growth on debt; however, the reverse effect of debt on growth is not significant. A positive shock to the deficit translates into a positive response by the CPI. Examining emerging market economies, Jawadi et al. (2016) show that an unexpected fiscal policy expansion has a positive effect on output and has a persistent and positive effect on the price level.

4.6 Robustness Tests

As a robustness test, we first use an alternative PVAR model and the least squares dummy variable estimator, as described by Cagala and Glogowsky (2015). In Appendix 1, Fig. 6, we provide the IRFs using this approach. The results are similar, except for the response of the FSI to a growth shock (bottom left), which is now positive and significant after a lag. Furthermore, the responses of the FSI and the CPI to CPI and GDP growth shocks, respectively, have become nonsignificant. Second, we conduct sensitivity analyses with respect to different Cholesky orderings; additionally, we construct and examine cumulative IRFs. More volatile variables are usually placed at the end of the model, as they are expected to affect all other variables contemporaneously but themselves are affected by all other variables with a lag. As GDP and the deficit are expected to affect all other variables contemporaneously but are themselves affected by all others with a lag, they can be found at the beginning of the system; however, the FSI can be always found at the end of the Cholesky ordering, as it is expected to react contemporaneously to all other variables in the system but to affect the other variables with a lag. The following models were estimated:

i. GDP→DEF→CPI→HP→FSI,
ii. DEF→GDP→HP→CPI→FSI,
iii. DEF→GDP→CPI→HP→FSI.

To further examine our previous result from the Granger causality analysis that the FSI Granger causes GDP and CPI, we invert the Cholesky ordering and we put the FSI first, implying that financial stress has an immediate impact on real economy variables.

iv. FSI→GDP→DEF→CPI→HP.

Figure 4 presents the cumulative IRFs for the baseline model, and Fig. 5 presents them for our augmented model. The results verify our previous findings: GDP growth leads to a higher level of inflation. The CPI leads to higher financial stress but lower GDP growth, while the FSI leads to lower inflation and GDP growth. In addition, we

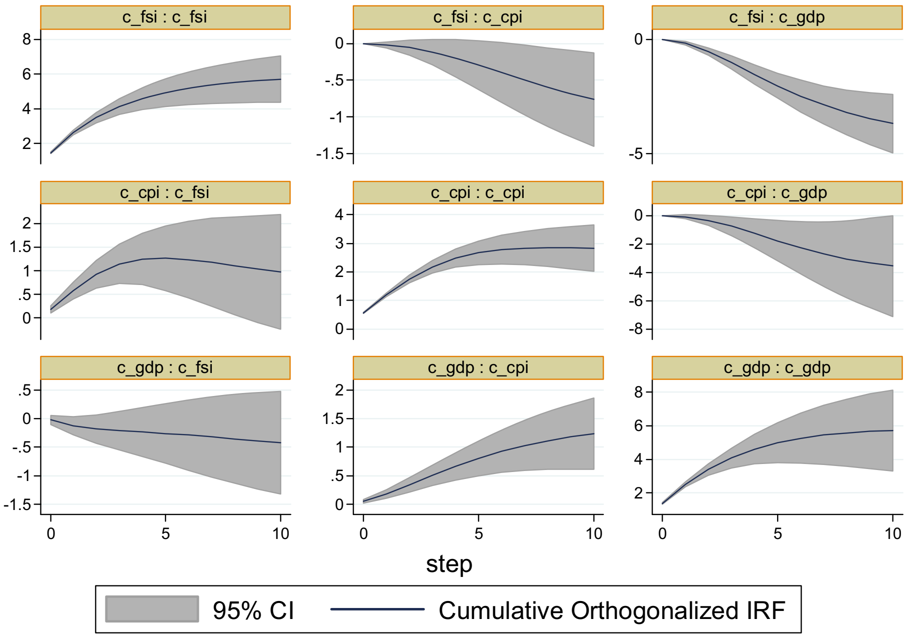

Fig. 4 Accumulated IRFs of shocks. Note: VAR(2), error bands were drawn from 500 repetitions

