WORKING paper

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How does Financial Vulnerability amplify Housing and Credit Shocks?

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ABSTRACT

In this paper we study how households' financial vulnerability affects the propagation of housing and credit shocks. First, we estimate a non-linear model generating impulse responses that depend on the evolution of households' Debt to Service Ratio, i.e. the fraction of income that households use to pay back their debt. Second, we use sign restrictions to jointly identify a wide set of financial and economic shocks. We find that financial vulnerability: i) amplifies the response of the economy to housing shock, ii) makes the response to expansionary credit shocks less persistent and even negative after the first year since the arrival of the shock. Finally, overall recessionary shocks have larger effects with respect to expansionary ones of the same size.

Keywords: Financial Vulnerability, Macroprudential Policy, non-linear Models, Housing, Credit

JEL classification: C32; E51; G01; G51

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NON-TECHNICAL SUMMARY

Households' financial vulnerability can help to explain the unusual magnitude of the economic downturn observed during the Great Recession. When agents' debt burden is high, shocks having a direct impact on financial conditions are expected to have a larger impact with respect to the case where the debt burden is low (Kiyotaki 1997).

In this paper we ask how financial vulnerability affects the propagation of housing and credit shocks.

To answer this question, we estimate an econometric model on US data, in which the impact of shock depends on the level of financial vulnerability. To track financial vulnerability, we use the Debt Service Ratio (thereafter DSR), i.e. the fraction of income that households use to pay back their debt (pay interest and amortize the principal), in three-year difference. Our model includes real, financial and monetary variables and, through sign restriction method, we jointly identify a wide set of structural shocks: financial shocks (housing, credit shocks), monetary shocks and real shocks (aggregate demand, aggregate supply, investment shocks).

The choice of DSR features different positive aspects. First, the DSR is a measure of financial fragility that takes into account three different components of financial vulnerability: i) the cost of debt, related to the effective interest rate payed by the average household; ii) the aggregate stock of debt issued by households, iii) the evolution of households' income.

Second, the DSR ex-ante informs about the build-up of financial risks in households' sector, as opposed to variables which signal only current financial distress (e.g. financial stress indicators) or ex-post signalling indicators (e.g. NBER recessionary periods, industrial production evolution). In this respect, the transformation in DSR is widely used in risk analysis to detect the build-up of financial risk in the economy given its good signalling properties as an early warning indicator of financial crisis.

The key message of this paper is that the propagation of financial shocks under financial vulnerability depends on the origin of the shock itself..

First, financial vulnerability amplifies the impact of housing shocks and make them more persistent. Under high vulnerability the effect on output to a housing shock is overall twice as large as the effect obtained in a linear model featuring the same specification. Instead, under low vulnerability, the response to an housing shock of a similar size is not statistically significant. The amplification under financial vulnerability can be read in light of the theoretical works that study the presence of financial accelerators in the economy (Kiyotaki 1997). In these models, agents are subject to borrowing constraints and can borrow only up to fraction of their collateral. If their collateral decreases because of an incoming shock, so does the debt limit: agents will be forced to reduce their leverage and spend less, amplifying the initial fluctuation. This type of channel seems to be stronger after a large increase in the DSR. A possible interpretation could be that the DSR provides information on the probability of default of households, whereas collateral value determines the Loss Given Default of their loan. When DSR is high, agents feature a larger probability of default, making lenders more sensitive to the evolution of collateral value (i.e. Loss Given Default).

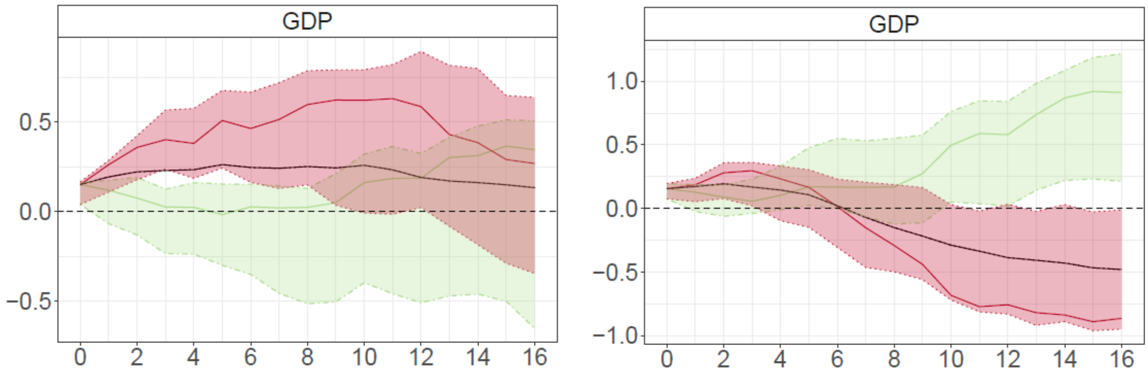
Second, the positive effect of credit shocks are overturned under high vulnerability: expansionary credit shocks have negative effect on the medium term. The overshooting of credit shocks under high vulnerability is consistent with the presence of debt overhang, which induces financially vulnerable agents to deleverage after a period of debt expansion.

In an extension of our baseline model we find that under high vulnerability recessionary housing and credit shocks have a more persistent effet on output than expansionary shocks..

In another extension, we further disentangle credit demand shocks from credit supply shocks. This identification allows to establish that financial vulnerability makes them less persistent or even negative on the medium run, in line with the interpretation that such expansions are hampered by possible debt overhang. However, this amplification is substantially stronger for credit supply shocks.

Those results call for the monitoring of households financial vulnerability to correctly assess the potential amplification effects of incoming financial shocks. Moreover, they highlight the potential beneficial effects of macroprudential policies in limiting the excessive build-up of financial vulnerability, and consequently reducing the sensitivity of the economy to financial shocks.

State-dependent responses of output to housing shocks and credit shocks



Note: Responses of output growth are cumulated. The red (green) lines are impulses at high (low) state. Left-hand panel (Right-hand) report responses to a housing (credit) shock. Shaded areas represent the 67% confidence intervals

Comment la vulnérabilité financière amplifie-t-elle les chocs immobiliers et de crédit ?

