UNIVERSITEIT GENT

**FACULTEIT ECONOMIE
EN BEDRIJFSKUNDE**

**TWEEKERKENSTRAAT 2
B-9000 GENT
Tel. : 32 - (0)9 – 264.34.61
Fax. : 32 - (0)9 – 264.35.92**

WORKING PAPER

Financial shocks and the real economy in a nonlinear world: From theory to estimation

Andrea Silvestrini

Andrea Zaghini

June 2015

2015/910

D/2015/7012/12

Financial shocks and the real economy in a nonlinear world: From theory to estimation

Andrea Silvestrini* & Andrea Zaghini‡

Abstract

We examine the inter-linkages between financial factors and real economic activity. We review the main theoretical approaches that allow financial frictions to be embedded into general equilibrium models. We outline, from a policy perspective, the most recent empirical papers focusing on the propagation of exogenous shocks to the economy, with a particular emphasis on works dealing with time variation of parameters and other types of nonlinearities. We then present an application to the analysis of the changing transmission of financial shocks in the euro area. Results show that the effects of a financial shock are time-varying and contingent on the state of the economy. They are of negligible importance in normal times but they greatly matter in conditions of stress.

Keywords: financial crisis; nonlinearities; financial shocks

JEL classification: C32; E32; E44; E58

* Department of Financial Economics, Ghent University, Sint-Pietersplein 5, B-9000 Ghent, Belgium; Bank of Italy, DG Economics, Statistics and Research. Via Nazionale 91, 00184 Rome, Italy. E-mail address: andrea.silvestrini@bancaditalia.it

‡ Bank of Italy, DG Economics, Statistics and Research. Via Nazionale 91, 00184 Rome, Italy. E-mail address: andrea.zaghini@bancaditalia.it

> "*To motivate interest in a paper on financial factors in business fluctuations it used to be necessary to appeal either to the Great Depression or to the experiences of many emerging market economies. This is no longer necessary. Over the past few years the United States and much of the industrialized world have experienced the worst post-war financial crisis, and the global recession that has followed also appears to have been the most severe of this era.*" Gertler and Kiyotaki (2010).

1 Introduction[1]

The most recent empirical evidence supports the view that financial and real fluctuations are closely intertwined, and that financial and credit conditions are important drivers of the economy, contributing significantly to the propagation of economic shocks. Indeed, the severity of the global financial crisis has highlighted that the financial sector has turned out to be inherently procyclical, capable of amplifying macroeconomic volatilities and business cycle fluctuations. During the contractionary phases of the business cycle, profitability falls as asset prices decline, credit conditions deteriorate, loan defaults rise, and the provision of credit is tightened, aggravating the downturn.[2] These observations point to the relevance of the linkages and feedbacks that characterise the interaction between financial markets, the credit market, the housing sector, and the real economy.

From a theoretical modelling viewpoint, the recent episodes of financial turmoil have clearly shown that macro models based on frictionless financial markets cannot reproduce salient features of the business cycle. In particular, those macroeconomic models which, in the decade prior to the crisis, implicitly assumed perfectly functioning capital markets and no role for financial intermediation, have been unable to capture the procyclicality of the financial system and to predict the persistence and the intensity of the "Great Recession". As a result, in recent years, a large

[1] While assuming scientific responsibility for any error in the paper, the authors wish to thank Giuseppe Grande, Gert Peersman, Dimitrios D. Thomakos and Raf Wouters for useful suggestions and discussions. The views expressed in this paper are those of the authors and do not necessarily reflect those of the Bank of Italy.

[2] In this context, central banks have started to intervene with active monetary policies to reduce excessive financial market volatility (Botzen and Marey, 2010, Hoffmann, 2013).

theoretical literature has attempted to incorporate financial frictions and the banking sector into standard real business cycle models or New Keynesian dynamic stochastic general equilibrium models as in Woodford (2003), Christiano, Eichenbaum and Evans (2005), and Smets and Wouters (2007).[3] Yet, the interest in incorporating financial frictions in business cycle models is not new. In particular, since the early 1980s, several attempts have been made to account for informational asymmetries between lenders and borrowers and non-convex transaction costs.

In parallel, abundant empirical research has analysed and quantitatively assessed the role of the financial sector in affecting the economy and the contribution of financial shocks to macroeconomic fluctuations, both for the euro area and for the US. A common finding of this empirical literature is that the transmission of shocks to the economy differs according to the state of the world: it has been emphasised, for instance, that output reacts to a greater extent to financial shocks in periods of high stress than in tranquil ones (Hubrich and Tetlow, 2015). In this context, one of the explanations that has been proposed for the failure of many reduced-form vector autoregression (VAR) models to mimic the response of economic variables to shocks originating in the financial sector during the crisis is the common assumption that coefficients (and the variance-covariance matrix of the disturbances) are constant over time.

In order to illustrate the importance of all the quoted issues from a policy perspective we present an empirical application aimed at sizing the time-varying impact of financial shocks on fluctuations of output, inflation, credit and interest rate in the euro area. As a preview of the results, we find that the consequences of a financial shock are time-varying and contingent on the state of the economy: they are of negligible importance in "normal" times but they matter greatly in conditions of "stress". As a consequence, deriving policy implications exclusively on the basis of constant-parameter models may provide misleading guidance for the euro-area authorities, especially when the

[3] See, among others, Nolan and Thoenissen (2009), Hirakata, Sudo and Ueda (2009), Christiano, Motto and Rostagno (2014), Meh and Moran (2010), Gertler and Kiyotaki (2010), de Walque, Pierrard and Rouabah (2010), Gerali et al. (2010), Cúrdia and Woodford (2010), Gertler and Karadi (2011), and Jermann and Quadrini (2012). From a more applied perspective see also Buch and Pierdzioch (2005).

functioning of financial markets is disrupted. Furthermore, the adequate policy response (be it from a macro-prudential or a monetary policy perspective) should also be calibrated depending on the state of the economy.

The rest of the paper proceeds as follows. Section 2 explains how highly influential theoretical studies have embedded financial frictions into a macroeconomic framework, discussing some conceptual issues related to the external finance premium and collateral constraints. Section 3 reviews the most recent empirical literature that quantifies the contribution of exogenous shocks to output growth and inflation during the crisis, with a special emphasis on those papers featuring time-varying parameter models and other types of nonlinearities, such as Markov-switching. Section 4 sketches the model used in the empirical application and describes the dataset. Section 5 presents the results for the euro area. Section 6 discusses the policy implications and draws some conclusions.