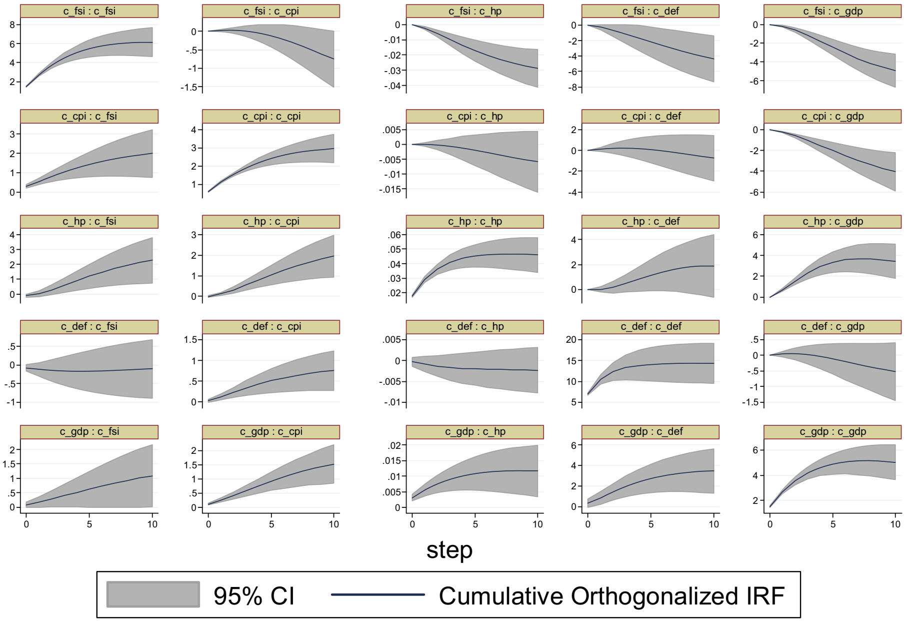

Fig. 5 Accumulated IRFs of shocks, 5-variable model. Note: VAR(1), error bands were drawn from 500 repetitions

observe no significant response by the FSI to a GDP growth shock. In Fig. 5, we observe that a shock to housing prices has a positive and significant impact on financial stress but that a financial shock has a negative impact on the deficit and housing prices.

In Appendix 1, Figs. 7-10, the IRFs of the different orderings of the five-variable PVAR model are shown. The IRFs are similar to the initial ordering, and we can argue that our findings are resistant to the different variable orderings. In Fig. 10, we provide the results of putting the FSI first in the ordering (iv), which remain similar to previous findings. The response of GDP to an FSI shock remains negative and significant, while the response of deficit remains negative but has become not significant. The response of financial stress to a GDP shock is positive but remains not significant.

5 Conclusions

This paper examines the macroeconomic-financial stress relationship by applying a PVAR approach for 19 advanced economies and constructing IRFs over the 1999–2016 period. To the best of our knowledge, this paper is the first to adopt a PVAR framework to study the relationship among financial stability, monetary stability and growth. The results reveal that a positive shock to financial stress results in a negative impact on all macroeconomic variables; first, it has a negative impact on growth and a negative impact on inflation. The response by housing prices and the deficit are also negative. Financial stress is positively influenced by shocks to inflation and increases in housing prices. In contrast, neither a positive economic shock nor an increase in the deficit influence financial stress. Analyses of variance decomposition and Granger causality further support our findings of the relationship between financial stress and macroeconomic variables. We find that growth, the deficit, housing prices and inflation explain approximately 30% of the variation in financial stress. Monitoring the risk stemming from potential housing bubbles is important for the resiliency of the financial system. Overall, our findings provide new insights about the importance of financial stability in the context of macroprudential policy and regulation. In this light, it is important for policymakers and central bankers to develop a macroprudential monitoring framework and tools for examining financial stability and soundness. Future research should study the relationship between financial stress and macroeconomic variables, focusing on the potential differences between developed and developing countries.