Nous étudions dans ce papier la façon dont la fragilité financière des ménages affecte les chocs immobiliers et de crédit aux États-Unis. Pour cela, nous estimons premièrement un modèle non-linéaire dans lequel les réponses aux chocs dépendent de l'évolution passée de la charge de la dette des ménages, c'est-à-dire de la part de leur revenu qu'ils utilisent pour rembourser leurs dettes. Secondement, nous utilisons des méthodes de restriction de signe pour identifier conjointement un ensemble de chocs financiers et économiques. Nous trouvons que la vulnérabilité financière : i) amplifie les réponses aux chocs immobiliers et ii) rend les réponses aux chocs expansionnistes d'offre de crédit moins persistantes, et même négative à moyen terme. Finalement, durant la première année après le choc, les chocs récessifs ont un effet plus fort que les chocs expansionnistes de même ampleur.

Mots-clés : Vulnérabilité Financière, Politique Macroprudentielle, Modèles non-linéaires, Immobilier, Crédit

Les Documents de travail reflètent les idées personnelles de leurs auteurs et n'expriment pas nécessairement la position de la Banque des règlements internationaux, la Banque de France, l'Eurosystème, la Réserve fédérale d'Atlanta ou la Réserve fédérale. Ce document est disponible sur publications.banque-france.fr

1 Introduction

Households' financial vulnerability is key to explain the large cost of financial crises, as observed during the Great Recession (Jordà et al. (2013); Mian et al. (2017)). In macroeconomic modelling, the presence of debt generally amplifies the response of the economy to shocks affecting financial conditions (Kiyotaki and Moore (1997)). However, the effects of financial shocks can vary according to their origin, in that exogenous variations in collateral prices or in lending conditions can feature different propagation mechanisms.

In this paper we ask how financial vulnerability affects financial shocks that originate in different sectors of the economy, namely housing and credit shocks. To answer this question, we estimate a non-linear econometric model on US data by using Local Projections (LP, Jordà (2005)) with state effects. To track financial vulnerability, we use the Debt Service Ratio (thereafter DSR), i.e. the fraction of income that is used to pay interest and amortize the principal. This choice allows to obtain impulse responses that depend on households' financial vulnerability. Our model includes real, financial and monetary variables and, through sign restrictions, we jointly identify a wide set of structural shocks: financial shocks (housing, credit shocks), monetary shocks and real shocks (aggregate demand, aggregate supply, investment shocks). In line with the sign restrictions strategy by Furlanetto et al. (2017), the ratio between debt stock and house prices is used to to disentangle housing from credit shocks, in that an expansionary credit (housing) shock has a positive (negative) impact on this ratio. We find that financial vulnerability has different effects on housing and credit shocks. First, under high vulnerability the effect on output to a housing shock is overall twice as large as the effect obtained in a linear model featuring the same specification. Instead, under low vulnerability, the response to an housing shock of a similar size is not statistically significant. Second, under high financial vulnerability an expansionary credit shock has a positive effect on output only during the first year since the arrival of the shock, whereas its effect turns negative for the rest of the projection.

The choice of DSR features different positive aspects. First, the DSR is a structural measure of financial fragility that takes into account three different components of financial vulnerability: i) the cost of debt, related to the effective interest rate payed by the average household; ii) the aggregate stock of debt issued by households, iii) the evolution of households' income. For this reason, the DSR is one of the main indicators used in banking, to assess households' risk in the mortgage sector. Second, the DSR can inform about the *ex-ante build-up of financial risks* in households' sector, as opposed to variables which signal the *ex-post materialization of risk*, through distress indicators, either financial (e.g. financial stress indicators) or economic (e.g. NBER recessionary periods, industrial production evolution). In this respect, the evolution of the DSR is widely used in risk analysis to detect the build-up of financial risk in the economy given its good signalling properties as an early warning indicator of financial crisis. Together with its good early warning performance, expressing the DSR in its 3 years difference helps getting rid of the low-frequency structural change of the variable and focusing on its signalling property. Importantly, our results are robust to using the DSR expressed in levels, as well as in longer or shorter differences.

The key message of this paper is that the propagation of financial shocks under financial vulnerability depends on the origin of the shock itself.

First, financial vulnerability generally amplifies the response of housing shocks. The role of financial vulnerability in amplification can be read in light of the theoretical works that study the presence of financial accelerators in the economy (Kiyotaki and Moore (1997)). In these models, agents are subject to borrowing constraints and can borrow only up to fraction of their collateral. If their collateral decreases because of an incoming shock, so does the debt limit: agents will be forced to reduce their leverage and spend less, activating a collateral channel that amplifies the initial fluctuation. This type of channel seems to be stronger after a increase in the DSR. From the point of view of a lender, the DSR provides information on the Probability of Default of households, whereas collateral value determines the Loss Given Default. When DSR is high, agents feature a larger probability of default, making lenders more sensitive to the evolution of collateral value (i.e. Loss Given Default). Second, the initial positive effects on output of credit shocks are overturned under high vulnerability. The overshooting of credit shocks under high vulnerability is consistent with a story of debt overhang, which induces financially vulnerable agents to deleverage when their debt burden is too high. An interpretation of the asymmetry in the results of housing shock and credit shock is provided by Justiniano et al. (2015), who show that, in their model, only housing shocks are able to induce a collateral effect strong enough to explain the credit cycle observed over the financial crisis. In an extension of our model, we allow for the possibility to obtain sign effects by complementing the benchmark model with interaction terms between the standard regressors and indicator functions, assuming value equal to 1 when the variables are below their historical median value, and zero otherwise. The presence of these terms generates impulse responses that vary according to the sign of the shock. In the first year of the projection, recessionary housing and credit shocks have an effect on output that is two times larger under high vulnerability with respect to the expansionary shocks in absolute terms. Interestingly, our results are in line with the findings of Guerrieri and Iacoviello (2017) and Jensen et al. (2020). In their models, since the borrowing constraints are only occasionally binding, recessionary shocks have a stronger and more concentrated effect with respect to the expansionary ones, given the asymmetric role played by the collateral channel in shocks transmission. In another extension of the model, we further disentangle credit demand shocks from credit supply shocks, by restricting the response on impact of the mortgage rate, in that an expansionary demand (supply) shock has a positive (negative) effect on the mortgage rate. According to our results, for both types of shocks, financial vulnerability amplifies the effects of the shocks during the first year and makes them less persistent for the rest of the projection, in line with the interpretation that such expansions are hampered by possible debt overhang. However, this amplification seem stronger for credit supply shocks.