2 Financial frictions, the financial accelerator and collateral constraints

This Section briefly refers to the leading economic theories that explain how the financial sector can influence the real economy. It also sheds light on the role of financial frictions as a source of propagation of shocks. While revisiting the main theoretical frameworks of frictions within financial markets, it explains in detail, mostly intuitively, the basic mechanisms at the heart of the models.

An extensive theoretical literature departing from the Modigliani and Miller (1958) framework and featuring credit market imperfections has grown out of Bernanke (1983), Bernanke and Gertler (1989), Kiyotaki and Moore (1997) and Carlstrom and Fuerst (1997).[4] Although early approaches to modelling financial frictions already existed, the above papers should be considered the seminal

[4] See Gertler and Kiyotaki (2010) for an assessment of this research in the past two decades.

contributions in the field. According to Adrian and Shin (2010), the common thread among these works is the focus on fluctuations in the creditworthiness of the non-financial borrower. In fact, fluctuations in borrowers' net worth is the essential ingredient that can contribute to the amplification and persistence of exogenous shocks to the economy. Yet, while the key concept in Bernanke and Gertler (1989) is the "external finance premium" due to the presence of asymmetry of information between borrowers and lenders, collateral constraints are at the heart of Kiyotaki and Moore (1997).

The external finance premium can be broadly defined as the difference in cost between funds raised externally, by issuing equity or debt, and funds generated internally (retained earnings). It hinges upon the assumption of a "costly state verification" mechanism (Townsend, 1979) – meaning a setup in which verification of the entrepreneur's performance is costly, and lenders incur a monitoring cost – which drives a wedge between the cost faced by a borrower when raising funds externally and the opportunity cost of internal funding. It is through this premium that credit market frictions are endogenised and introduced in otherwise frictionless models.

After Bernanke and Gertler (1989), other authors have highlighted the contribution of informational asymmetries to business cycle dynamics. Carlstrom and Fuerst (1997) introduce financial frictions into a standard real business cycle model and show how they may affect its properties. To generate frictions, they assume asymmetric information between entrepreneurs and households providing funds and a "costly state verification" environment. This idea is strictly related to the original overlapping generations model developed by Bernanke and Gertler (1989), in which asymmetries between borrowers and lenders (informational frictions) generate agency costs that manifest themselves through a premium on external funds with respect to the risk-free rate. Agency costs are inversely related to the borrower's net worth. Countercyclical agency costs are crucial for the propagation of real shocks (such as shocks to productivity) and for generating "accelerator effects on investment".

Consistently with this way of reasoning, many authors have drawn on these insights and developed models incorporating an external finance premium. In a highly influential study, Bernanke, Gertler and Gilchrist (1999) introduce a “financial accelerator” mechanism in a model featuring nominal price rigidities, in which procyclical movements in non-financial borrowers’ net worth and countercyclical movements in the cost of external funds relative to internal funds can generate large changes in output from relatively small productivity and demand shocks. As already mentioned, this mechanism helps to explain how small and temporary shocks can result in large and persistent business cycle fluctuations.

The basic mechanism operates as follows. The external finance premium (EFP) and net worth of non-financial borrowers are negatively related: the higher the borrower’s net worth, the lower are the expected agency costs of financing investment. Thus, since the borrower’s net worth is procyclical, when investment, output and asset prices go up (following, for instance, a positive productivity shock), the net worth of borrowers also increases, and leverage falls, endogenously reducing the external finance premium. This in turn increases investment and amplifies the upturn. The reverse happens during recessions. In particular, adverse shocks to the economy lead to a reduction of asset prices and net worth; leverage and the external finance premium rise: this increases financial frictions, and borrowers are thus forced to invest less (see Figure 1). All this leads to the amplification and propagation of shocks. In this sense, as neatly explained by Bernanke and Gertler (1989): ”The condition of borrowers’ balance sheets is a source of output dynamics”.

<< Insert Figure 1 here >>

The “financial accelerator” theory also applies to monetary policy shocks: in fact, the response of output to a monetary policy shock is significantly larger in models featuring financial frictions than in models in which they are not present. Consider, for instance, a monetary policy tightening: the decision not only increases the cost of capital through the conventional interest rate channel, but also leads to a fall in the net worth of the borrower and, as a consequence, to a higher cost of external financing. This confirms that financial frictions affect the transmission of monetary policy and that the financial accelerator constitutes a mechanism of amplification of a wide range of (both real and nominal) shocks to the economy.

Financial frictions and the financial accelerator have also been introduced in otherwise standard models following other approaches, such as assuming collateral constraints in the modelling framework. An outstanding example is given by Kiyotaki and Moore (1997), who highlight the contribution of collateral constraints to business cycle fluctuations through feedback effects. In particular, they develop a real business cycle model in which debt must be fully secured by collateral and lending occurs only when collateralised. Binding credit constraints are determined by the value of collateralised assets.

Their main finding is that recessions are amplified when, during the economic downturn (e.g., following an unanticipated adverse productivity shock), agents are affected by the depreciation of assets used as collateral (in the economy considered by Kiyotaki and Moore, 1997, there is a single durable asset, land, which serves as collateral). The way the mechanism operates is very intuitive: with collateral requirements, the borrower faces a wealth effect; in a recession, the income from capital falls, capital becomes less valuable as collateral, and this forces firms to reduce their borrowing and to curtail their investment, thereby causing an additional decline in output and a worsening of the recession.

More recently, the financial accelerator mechanism as in Bernanke, Gertler and Gilchrist (1999) has been explicitly extended to financial intermediaries (and not only applied to non-financial borrowers as in the earlier literature with financial frictions, which treated intermediaries largely as a veil). Notably, Gertler and Kiyotaki (2010) introduce agency problems in a model featuring banks that intermediate funds between households and firms. With financial frictions, the model is able to generate a decline in output following an exogenous shock capable of depressing asset prices that is roughly twice as large as in the frictionless case, and more persistent. In a similar vein, Gertler and Karadi (2011) develop a monetary dynamic stochastic general equilibrium (DSGE) model with financial intermediaries facing balance sheet constraints: these constraints may limit the ability of firms to obtain funds, and this mechanism produces financial frictions. Other examples of models with financial intermediation are Cúrdia and Woodford (2010) and Gerali et al. (2010).