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Appendix 1: Robustness tests

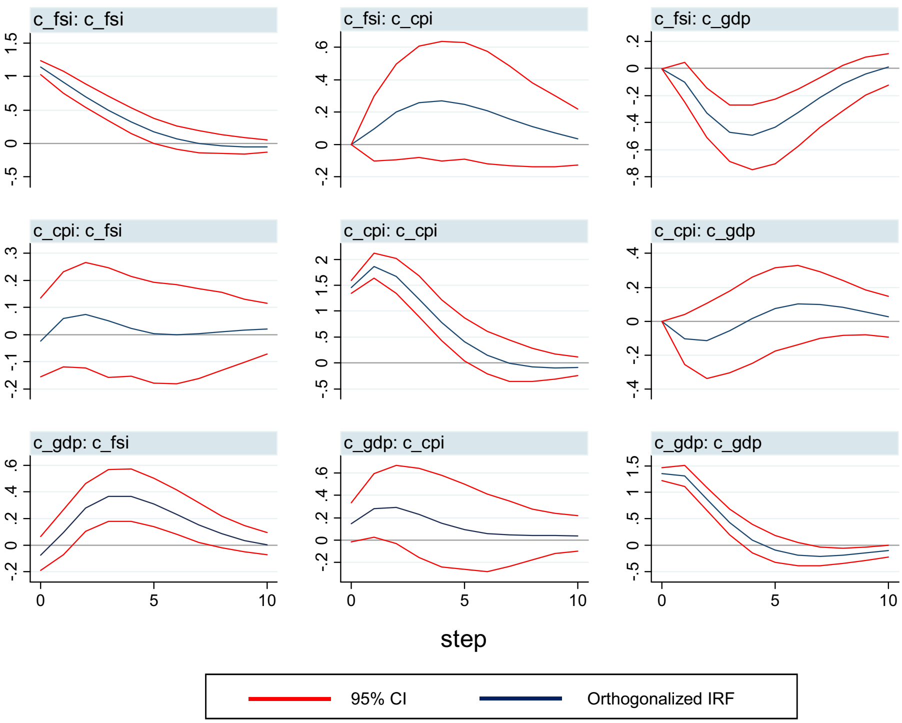

Fig. 6 Orthogonalized IRFs of shocks, using the least squares dummy variable estimator. Note: VAR(2), error bands were drawn from 500 repetitions. 95% confidence intervals

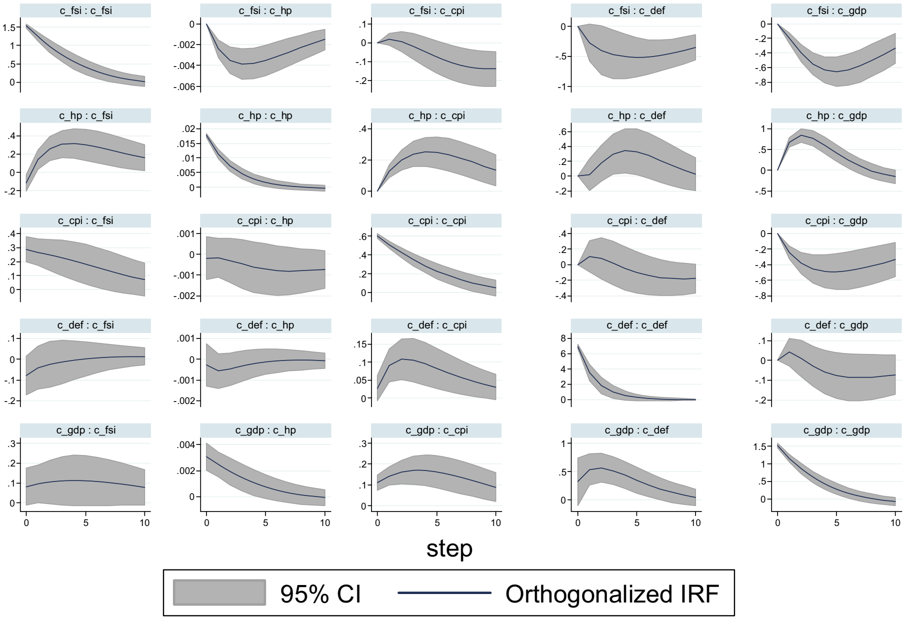

Fig. 7 Different Cholesky ordering: GDP → DEF → CPI → HP → FSI. Note: VAR(1), error bands were drawn from 500 repetitions