This set of results highlight the importance of macroprudential policies in preventing the excessive build-up of financial vulnerability. In particular macroprudential tools which are successful to contain large increases in the DSR over the medium term, can reduce the sensitivity of the economy to incoming financial shocks. The remainder of the paper is as follows. Section 2 frames the paper in the literature. Section 3 presents the empirical model. In Section 4, data and the identification strategy are presented. Section 5 presents the results and sensitivity analysis. Section 6 discusses our empirical results in light of macroeconomic theory. Section 7 concludes. Finally, robustness exercises are housed in the Appendix.

2 Literature

This work contributes to three streams of literature.

A first stream of literature investigates on the impact of financial shocks across the state of the economy. Cheng and Chiu (2017) study the impact of mortgage rate shocks across the business cycle while Barnichon et al. (2016), Carriero et al. (2018) and Colombo and Paccagnini (2020) analyze whether credit shocks are subject to state and sign effects.[1] Through different identification techniques, these papers identify how financial shocks are amplified under a certain state of the economy (respectively credit distress and recession). In our paper, we disentangle financial shock according to their origin (housing, credit supply and credit demand shocks) and find that this distinction is key to detect non-linear effects in that: i) both housing and credit shocks determine a stronger effect when financial vulnerability is high in the first year of the projection, but ii) only housing shocks are persistent, while credit supply shocks have on the medium run a negative effect when vulnerability is high. Differently from these papers, our state variable is a measure of the build-up in financial vulnerability (the DSR) which has good ex-ante signalling properties in risk assessment (Lang et al. (2019)), as opposed to state variables capturing materialized crisis time only ex-post. Finally, Carriero et al. (2018) and Barnichon et al. (2016) detect important sign effects in that credit recessionary shocks have a stronger impact than expansionary

[1]Carriero et al. (2018) estimate a Smooth Transition- Multivariate Autoregressive Index model (ST-MAI model) to analyze how positive and negative structural shocks are amplified in periods of credit distress. Through Gaussian Mixed Average approaches Barnichon et al. (2016) assess how expansionary and recessionary credit supply shocks in the economy propagate according to the state of the business cycle.

shocks. We find the same type of evidence for the first year since the arrival of the shock.[2].

A second stream of literature focuses on the identification of credit and housing shocks. Among others, Furlanetto et al. (2017); Gambetti and Musso (2017); Musso et al. (2011); Walentin (2014) propose different identification strategies, based on Cholesky ordering or sign restrictions. These works have been mostly conducted in a linear framework. In particular Furlanetto et al. (2017) provide a series of set-ups to jointly identify different types of financial shocks (housing, credit demand and credit supply shocks). We expand their analysis, by applying their type of identification strategy in a non-linear framework so to obtain impulse responses depending on the evolution of the DSR.

Finally, financial frictions generating amplification mechanisms became central in theoretical models with financial accelerators, where agents' financial conditions affect the propagation of financial shocks (Bernanke et al. (1996); Christiano et al. (2015); Kiyotaki and Moore (1997); Liu et al. (2013)). Our paper contributes to this literature by looking for empirical evidence of shocks' amplification, related to financial vulnerability. If our results are overall in line with the types of non-linearities produced by Guerrieri and Iacoviello (2017) and Jensen et al. (2020), they also highlight asymmetries in the propagation of housing and credit shocks that are not always found in those models.

3 Empirical model

3.1 Econometric model

Our empirical setting is a Smooth Transition Local Projection model (thereafter STLP). This framework allows to model the smooth transition of the economy between two states (e.g. high regime versus low regime). The in-

[2]Other works study non-linear effects focusing on the propagation of monetary shocks (Aikman et al. (2016, 2017); Alpanda and Zubairy (2017); Barnichon and Matthes (2016); Bauer and Granziera (2016); Franz (2017); Harding and Klein (2018); Hofmann and Peersman (2017))

teraction between a continuous state variable and the explanatory variables delivers impulse responses that depend on the regime of the economy (e.g. in our case the 3-year change in the DSR).

Impulse responses are extracted via Local Projections (thereafter LP, Jordà (2005)). The model is estimated at different forecast periods: $h = 1, ..., H$. Impulse responses for the horizon h are directly recovered from the coefficients estimated for that particular horizon, without computing the Moving Average representation of the model. The use of LP with respect to other VAR-type approaches is motivated by three reasons. First, LP allow flexibility in the inclusion of regressors, which is very useful in our context since we incorporate different types of non-linearities. Second, when the model is misspecified with respect to the data generating process, LP avoid to accumulate the misspecification error over the projection horizon. Third, in our context the transition variable endogenously evolves during the projection horizon: LP implicitly take this evolution into account, without the need to model it. [3]

For each period $t = 0, ..., T$ and each horizon $h = 0, ..., H$, with n the number of endogenous variables, and p the number of lags, our econometric setting is:

$$\begin{aligned} Y_{t+h} = \; & F(z_{t-1})(\alpha_h^{\mathcal{H}} + \beta_h^{\mathcal{H}} Y_{t-1} + \Sigma_{\ell=2}^{p} L_{h,\ell}^{\mathcal{H}} Y_{t-\ell}) \\ & + (1 - F(z_{t-1}))(\alpha_h^{\mathcal{L}} + \beta_h^{\mathcal{L}} Y_{t-1} + \Sigma_{\ell=2}^{p} L_{h,\ell}^{\mathcal{L}} Y_{t-\ell}) \\ & + u_{h,t}, \end{aligned} \tag{1}$$

where Y_t is the $(n, 1)$ vector of endogenous variables at time t, z_{t-1} is the scalar state variable at time $t-1$ and $u_{h,t}$ is the $(n, 1)$ vector of errors at horizon h at time t. The scalar function $F(z_t)$ governs the transition between high and low regime. As standard, the transition function is the logistic

[3] In recent years, this method has been extensively used to assess the effect of structural shocks on the economy. Among others, Alessandri and Mumtaz (2019); Tenreyro and Thwaites (2016) for monetary shocks, Auerbach and Gorodnichenko (2013) for fiscal shocks, Fieldhouse et al. (2018) for public asset purchase shocks.

transformation of the original z_t:

$$F(z_t) = \frac{1}{1 + exp\left(-\theta\left(\frac{z_t - c}{\sigma_z^2}\right)\right)} \tag{2}$$

This transformation normalizes z_t into the interval $[0, 1]$ and facilitates the interpretation of the state variable. The parameter c controls the fraction of the sample spent in either state.[4] The parameter θ determines the smoothness of the transitions between both states.[5] Both parameters are calibrated (Auerbach and Gorodnichenko (2013)). First, we set c at the historical median of the original state variable, so that the resulting state spends half of the time in both regimes. Second, we calibrate θ equal to 3, in line with Tenreyro and Thwaites (2016) and Franz (2017). Our results are robust to a large range of other calibrations.