The present Section, which has briefly revisited the leading economic theories on financial frictions, is complemented, next, by a review of policy-relevant empirical research on the time-varying contribution of exogenous shocks to business cycle fluctuations.

3 The empirical literature on the time-varying transmission of shocks to the economy

The goal of this Section is to survey the most recent empirical papers dealing with the changing transmission of shocks to the economy and to highlight the main policy implications stemming from these contributions.[5] Particular attention will be given to reduced-form models featuring nonlinear forms of time-variation: in fact, the most recent empirical evidence based on the financial crisis suggests that describing quantitative relationships between the financial and the real sectors requires a nonlinear framework.

Only works that adopt a modelling approach based on standard reduced-form VAR models will be considered (threshold-VARs, time-varying parameter VARs, Markov-switching VARs), while the fast growing literature on DSGE models with financial frictions will not be covered, as it requires separate attention, beyond the scope of this work. Further, the focus hereafter will be on the effects produced by monetary policy and financial shocks, which are the most relevant for the purpose of this paper.

Threshold-VAR models have been initially proposed in the literature in order to allow for nonlinear interactions between time series. These models assume that there exists more than one possible regime for the variables in the system: which regime applies to a given point in time

[5] See Silvestrini and Zaghini (2015) for an extensive review of theoretical and empirical contributions exploring the inter-linkages between financial factors and real economic activity.

depends on whether a threshold variable exceeds a given threshold value. Two of the first applications of threshold-VAR models in macroeconometrics examine whether there are any nonlinearities in the relationship between credit and economic activity (Balke, 2000; Calza and Sousa, 2006). Balke (2000), using US data, estimates a two-regime threshold-VAR model where the regime depends on conditions prevailing in the credit market. An indicator of credit conditions is included in a standard three-variable VAR featuring output growth, inflation, and a short-term interest rate. Nonlinear impulse response analysis – which allows for regime switching throughout the duration of the response – suggests that the identified monetary policy shocks have a larger effect on output growth in a tight credit regime than in normal times, and that contractionary monetary policy shocks have a larger effect than expansionary ones.

Calza and Sousa (2006) focus on the euro area and adopt the same methodological approach as in Balke (2000) to test whether output and inflation respond asymmetrically to credit shocks. Overall, using data from 1981:Q2 to 2002:Q3, they find evidence of threshold effects.[6] The estimated conditional linear impulse responses provide evidence of asymmetric reactions of output and inflation to credit shocks over the cycle. Turning to nonlinear impulse responses, like Balke (2000), Calza and Sousa (2006) find that when credit conditions are tighter output effects seem to be more pronounced.

In addition to threshold-VARs, another approach that has been suggested in recent years to account for nonlinearities is based on time-varying parameter VAR models. These models have been designed in order to account for (gradual) structural shifts in the economy. In fact, as several authors have argued, time-invariant coefficients and volatilities may turn out to be a restrictive assumption in capturing the evolution of economic time series.

There are still very few papers employing time-varying parameter VAR models to examine the evolution and heterogeneity of the linkages between real economic variables and financial

[6] The threshold critical value for the quarter-on-quarter growth of real loans is estimated in 0.78%. In the light of the global financial crisis, according to this value the euro area would be in a regime of low credit growth since 2009:Q1.

variables. One of the first attempts is by Ciccarelli, Ortega and Valderrama (2012), who build a time-varying panel VAR model without stochastic volatility featuring real and financial variables (stocks, real estate and bank leverage) for a set of majors European economies plus the US, Canada and Japan. A panel framework with time-varying parameters enables them to examine the cross-country interdependence and the time evolution of real-financial linkages, accounting simultaneously for spill-overs and heterogeneity. Estimation results point to a statistically significant common component for all countries, especially during the 2008-09 recession. Yet, country-specific factors are also relevant, due to the presence of a heterogeneous pattern in the relationship between the financial sector and the real economy.

Another attempt is made by Prieto, Eickmeier and Marcellino (2013), who incorporate key financial variables (credit spread, house and stock prices) in a time-varying parameter VAR model with stochastic volatility in order to examine the contribution of financial shocks to output growth in the US. Among the main findings, the authors report that, during the global financial crisis, the explanatory power of financial shocks for GDP growth has risen to 50 percent, compared with 20 percent in normal times (the sample period is 1958:Q1–2012:Q2).

Within the class of reduced-form nonlinear models, Markov-switching models have also been used to account for parameter instability over time. Unlike time-varying parameter VARs or other time-varying models proposed in the literature, in Markov-switching models parameters switch according to an unobservable state indicator that follows a Markov process. Being unobservable, the state is estimated jointly with the other model parameters. The state estimate determines different regimes of the economy.

Peersman and Smets (2001) employ a multivariate two-state Markov-switching model in order to examine the role of financial frictions in the transmission of monetary policy, contingent on the state of the economy (recession or boom). In a subsequent paper, Peersman and Smets (2005) estimate the effects of a common monetary policy shock on output growth in eleven industries of seven euro-area countries and find that, on average, the negative effect of an interest rate tightening is significantly greater in recessions than in expansions. In line with the theoretical literature discussed in Section 2, these authors find that financial accelerator mechanisms can partly explain the differential impact in recessions versus booms (the external finance premium is more sensitive to shocks during a recession than during an expansion).

A closely related research is undertaken by Hartmann et al. (2015). These latter authors study how financial stress affects macroeconomic dynamics and, to this aim, estimate a macro-financial Markov-switching VAR model for the euro area employing a sample running from January 1987 to December 2010. They argue that the Markov-switching VAR model provides a rigorous statistical framework to examine nonlinearities and makes it possible to compare how financial variables affect the real economy in regimes of "low" and "high" financial stress. The effect of nonlinearities in the transmission of the financial stress shock to the real economy is analysed on the basis of regime-dependent impulse response functions. Results reveal that there is a large amplification effect during periods of severe systemic stress: namely, in times of crisis, a positive shock to the systemic stress indicator generates a pronounced contraction of industrial production. By contrast, in normal times, the effect is negligible. Further, bank lending seems to play a role in amplifying the transmission of financial stress to the real economy.

All in all, the most recent empirical literature offers evidence of a significant interplay between financial and real variables in the transmission of shocks, as predicted by theoretical models. In particular, financial conditions are capable of affecting the real economy and have a prominent role in amplifying business cycle fluctuations (Gilchrist and Zakrajšek, 2012).