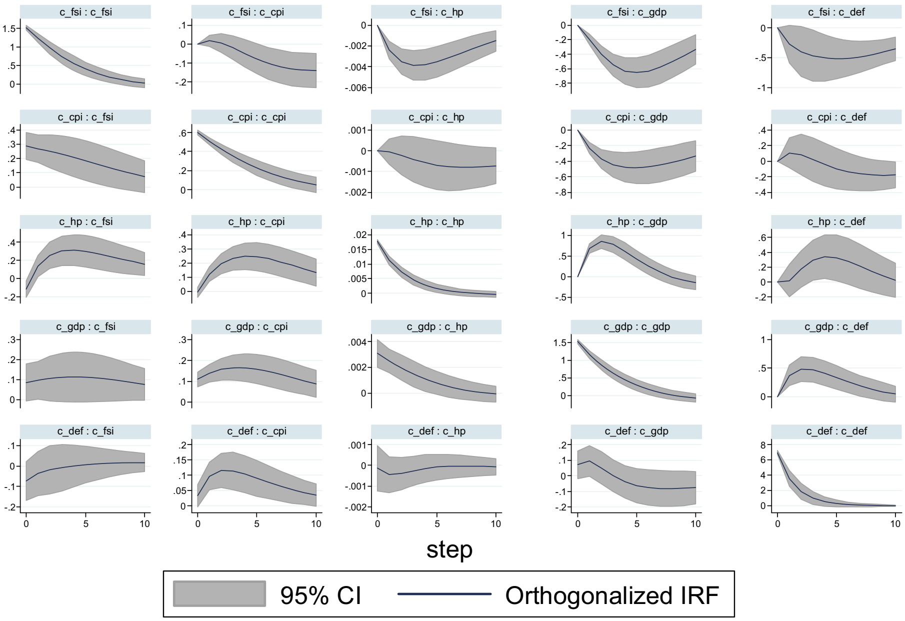

Fig. 8 Different Cholesky ordering: DEF → GDP → HP → CPI → FSI. Note: VAR(1), error bands were drawn from 500 repetitions

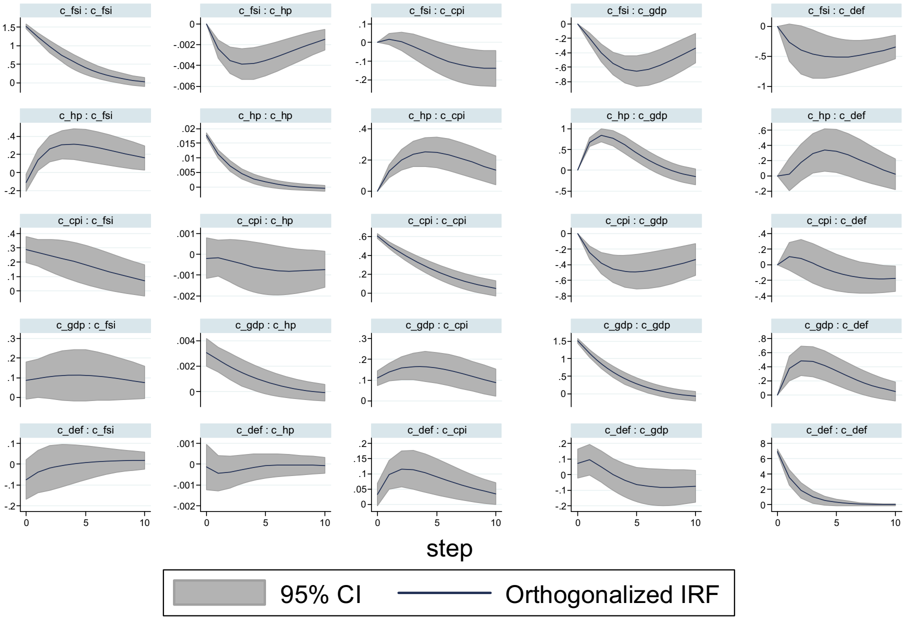

Fig. 9 Different Cholesky ordering: DEF → GDP → CPI → HP → FSI. Note: VAR(1), error bands were drawn from 500 repetitions