We construct confidence intervals using the block-of-blocks bootstrap approach, suggested for LP by Kilian and Kim (2011) to account for the autocorrelation in time series.[6] For robustness check, we compute confidence intervals through alternative methods. First, we use the bootstrap-after-bootstrap method, which corrects for bias in bootstrap estimates (see Kilian (1998); Kilian and Kim (2011)). Second, we use the covariance matrix approach.[7]

[4] $z_t > c$ is equivalent to $F(z_t) > 0.5$. Defining c as the $p - th$ quantile of the historical time series of z_t forces $F(z_t)$ to spend $p\%$ of the time below 0.5, i.e. in the low regime.

[5] The higher θ, the faster $F(z_t)$ goes toward 0 and 1, i.e. converging to a dummy-regime switching.

[6] This method consists in constructing all possible overlapping tuples of m consecutive dates in the matrix Y of endogenous variables, along with the corresponding block of regressors for each selected dates, at each horizon of regression (hence the blocks-of-block denomination). We then draw in this family of blocks to construct the bootstrapped time series. We follow Horowitz (2018) recommendation of $m \propto T^{1/3}$, resulting in $m = 5$ following. We thus select blocks of five consecutive dates to build the bootstrap time series.

[7] In particular, we use the so-called Spacial Correlation Consistent (SCC) covariance matrix proposed by Driscoll and Kraay (1998). This approach allows to compute cumulative IRF, when the coefficients for different horizons are mechanically correlated. In fact, this method is a panel data generalization of Newey and West (1987) and accounts for autocorrelation, heteroskedascity and also cross-serial correlation between different individuals in different times. By treating horizons as individuals, we control for their correlation (Falck et al. (2018)).

3.2 Shocks identification

Our strategy for structural shock identification relies on sign restrictions (Canova and De Nicolo (2002); Rubio-Ramirez et al. (2010); Uhlig (2005)). As in the literature of VAR models, the reduced-form error for horizon h, $u_{t,h} \sim N(0, \Omega_h)$, can be written as a linear combination of structural shocks $\epsilon_{t,h} \sim N(0, I)$:

$$u_{t,h} = \Gamma \epsilon_{t,h}, \tag{3}$$

with $\Gamma\Gamma' = \Sigma$. To identify Γ, a set of restrictions is needed. In this paper, we use the algorithm proposed by Rubio-Ramirez et al. (2010). In a first step, we recover the variance covariance matrix of the reduced form error $\hat{\Omega_h}$ from the main equation 1 at horizon 1. Second, we compute the diagonal matrix D of eigenvalues and a matrix of eigenvectors Υ define $\Omega = \Upsilon D^{1/2}$ so that $\Gamma\Gamma' = \hat{\Omega}$. Then for each round, we draw a matrix of independent normal vectors $W \sim MN(0, I_{N^2})$, we take Q from its QR decomposition and we generate the impulse response ΓQ. If the generated impact matrix verifies the sign conditions, the proposed impulse is accepted and stored, otherwise it is rejected. This process is repeated until a sufficiently large number of draws has been accepted [8]. To compute the median response from the set of accepted draws we use "Median-Target" strategy proposed in (Fry and Pagan (2011)).[9] We use this method for each of the bootstraped time series.

4 Data

Our database includes US macro and financial data from 1983Q1 to 2019Q1. As starting date, we select the beginning of the Great Moderation Depending

[8] We take 500 accepted draws for the point estimate and 100 for the bootstraps. Increasing the latter to 10,000 provides no substantial improvement, while considerably increasing the computational burden

[9] As there are multiple accepted draws for the same $\hat{\Gamma}$, each draw implicitly corresponds to a specific *model*, and it is necessary to summarize the information. The Median Target Strategy consists in selecting a single shock among all acceptable shocks, the one that has minimal euclidean distance to the median impact matrix. Another common practice consists in taking the matrix of the median impulse response. However, as pointed in Fry and Pagan (2011), this method is not suited for summarizing information of the models, as this might select structural shocks identified from different draws (i.e. different models).

on the specification, our set of endogenous data includes quarterly growth in real output (GDP), inflation (CPI), the short term rate, stock prices (S&P500), all in quarterly log-difference, 30-year fixed rate mortgage rates, the ratio between investments (real gross private domestic investments) and output, the ratio between households' debt (loans and debt securities) and the total value of real estate held by households. The series of output, inflation, mortgage rate, investment and total value of households' real estate come from Federal Reserve Bank of St. Louis Database (FRED®), stock prices come from Yahoo®. In order to overcome the non-linearity introduced by the Zero Lower Bound and take into account the expansionary non-conventional monetary policy, the short term rate is the shadow rate computed by Wu and Xia (2016). In robustness checks, we use the Effective Federal Fund Rate and the one-year Treasury rate.

4.1 The choice of the interaction variable

We capture households' financial vulnerability by using the Debt Service Ratio. The DRS is the share of a borrower's income dedicated to debt repayment. At the macroeconomic level, it can be approximated as (see Drehmann et al. (2015a)):

$$DSR_t \equiv \frac{D_t}{Y_t} \frac{i_t}{1 - (1 + i_t)^{-m}}, \tag{4}$$

where Y_t is income, D_t is debt, i_t is the lending interest rate, m is the maturity. The DSR captures the debt repayment capacity of a borrower: the higher the DSR, the less financial buffer she has to shoulder an adverse shock before being bankrupt, this shock being lower income, higher rates or early repayment of debt. As such, the use of Debt Service Ratio as transition variable allows to directly capture the effects of financial vulnerability on the impulse responses.