In addition, besides playing an important role in the propagation of real and nominal shocks, financial factors represent themselves an independent source of shocks. In this context, another relevant finding of the literature is that the reaction of real variables to financial shocks is nonlinear: the same shock has larger effects in times of (financial) stress than in normal times.

These results yield two relevant policy implications. The first one is that in order to analyse macro-financial linkages and the propagation of shocks to the economy it is not possible to rely exclusively on models that do not allow for nonlinearities, since the resulting implications might be flawed and misleading. The second one is that the policy response from the authorities has to be time-contingent, given that during bad times the shock transmission is different from good times.

4 The TVP-VAR model specification and the dataset

In this Section we set up and estimate a time-varying parameter vector autoregressive model (TVP-VAR) with stochastic volatility for the euro area in order to examine how financial shocks transmit to the economy and to assess whether there is time variation in the intensity of macro-financial linkages. While threshold and Markov-switching VAR impose abrupt changes in the state of the economy providing often completely different sets of estimated parameters for the different states of the world, we favour the TVP-VAR approach because it is potentially better suited to account for a more gradual development of the economy (even without significant shocks), which seems to be the case for the euro area.

The empirical application we propose differs in several respects from the studies surveyed in Section 3. The two papers most closely related to our analysis are Ciccarelli, Ortega and Valderrama (2012) and Prieto, Eickmeier and Marcellino (2013), which are both based on TVP-VAR models. On the one hand, unlike Ciccarelli, Ortega and Valderrama (2012), we allow for stochastic volatility (whereas they assume time variation only in the autoregressive coefficient matrix): in this way, we account for potential time variation in shocks' size. On the other hand, while maintaining a very similar methodological approach as Prieto, Eickmeier and Marcellino (2013), we focus on the euro area instead of the US.

Relying on Primiceri (2005), we assume that y_t follows a time-varying parameter VAR model with stochastic volatility in reduced-form:

$$y_t = c_t + B_{1,t} y_{t-1} + \ldots + B_{k,t} y_{t-k} + u_t \qquad t = 1,\ldots,T \tag{1}$$

where y_t is an (n×1) vector of observed macroeconomic variables, c_t is an (n×1) vector of time-varying intercepts, $B_{s,t}$ (s=1,…,k) are (n×n) matrices of time-varying coefficients, u_t are heteroskedastic disturbances with zero mean and variance-covariance matrix denoted Ω_t.

The variables in y_t are the real GDP growth rate, the inflation rate, the short-term interest rate, the growth rate of the stock of credit to the private sector, and an indicator of financial stress especially designed for the euro area (the Composite Indicator of Systemic Stress, or CISS, based on the work of Holló, Kremer, and Lo Duca, 2012). All the variables except the financial stress indicator and the short-term interest rate are expressed in quarter-on-quarter growth rates.

In (1), the variance-covariance matrix Ω_t is time-varying and can be diagonalised in the following way:

$$A_t \Omega_t A_t^{'} = \Sigma_t \Sigma_t^{'} \tag{2}$$

where A_t is lower triangular (with ones on the main diagonal and time-varying coefficients below it) and Σ_t is a diagonal matrix of standard deviations $\sigma_{1,t},\ldots,\sigma_{n,t}$.

Based on (1) and (2), the resulting model becomes:

$$y_t = c_t + B_{1,t} y_{t-1} + \ldots + B_{k,t} y_{t-k} + A_t^{-1} \Sigma_t \varepsilon_t \tag{3}$$

with identity variance-covariance matrix $var(\varepsilon_t)=I_n$. Stacking in a vector β_t all the time-varying coefficients (c_t, $B_{s,t}$ with s=1,…,k), the dynamics of the model's time-varying parameters is then specified as follows:

$$\beta_t = \beta_{t-1} + \nu_t$$

$$\alpha_t = \alpha_{t-1} + \varsigma_t$$

$$\log(\sigma_t) = \log(\sigma_{t-1}) + \eta_t \qquad (4)$$

where α_t is the vector of non-zero and non-one elements of the matrix A_t (stacked by rows) and σ_t is the vector of the diagonal standard deviations of the matrix Σ_t in (2). These are all unobserved states that vary over time. These parameters are modelled as random walks in order to reduce the computational burden in estimation.

All the model' innovations are assumed to be jointly normally distributed with variance-covariance matrix:

$$V = \text{var}\left(\begin{bmatrix} \varepsilon_t \\ \nu_t \\ \varsigma_t \\ \eta_t \end{bmatrix}\right) = \begin{bmatrix} I_n & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & W \end{bmatrix} \qquad (5)$$

where Q, S and W are conformable positive definite matrices.

The model is estimated over the period 1987–Q1:2013–Q4 adopting a Bayesian approach, which allows to evaluate the posterior distributions of the parameters of interest, i.e., the unobservable states, β_t, A_t, Σ_t and the hyperparameters of the variance-covariance matrix *V*.[7] A training sample of the first twenty quarters of data is considered. A sample of 30,000 iterations of the Gibbs sampler is employed, discarding the first 20,000 (burn-in period).

Identification is achieved by applying a recursive (Cholesky) ordering identification scheme. The variables enter the model in this order: real GDP growth rate, inflation rate, bank credit growth rate, the short-term interest rate and the CISS indicator. Given that the CISS indicator is placed last, the recursive identification scheme implies delayed effects of the financial stress shock on GDP, inflation, interest rate and credit shocks; at the same time, output, inflation, interest rate and credit

[7] A multivariate normal-inverted Wishart framework is adopted. Further estimation details are skipped. The interested reader is referred to Appendix A in Primiceri (2005, pp. 844–847) for a description of the priors and of the whole estimation procedure. The computer code used incorporates the recent corrigendum by Del Negro and Primiceri (2015).

shocks have a contemporaneous impact on the CISS. The same ordering is used by Hartmann et al. (2015): the underlying economic assumption is that asset prices respond instantaneously to macro variables, whereas these latter are usually more sluggish and react with a delay.[8]