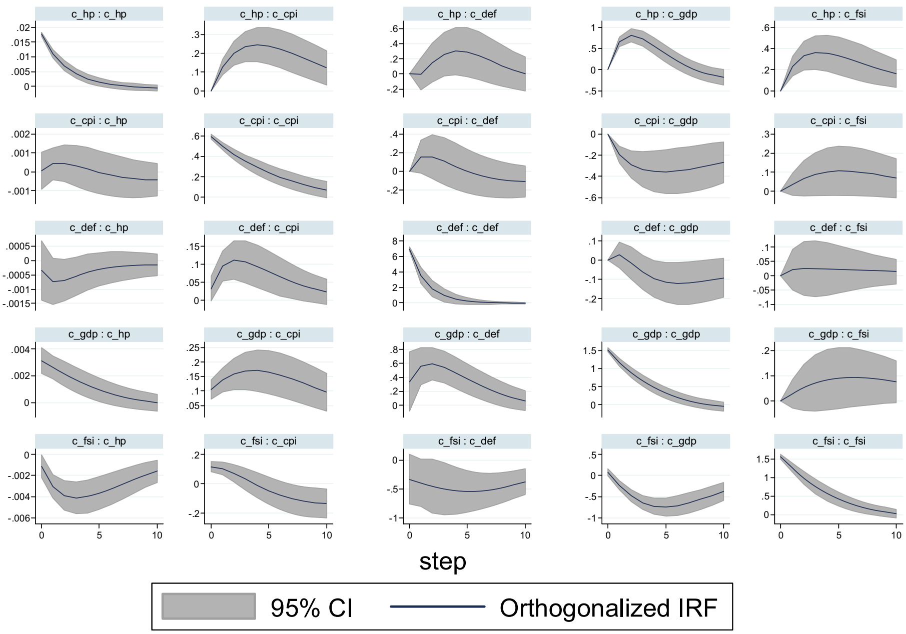

Fig. 10 Different Cholesky ordering: FSI → DEF → GDP → CPI → HP. Note: VAR(1), error bands were drawn from 500 repetitions

Appendix 2: Data description

A) FSI components.

Component	Calculation	Source
Banking beta (CAPM)	$B_{it} = {}^{cov\left(r_{it}^{M}, r_{it}^{B}\right)}\big/_{\sigma^2_{i,M}}$	DataStream
Inverted term spread	The government short-term rate minus the government long-term rate	DataStream and OECD
Sovereign risk	The long-term interest rate - the US long-term interest rate (0 for the US)	DataStream and OECD
Stock market returns	The inverted month-over-month change in the stock index	DataStream
Stock market volatility	GARCH (1.1)	DataStream
Exchange market volatility	GARCH (1.1)	BIS

Note: Monthly series. The aggregate FSI is compiled by standardizing and summing the six components: FSI_t = Banking beta + Inverted term spread + Sovereign risk+ Stock market returns + Stock market volatility + Exchange market volatility.

B) Description of the time series used in the second part of the paper.

Series	Frequency	Source	Description
GDP	Q	DataStream	Real gross domestic product, % YoY, Standardized
CPI	M	DataStream	Consumer price index, % YoY, Standardized
House prices	Q	BIS, DataStream	Residential Property Prices; Long Series, NSA &OE Residential Property Prices: All Dwellings, % MoM
Govt. debt	M	DataStream	Central Government Deficit/Surplus, CHG YoY, Standardized, CURN

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