In our benchmark estimation the DSR is expressed in 3 years difference for two reasons. First, in this way we get rid of the low frequency structural change. Second, the DSR in difference has been showed to be a performing early warning indicator in the prediction of crisis (Lang and Welz (2017)).

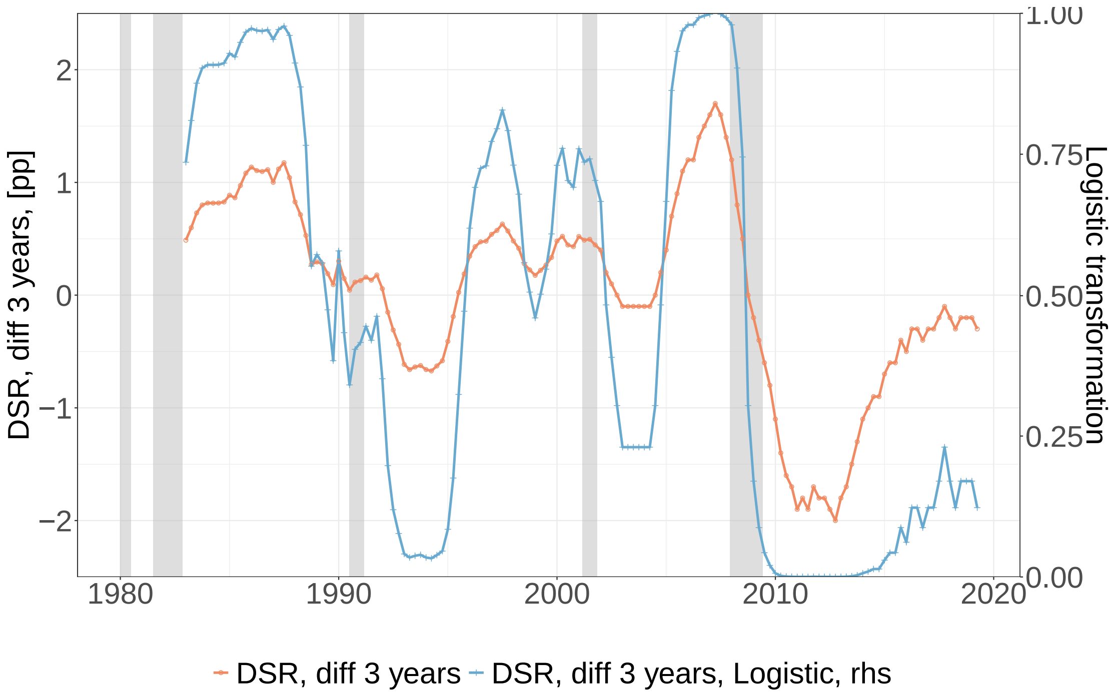


Figure 1: Debt to Service Ratio (DSR) in 3 years difference. Note: the orange line with circles presents the DSR ratios computed by the BIS, in 3-year difference. The blue line with crosses is the transition function from high to low state regimes, obtained in our benchmark estimation with $c = 0.5$ and $\theta = 3$. Grey bars indicate NBER recessions.

However, for robustness we also estimate the model by using the DSR in levels and we find qualitatively similar results.

We use the DSR computed by Drehmann et al. (2015b) for the Bank of International Settlements. Since the series starts in 1999, we compute it backward using their methodology.[10]

As shown in Figure 1, the DSR in 3 years difference has the two highest peaks in the second half of the 1980's, in the pre-crisis period, whereas its troughs can be found at the beginning in the first half of the 1990's and in the aftermath of the crisis.

[10] An alternative measure providing information on the position of households would be the Loan-to-Value ratio (the ratio between total loans and the collateral value). However, the LTV features a poor performance in signalling the build-up of financial vulnerability, mostly due to the higher level of pro-cyclicality of collateral prices.

5 Results

5.1 Housing and credit shocks

In our benchmark exercise we assess how financial vulnerability affects the propagation of housing and credit shocks. The benchmark specification features 2 lags, but results are robust to other lags choices (robustness results using 3 lags can be found in the Appendix). We estimate the response of the economy for 16 quarters.

This specification includes the following set of endogenous variables: real output quarterly growth, quarterly inflation, the ratio between investments and output, the shadow policy rate, stock prices quarterly growth and the ratio between households' total credit (loans and debt securities) and real estate at market value (flow of funds).

Sign restrictions are built on the identification strategy used by Furlanetto et al. (2017) as reported in Table 1.[11] Overall our identification restrictions are in line with the standard dynamics found in most theoretical and empirical DSGE models. Aggregate Demand and Aggregate Supply shocks are in line with standard economic theory: output and inflation have a positive co-movement for an Aggregate Demand shock, while the comovement is negative for Aggregate Supply shocks. To disentangle aggregate demand shocks from the investment shocks we add another restriction on the ratio between investments and output. If the impact of the shock is positive (negative), we identify an investment shock (Aggregate Demand). This restriction is in line with Smets and Wouters (2007) and Justiniano et al. (2010), for which investments shocks have a stronger impact on investment growth than on output, opposite to the aggregate demand shocks. In order to disentangle investment shocks from financial shocks, we assume that the former have a negative impact on stock prices while the latter have a positive effect. This

[11] In our benchmark application, we jointly identify housing, credit and monetary policy shocks, while Furlanetto et al. (2017) follow a two step procedure. In a first exercise, they identify monetary policy and financial shocks, without disentangling credit form housing shocks. In a second exercise, they disentangle housing and credit shocks but exclude the monetary policy shock to ease the computational burden associated with a too large number of structural shocks to identify.

	Output	Inflation	Policy rate	Inv/Out ratio	Stock prices	Credit/RE ratio
Agg.Demand	+	+	+	-		
Agg.Supply	+	-			+	
Mon.Policy	+	+	-			
Investment	+	+	+	+	-	
Housing	+	+	+	+	+	-
Credit	+	+	+	+	+	+

Table 1: The table presents the sign restrictions assumed on the reaction on impact of endogenous variables (column) to identify the structural shocks shocks (row). When the space is empty, the response is left unrestricted.