For our estimations, we draw on up-to-date euro-area macroeconomic time series from the Area Wide Model (AWM) dataset, which has become a standard reference for empirical studies on the euro area (Fagan, Henry and Mestre, 2001). Quarterly aggregate euro area data on real GDP, the consumer price index (HICP), and the nominal short-term interest rate are available from 1970:Q1 onwards. Since credit variables are not included in the AWM dataset, we have gathered data on nominal total bank credit to the private non-financial sector (non-financial corporations and households) relying on historical quarterly time series recently made available by the BIS.[9]

In order to identify a financial stress shock hitting the economy, we rely on the CISS index, which is an indicator of instability in the euro-area financial system. The CISS comprises 15 market-based financial stress measures that pertain to five broad market segments, namely the financial intermediaries sector, money markets, equity markets, bond markets and foreign exchange markets. It starts in 1999. It has been extended 12 years backward on the basis of some proxy of some pre-EMU aggregate time series (hence the series starts in January 1987).[10] As explained by the authors, the main methodological innovation in the construction of the CISS is the application of standard portfolio theory to the aggregation of the five segment-specific stress measures into a single composite indicator (with weights that reflect their time-varying cross-correlation structure). Given that the cross-correlation between the five sub-indexes is allowed to vary over time, the CISS

[8] Yet it should be noticed that, in their baseline specification, Hartmann et al. (2015) place credit after the short-term interest rate. In our paper, instead, total bank credit is ordered before the short-term interest rate. Our justification is that the interest rate pass-through is sluggish: as a result, the supply and demand of credit react only with a lag to innovations in the short-term rate. This choice is in line with Assenmacher-Wesche and Gerlach (2008) and Bouvatier et al. (2012).

[9] In the BIS dataset, long series on total bank credit to the private non-financial sector for the euro area are available only as of 1998:Q1. Prior to 1998, we have thus aggregated country level data in order to extend the euro area credit time series backward in time. The aggregate data refers to the euro area 12 (fixed composition).

[10] We are grateful to Manfred Kremer and Marco Lo Duca for providing us with the CISS series starting in 1987.

gives relatively more weight to periods of systemic stress, in which several market segments are impaired at the same time.

<< Insert Figure 2 here >>

As it can be seen from Figure 2, the euro area CISS increases during periods of systemic financial stress, such as the stock market crash of 1987, the 1992 Exchange Rate Mechanism crisis and the September 11 terrorist attacks. It reaches its highest point after the collapse of Lehman Brothers, and throughout the sovereign debt crisis.

5 The transmission of financial shocks in the euro area

Using the specification of the TVP-VAR model described in Section 4, we study the effects of a financial shock on GDP, inflation, credit and interest rate, before and during the financial crisis. Our objective is to assess whether there is any time variation in the propagation of this shock to the economy. In order to tackle this question, we report the impulse response functions considering two data points: 2004:Q4 (Pre-crisis); 2011:Q4 (Sovereign debt crisis). The first data point (2004:Q4) corresponds to the period preceding the global financial crisis, which erupted in the US in August 2007 and intensified in September 2008 after the collapse of Lehman Brothers. The following years 2010-2011 are characterised by the euro area sovereign debt crisis, which started at the end of 2009 (when the Greek government disclosed the true country's fiscal situation), with the sovereign spreads rising sharply for most of the euro-area countries. The situation improved quickly in summer 2012, after the Mario Draghi's "Whatever it takes" statement. Thus, the choice of the second data point (2011:Q4) proxies the most acute phase of the sovereign debt crisis.

The impulse response functions are presented in Figures 3 and 4: Figure 3 shows the responses of real GDP, prices and CISS to a financial stress shock, whereas Figure 4 presents the responses of credit, short-term interest rate and CISS to the same shock. Notice that the size of the shock has been normalized to one standard deviation in both periods in order to make the impulse response functions comparable over time. The figures report the posterior median of impulse responses to a shock to the CISS indicator in 2004:Q4 and 2011:Q4, together with 16 percent and 84 percent posterior probability regions.

Interestingly, the shock hitting the CISS is more persistent in 2011:Q4 than in 2004:Q4: consistently, impulse response functions of real GDP, inflation, credit and short-term interest rate are in general much less persistent before than during the crisis.

Coming to the magnitude of impulse responses, a positive shock to the CISS leads to a large decline of real output in 2011:Q1, while in 2004:Q4 the real contraction is not significant. It also induces a very modest decline of inflation in 2011:Q4 (in 2004:Q4 inflation hardly reacts, Fig. 3). Furthermore, the decline of the short-term interest rate seems to be of similar extent in both periods. Remarkably, in 2011:Q4 the financial stress shock is accompanied by an exceptional drop of total bank credit. After 6 quarters, total bank credit is almost one percentage point below its trend. These effects are very persistent, and are statistically significant after 12 and 20 quarters (Fig. 4). In 2004:Q4 the credit response is instead much less pronounced.

<< Insert Figures 3 and 4 here >>

In summary, these results indicate that, in times of crisis, financial market fluctuations propagate intensively and persistently to the economy and feature an amplifying mechanism capable of producing a large contraction of output and a marked credit tightening, a finding that can be explained theoretically by the financial accelerator mechanism.[11] In normal times, conversely, real effects are in general modest, loans exhibit a very mild decline and the shock propagation is negligible.

[11] There is also another strand of the literature, based on a convex short-run aggregate supply curve, which predicts that monetary policy has a stronger effect on economic activity in a recession than during a boom. According to this theory, convexity implies that the slope of the short-run supply curve is steeper at higher levels of inflation then at lower levels. As a consequence, shifts in aggregate demand that are driven by changes in monetary policy will have a stronger effect on output and a weaker effect on inflation in recessions and the reverse in expansions (see Peersman and Smets, 2001, and the references therein).

6 Conclusions

This paper examines the inter-linkages between financial conditions and real economic activity, focusing on the transmission mechanism of financial shocks to the economy and on policy implications.

First, it revisits the main theoretical frameworks that allow financial frictions to be embedded into general equilibrium models, explaining intuitively how the financial accelerator mechanism (Bernanke, Gertler and Gilchrist, 1999) and collateral constraints (Kiyotaki and Moore, 1997) are able to amplify the impact of financial shocks on the real economy. Then, it analyses the most recent empirical papers that incorporate time variation and other types of nonlinearities into standard constant parameter reduced-form models. Indeed, this latter branch of the empirical literature is the one that provides the most relevant policy implications.