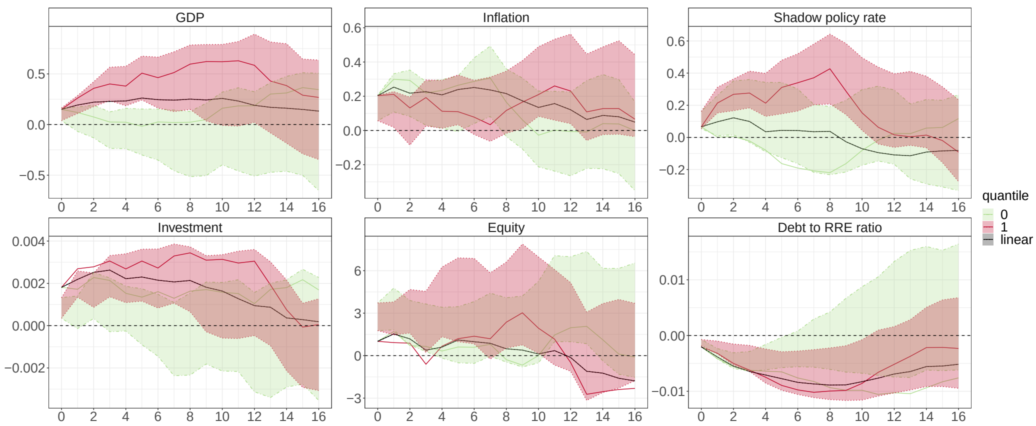


Figure 2: Impulse responses of a selection of the endogenous variables to a housing shock. Note. The responses of output growth and equity growth are cumulated, while the responses for the ratio of investment/output are in levels. The red (green) lines are the impulses when leverage is high (low). Shaded areas represent the 67% confidence intervals.

restriction derives from Christiano et al. (2010), in which investment shocks, by increasing the efficiency in the accumulation law of capital, increase capital supply and decrease its price (i.e. stocks prices). Finally, to disentangle financial shocks in housing and credit shocks we use the ratio between total credit and housing value, assuming that credit (housing) shocks have a positive (negative) impact on this ratio.

In Figure 2 we report the responses of our endogenous variables to a housing shock. The lines in red are the responses when vulnerability is high ($F(z_t) = 1$), while the line in green are the responses when vulnerability is low ($F(z_t) = 0$). In order to assess the role of state effects we report the response of the linear model (black line), estimated using the same variables used in the non-linear specification, but with no state effect. To ease the comparison, for the linear model we use the same impact matrix used in the non-linear specification. From the comparison of the impulse responses across the different regimes, we find that higher vulnerability substantially amplifies housing shocks. Under high vulnerability, the response of output to an housing shock is statistically significant for the first two years and is at least twice as large as the response obtained in the linear model. Conversely, under low vulnerability, the response of output is not significantly different from zero for all the projection horizon. A one standard deviation housing shock determines on impact a positive reaction of output equal to 0.2%, coupled with a a positive reaction of inflation (+0.2%). After two years (8th horizon), the response of output will be equal to 0.6% under high vulnerability, and close to 0 under low vulnerability. Similar non-linear dynamics are found for the other variables: under high vulnerability the responses of investments over output ratio and equity are overall twice as large as the response under low vulnerability. The reaction on impact of the ratio investments/output implies that investments increases by 0.2% with respect to output on impact. After two years, under high vulnerability, the positive effect on this ratio is above 0.3%, whereas under high vulnerability the effect is not statistically different from zero. Given the expansion of the denominator (output stock), the significant increase in the ratio under high vulnerability implies that investments have a more pro-cyclical behaviour than output following an housing shock. Finally, the drop in the ratio between debt and house prices remains statistically significant across the horizon under high vulnerability, in line with a stronger and more persistent increase in house prices.

These results show an important amplification of the housing shocks under high vulnerability and are in line with the findings of the theoretical models featuring a financial accelerator (Kiyotaki and Moore (1997)), where borrowing constraints amplify collateral fluctuations: when collateral prices decrease, agents have to reduce their debt, spending less and further amplifying the negative fluctuations of house prices. The stronger role of the collateral channel after an increase in the DSR could be rationalised by the fact that the DSR provides information on the probability of default of house-

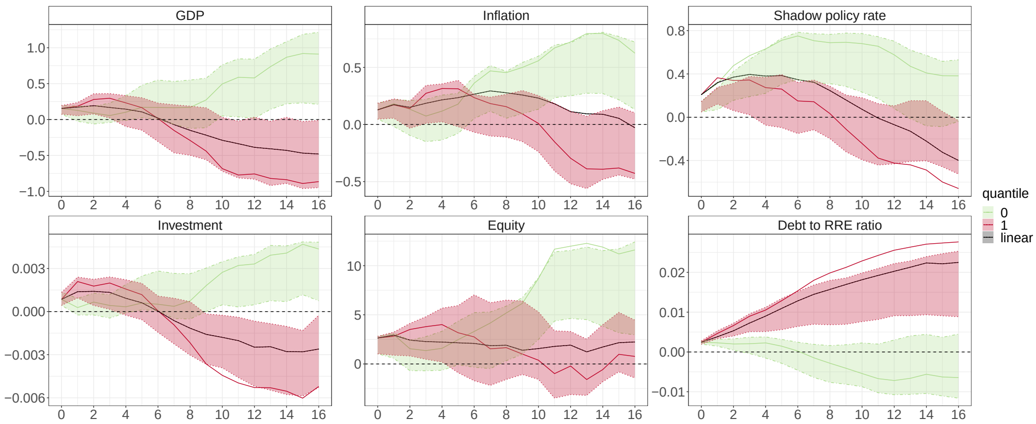


Figure 3: Impulse responses of a of output growth to a credit shock.
Note. The responses of output growth and equity growth are cumulated, while the responses for the ratio of investment/output are in levels. The red (green) lines are the impulses when leverage is high (low). Shaded areas represent the 67% confidence intervals.

holds, whereas house prices affect the Loss Given Default. From a potential lender's perspective, an increase in the DSR (i.e. in the probability of default) makes variations in collateral value relatively more important in affecting lending decision.