To illustrate the relevance of these issues, the paper presents an empirical application to the euro area in order to assess the impact of financial shocks on fluctuations of macro aggregates and credit before and after the global financial crisis. Results show that the effects produced by a financial stress shock are time-varying and contingent upon the state of the economy. The financial shock, in particular, exerts a much higher contribution on economic activity and credit during crisis periods than in normal times: in fact, by comparing the impulse response functions before the global financial crisis (2004:Q1) with those estimated during the most acute phase of the sovereign debt crisis (2011:Q4) it emerges that, in this latter period, a financial stress shock has much larger and more persistent effects on the euro-area economy, not only with regard to output and inflation, but also for credit to the private sector.

The main policy conclusion we draw from the econometric analysis is that deriving implications on the basis of constant-parameter models may provide misleading guidance or even wrong indications, especially during episodes of severe financial and economic distress or when the functioning of financial markets is impaired. Rather, the response to exogenous shocks must be calibrated by the authorities in line with the state of the economy and the intensity of the shock.

Furthermore, the nonlinear nature of the macroeconomic effects of financial stress shocks requires activating well in advance macro-prudential policy tools aimed at preventing and managing financial instability (such as, for instance, support measures to the financial sector).

In terms of future research, a possible strand of investigation should aim to improve this very promising econometric framework in order to deepen our understanding of several relevant features of macro-financial linkages, such as heterogeneity and cross-country spill-overs, especially for the achievement of the financial stability objective.

References

[] Adrian, T., and H.S. Shin (2010). Financial intermediaries and monetary economics. In: Friedman, B.M. and M. Woodford (eds.), *Handbook of Monetary Economics*, Volume 3, Elsevier, Amsterdam, pp. 601–650.

[] Assenmacher-Wesche, K., and S. Gerlach (2008). Monetary policy, asset prices and macroeconomic conditions: a panel-VAR study. Working Paper Research, 149. National Bank of Belgium.

[] Balke, N.S. (2000). Credit and economic activity: credit regimes and nonlinear propagation of shocks. *The Review of Economics and Statistics*, 82(2), pp. 344–349.

[] Bernanke, B.S. (1983). Non-monetary effects of the financial crisis in the propagation of the great depression. *American Economic Review*, 73(3), pp. 257–276.

[] Bernanke, B.S., and A. Gertler (1989). Agency costs, net worth and business fluctuations. *American Economic Review*, 79(1), pp. 14–31.

[] Bernanke, B.S., Gertler, M., and S. Gilchrist (1999). The financial accelerator in a quantitative business cycle framework. In: Taylor, J.B. and M. Woodford (eds.), *Handbook of Macroeconomics*, Volume 1, number 1, Elsevier, Amsterdam, pp. 1341–1393.

[] Botzen, W.J.W., and P.S. Marey (2010). Did the ECB respond to the stock market before the crisis? *Journal of Policy Modeling*, 32(3), pp. 303–322.

[] Bouvatier, V., López-Villavicencio, A., and V. Mignon (2012). Does the banking sector structure matter for credit procyclicality? *Economic Modelling*, 29(4), pp. 1035–1044.

[] Buch, C.M., and C. Pierdzioch (2005). The integration of imperfect financial markets: Implications for business cycle volatility. *Journal of Policy Modeling*, 27(7), pp. 789–804.

[] Calza, A., and J. Sousa (2006). Output and inflation responses to credit shocks. Are there threshold effects in the euro area? *Studies in Nonlinear Dynamics & Econometrics*, 10(2), Article 3.

[] Carlstrom, C.T., and T.S. Fuerst (1997). Agency costs, net worth, and business fluctuations: A computable general equilibrium analysis. *American Economic Review*, 87(5), pp. 893–910.

[] Christiano, L.J., Eichenbaum, M., and C. Evans (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy*, 113(1), pp. 1–45.

[] Christiano, L.J., Motto, R. and M. Rostagno (2014). Risk shocks. *American Economic Review*, 104(1), pp. 27–65.

[] Ciccarelli, M., Ortega, E., and M.T. Valderrama (2012). Heterogeneity and cross-country spillovers in macroeconomic-financial linkages. ECB, WP Series, No 1498.

[] Cúrdia, V., and M. Woodford (2010). Credit spreads and monetary policy. *Journal of Money, Credit and Banking*, Volume 42, Issue Supplement s1, pp. 3–35.

[] Del Negro, M., and G.E. Primiceri (2015). Time varying structural vector autoregressions and monetary policy: A corrigendum. Mimeo.

[] de Walque, G., Pierrard, O., and A. Rouabah (2010). Financial (in)stability, supervision and liquidity injections: A dynamic general equilibrium approach. *The Economic Journal*, 120(549), pp. 1234–1261.

[] Fagan, G., Henry, J., and R. Mestre (2001). An Area-wide model (AWM) for the euro area. ECB, WP Series, No 42.

[] Gerali, A., Neri, S., Sessa, L., and F.M. Signoretti (2010). Credit and banking in a DSGE model of the euro area. *Journal of Money, Credit and Banking*, 42(S1), pp. 107–141.

[] Gertler, M., and N. Kiyotaki (2010). Financial intermediation and credit policy in business cycle analysis. In: Friedman, B.M. and M. Woodford (eds.), *Handbook of Monetary Economics*, Volume 3, Elsevier, Amsterdam, pp. 547–599.

[] Gertler, M., and P. Karadi (2011). A model of unconventional monetary policy. *Journal of Monetary Economics*, 58(1), pp. 17–34.

[] Gilchrist, S., and E. Zakrajšek (2012). Credit spreads and business cycle fluctuations. *American Economic Review*, 102(4), pp. 1692–1720.

[] Hartmann, P., Hubrich, K., Kremer, M., and R.J. Tetlow (2015). Melting down: Systemic financial instability and the macroeconomy. Mimeo.

[] Hirakata, N., Sudo, N., and K. Ueda (2009). Chained credit contracts and financial accelerators. Institute for Monetary and Economic Studies Discussion Paper Series 2009-E-30.

[] Hoffmann, A (2013). Did the Fed and ECB react asymmetrically with respect to asset market developments? *Journal of Policy Modeling*, 35(2), pp. 197–211.

[] Holló, D., Kremer, M., and M. Lo Duca (2012). CISS – a composite indicator of systemic stress in the financial system. ECB, WP Series, No. 1426.

[] Hubrich, K., and R.J. Tetlow (2015). Financial stress and economic dynamics: The transmission of crises. *Journal of Monetary Economics*, 70, pp. 100–115.

[] Jermann, U., and V. Quadrini (2012). Macroeconomic effects of financial shocks. *American Economic Review*, 102(1), pp. 238–271.

[] Kiyotaki, N., and J. Moore (1997). Credit cycles. *Journal of Political Economy*, 105(2), pp. 211–248.

[] Meh, C., and K. Moran (2010). The role of bank capital in the propagation of shocks. *Journal of Economic Dynamics and Control*, 34(3), pp. 555–576.

[] Modigliani, F., and M. Miller (1958). The cost of capital, corporation finance, and the theory of investment. *American Economic Review*, 48(3), pp. 261–297.

[] Nolan, C., and C. Thoenissen (2009). Financial shocks and the US business cycle. *Journal of Monetary Economics*, 56(4), pp. 596–604.

[] Peersman, G., and F. Smets (2001). Are the effects of monetary policy in the euro area greater in recessions than in booms? In: Mahadeva, L. and P. Sinclair (eds.), *Monetary Transmission in Diverse Economies*, Cambridge University Press, Cambridge, pp. 28–48.

[] Peersman, G., and F. Smets (2005). The industry effects of monetary policy in the euro area. *The Economic Journal*, 115(503), pp. 319–342.

[] Prieto, E., Eickmeier, S. and M. Marcellino (2013). Time variation in macro-financial linkages. Bundesbank Discussion Paper No. 13/2013.

[] Primiceri, G.E. (2005). Time-varying structural vector autoregressions and monetary policy. *The Review of Economics and Statistics*, 72(3), pp. 821–852.

[] Silvestrini, A., and A. Zaghini (2015). Financial shocks and the real economy in a nonlinear world: a survey of the theoretical and empirical literature. Bank of Italy Occasional papers No. 255.

[] Smets, F., and R. Wouters (2007). Shocks and frictions in US business cycles: A Bayesian DSGE approach. *American Economic Review*, 97(3), pp. 586–606.

[] Townsend, R.M. (1979). Optimal contracts and competitive markets with costly state verification. *Journal of Economic Theory*, 21(2), pp. 265–293.

[] Woodford, M. (2003). *Interest and prices: Foundations of a Theory of Monetary Policy*. Princeton: Princeton University Press.

Figure 1. Financial accelerator: the effect of an adverse shock

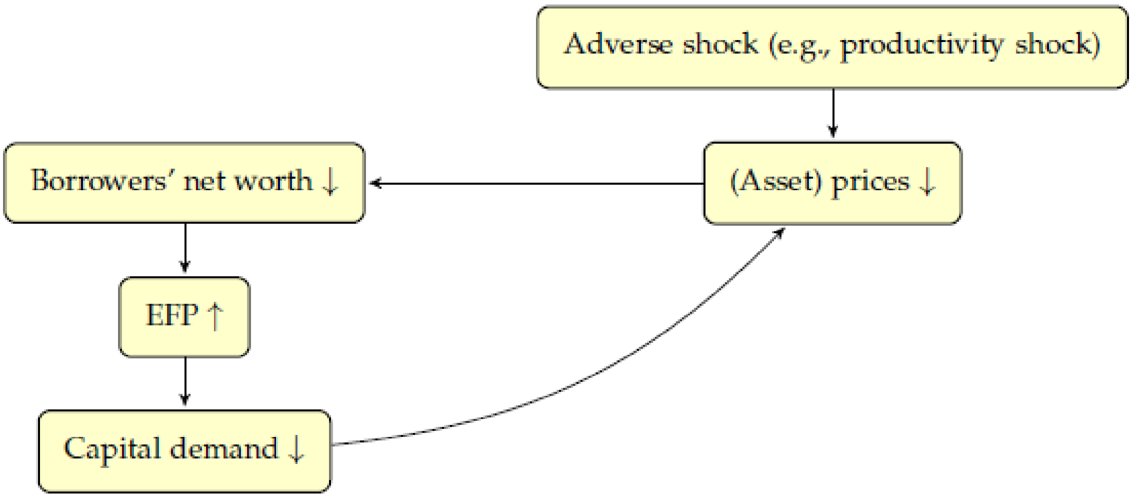


Figure 2. CISS and major financial stress events (1987:Q1–2013:Q4)