In Figure 3 we report the responses of output growth to a credit shock. As already found by Furlanetto et al. (2017), in the linear case, the response of output to credit shock is positive at the beginning of the projection (e.g. the first six quarters) and turns negative for the rest of the projection. The use of the non-linear specification allows us to shed light on this result. In the non-linear case, this overshooting in the response of output is found only under high vulnerability. Until the sixth quarter, the response of output is twice as large as the response in the linear case under high vulnerability. After the sixth quarter, effects become negative and are doubled with respect to the linear case. Quantitatively speaking, a one standard deviation credit shock is associated to an increase in output equal to 0.2% on impact. After few quarters (quarter 3), under high vulnerability this effect increases to 0.3%, while for the linear case the effect remains stable around 0.2%. At the end of the projection under the linear case, the response of output is equal to -0.5%, whereas under high vulnerability the response is equal -0.8%.

Vice-versa, under low vulnerability, the response of output is smaller with respect to the linear case in the first part of the projection: at the beginning of the projection, the effect is not statistically different from zero, while it becomes strongly positive after the first ten quarters (+0.8%). The other endogenous variables feature similar dynamics: investments and equity go through a stronger expansion under high vulnerability in the first part of the projection, while their response turn negative after two years since the arrival of the shocks. In particular, on impact the ratio of the investments over output increases by 0.1%. The effect is amplified during the first year (+0.2%) and becomes negative at the end of the projection (-0.5%). This variation of the ratio imply that the overshooting for investments is even stronger than the one found for output. Finally, the ratio Debt/Houses value shows an important non-linearity: when vulnerability is high, the response is strongly positive and significant across all the horizons, whereas under low vulnerability, the effect on the Debt/Houses ratio is not significantly different from zero. These results can be rationalised by the fact that households under high vulnerability can be more subject to debt overhang: the initial credit expansion pushes indebted households to deleverage in the following periods, overturning the initial positive effect of the shocks. The stronger reaction of Debt/House ratio under high vulnerability could signal that indebtedness of agents in terms of collateral is higher, i.e. the worth of collateral does not follow the debt expansion. Conversely, under low vulnerability the more stable response of Debt/Houses ratio is in line with a more sustainable credit expansion: debt expansion triggers an increase of collateral and allows agents to fully enjoy the credit expansion without need to deleverage.

The asymmetric result in the amplification of housing and credit shocks is one of the key result of the paper. This finding recalls the result by Justiniano et al. (2015). In this paper, a structural model is used to determine which shock, between housing and credit, is more likely to be at the origin of the credit expansion and the deleveraging observed in the US financial cycles over the Great Recession. According to their results, only the housing shock has the property to generate a persistent debt expansion as the one observed in the pre-crisis period.[12]

The amplification role of financial vulnerability highlights the stabilization role that macroprudential policies can play concerning housing shock and credit shocks. In particular, policies aiming to contain households' over-indebtedness (i.e. borrowers' based measures as caps to individual Debt Service Ratios) can lean against the build-up of vulnerability, reducing some of the non-linear effects highlighted so far. For example, if a persistent and strong expansion of indebtedness is expected to bring the DSR to its highest percentile in three years, macroprudential policies can be activated to impose agents to maintain the DSR at a constant level for 3 consecutive years. This will have two potential positive effects. First, after the potential arrival of a recessionary housing shock, the negative effects on output would be halved. Second, the output overshooting related to the possible debt overhang triggered by an expansionary credit shock could be halved as well. Finally, this overshooting could be even avoided in case the macroprudential measures would manage to further reduce DSR over the same horizon.

5.2 State and sign effects

In this extension, we assess how the amplification effects found in previous section vary according to the sign of the shock. To do so, we complement the original model with additional interaction terms between the standard regressors and indicator functions. These indicators take value equal to 1 when the regressor is below its historical median value and 0 otherwise. Thanks to this additional terms, the impulse responses will not only depend on the regime of the economy (i.e. the level of financial vulnerability) but also on the position of the explanatory variables.

[12]The model in Justiniano et al. (2015) features savers and borrowers, with the latter ones can borrow up to a fraction of their collateral. Their result is related to the fact that the housing shock pushes savers and borrowers to increase their spending in housing, producing a persistent positive effect on house prices. This substantial increase in house prices will allow borrowers to expand their debt, generating an important collateral channel. Conversely, the credit shock pushes only borrowers to increase their spending in housing, while the increase in house prices will bring savers to reduce their housing consumption: overall the different reactions between savers and borrowers will produce a milder increase in house prices, triggering a smaller collateral channel.

In practice, we modify Equation 1 the following way:

$$\begin{aligned} Y_{t+h} = \; & F(z_{t-1})(\alpha_h^{\mathcal{H}} + \beta_h^{\mathcal{H}} Y_{t-1} + \gamma_h^{\mathcal{H}} Y_{t-1}^{\mathbb{1},\bar{Y}} + \Sigma_{\ell=2}^{p} L_{h,\ell}^{\mathcal{H}} Y_{t-\ell}) \\ & + (1 - F(z_{t-1}))(\alpha_h^{\mathcal{L}} + \beta_h^{\mathcal{L}} Y_{t-1} + \gamma_h^{\mathcal{L}} Y_{t-1}^{\mathbb{1},\bar{Y}} + \Sigma_{\ell=2}^{p} L_{h,\ell}^{\mathcal{L}} Y_{t-\ell}) \\ & + u_{h,t}, \end{aligned} \tag{5}$$

with

$$Y_{t-1}^{\mathbb{1},\bar{Y}} = \begin{pmatrix} Y_{1,t-1} \mathbb{1}_{Y_{1,t-1} < \bar{Y_1}} \\ ... \\ Y_{n,t-1} \mathbb{1}_{Y_{n,t-1} < \bar{Y_n}} \end{pmatrix}, \tag{6}$$

where the term $Y_{t-1}^{\mathbb{1},\bar{Y}}$ is a (n,1) vector, delivering the sign effect. The $i-th$ element of $Y_{t-1}^{\mathbb{1},\bar{Y}}$ is the product between the $i-th$ element in Y_{t-1} and the indicator function $\mathbb{1}$, assuming value 1 (0) when the $i-th$ variable $Y_{i,t-1}$ is below (above) its cutoff value $\bar{Y_i}$. In order to obtain sign dependent impulse responses, we set the initial state of our endogenous variables to the cutoff value used in the estimation, so that the sign of the shock will determine which set of coefficients is activated.