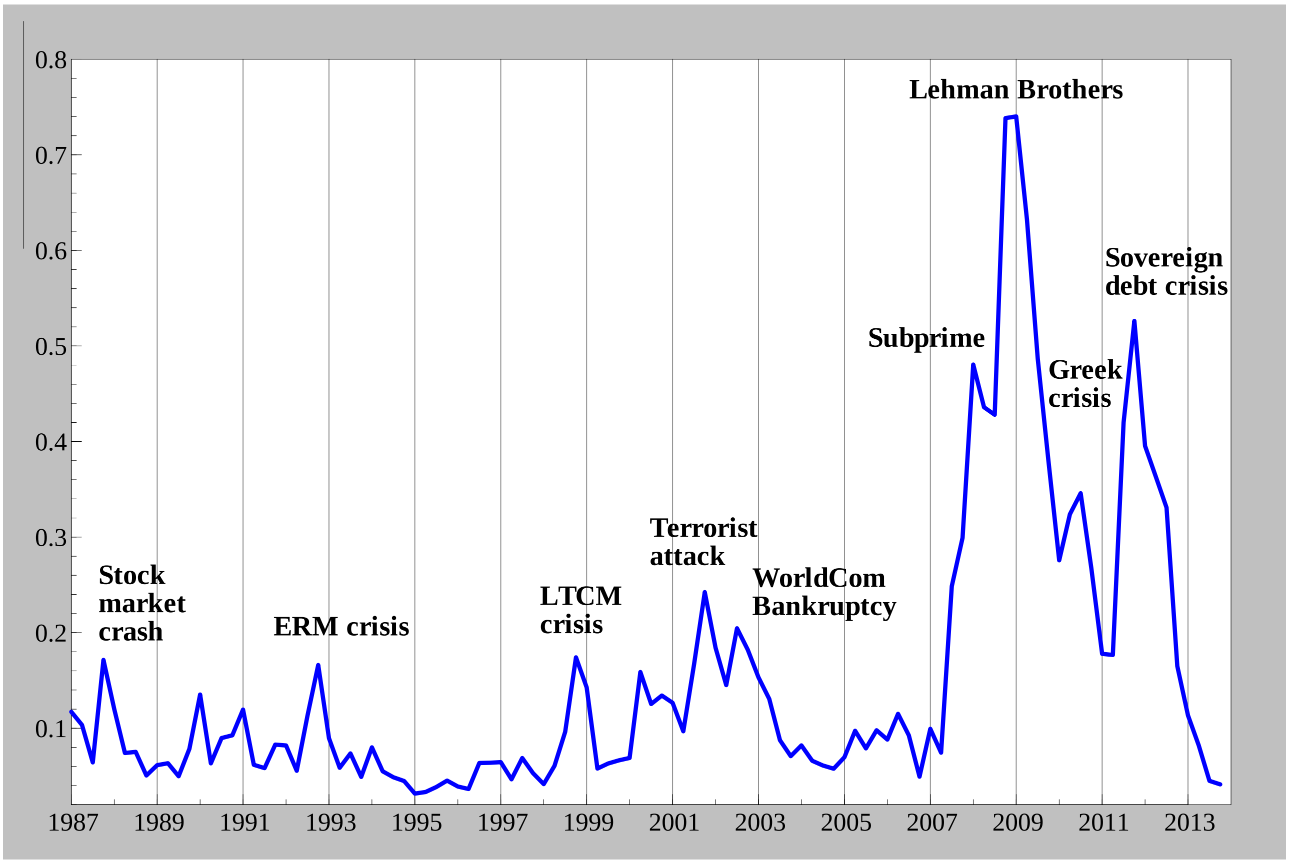
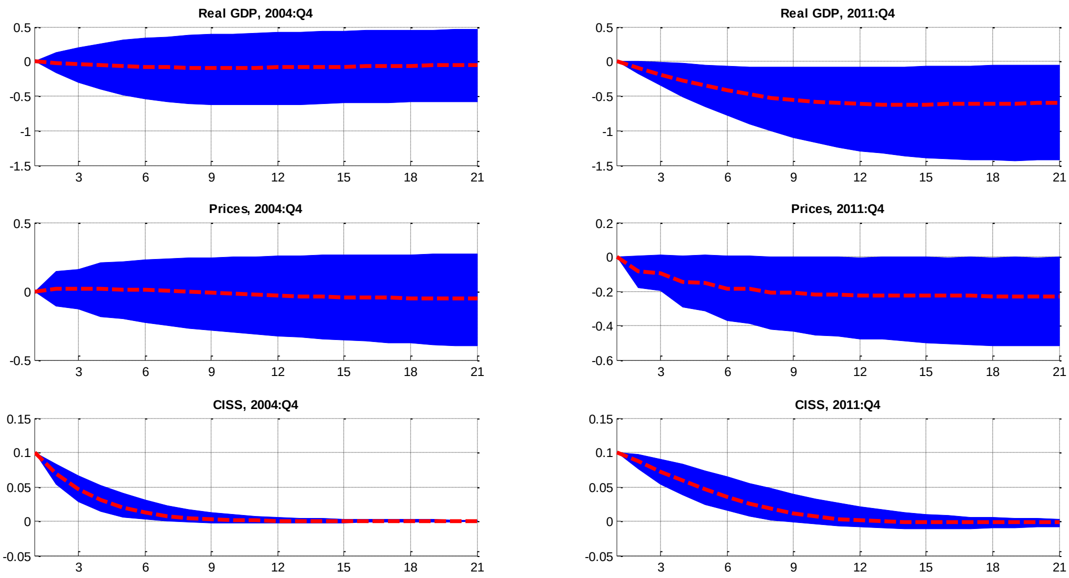
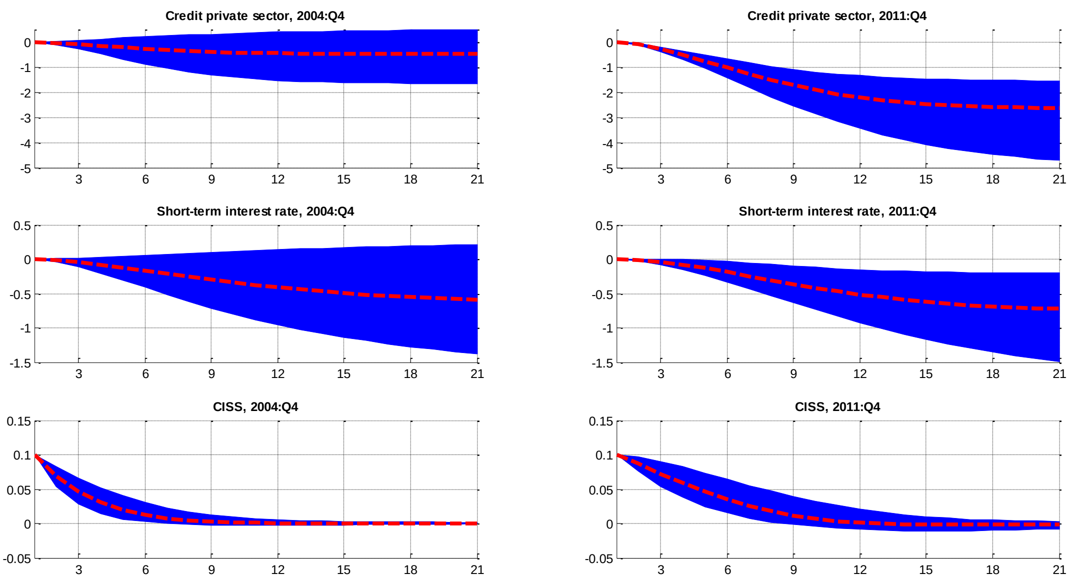


Figure 3. Impulse responses to financial stress shock at different times



Notes: Posterior median of impulse responses to a financial stress shock (hitting the CISS indicator in 2004:Q4 and 2011:Q4) and 16% and 84% posterior confidence regions. Responses in credit, short-term interest rate and CISS indicator. The CISS shock size is normalized to one standard deviation.

Figure 4. Impulse responses to financial stress shock at different times



Notes: Posterior median of impulse responses to a financial stress shock (hitting the CISS indicator in 2004:Q4 and 2011:Q4) and 16% and 84% posterior confidence regions. Responses in credit, short-term interest rate and CISS indicator. The CISS shock size is normalized to one standard deviation.