Thanks to this specification, we can jointly assess the state and the sign effects of housing and credit shocks. Except for those additional terms, we use the same variables and the identification strategy of the baseline model.

In Figure 4 we report the response of output and of the ratio of debt over house prices to housing shocks at a high vulnerability state. In the left (central) columns of the figure, we report the responses to a recessionary (expansionary) shocks. In the third column, we report the responses to expansionary and to recessionary shock. For the sake of comparability, we multiply by -1 the responses to the recessionary shock.

The response to a recessionary shock (orange line) remains statistically significant along all the projection horizon, while the response to the expansionary shock (blue line) is not statistically significant starting from the 10th quarter. Moreover, in absolute terms the response to the recessionary shocks is from 1.5 to 2 times larger than the expansionary one.

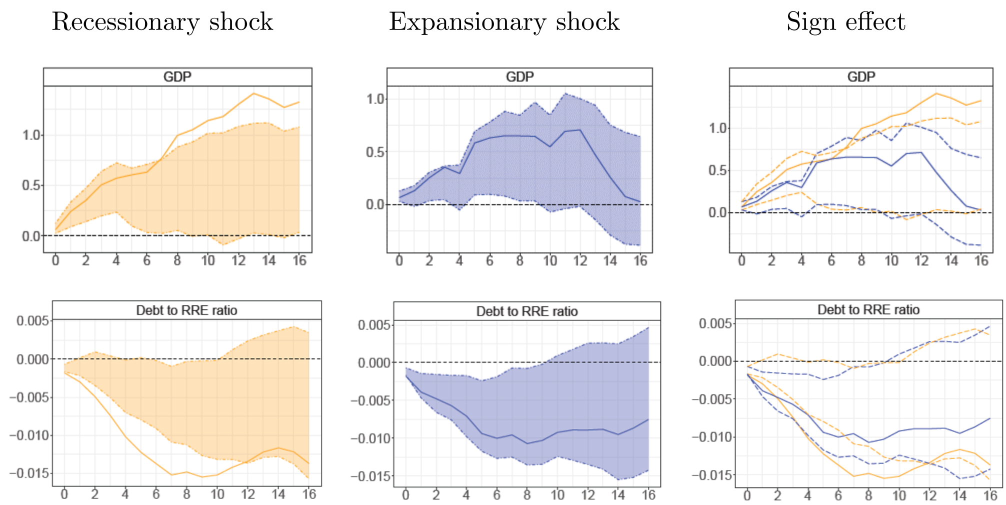


Figure 4: Impulse responses of output growth and debt/house price ratio to a housing shock at $F(z_t) = 1$.
Note. The responses of output growth and equity growth are cumulated, while the responses for the ratio of investment/output are in levels. Left-hand panel (central graph) report responses to a recessionary (expansionary) shock. Right-hand panel reports responses under the high state to an expansionary (recessionary) in blue (orange). Impulses to recessionary shocks multiplied by -1 for the sake of comparison. Shaded areas represent the 67% confidence intervals.

This result recalls the finding of Guerrieri and Iacoviello (2017), in that, in absolute terms, recessionary housing shocks are stronger than expansionary ones of the same size. The mechanism at the origin of their result is the following: when collateral prices drop, so does debt limits and constrained households can be forced to reduce their spending, amplifying the initial negative fluctuation. Instead, after expansionary shocks, households can decide to inter-temporally postpone their spending, limiting their debt expansion and producing a more limited effect on economic activity.

In Figure 5 we report the responses to credit shock under high vulnerability. While recessionary shocks have a significant negative effect for one year, the effect of expansionary shock vanishes immediately after the shock. This asymmetric response of output with respect to credit shocks recalls the findings by Jensen et al. (2020), where a DSGE model with occasionally binding borrowing constraints is used to explain the observed asymmetry in the business cycle. According to their result, recessionary credit shocks

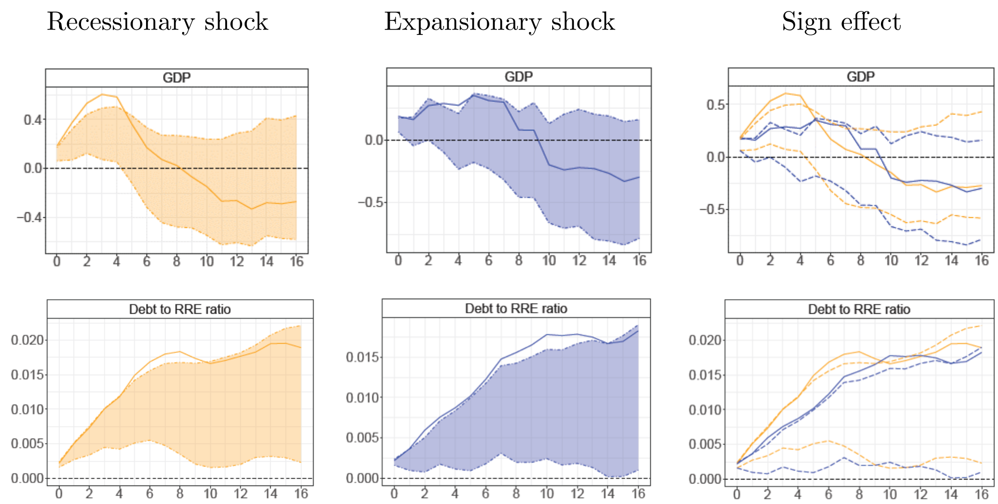


Figure 5: Impulse responses of a selection of the endogenous variables to a credit shock at $F(z_t) = 1$.
Note. The responses of output growth and equity growth are cumulated, while the responses for the ratio of investment/output are in levels. Left-hand panel (central graph) report responses to a recessionary (expansionary) shock. Right-hand panel reports responses under the high state to an expansionary (recessionary) in blue (orange). Impulses to recessionary shocks multiplied by -1 for the sake of comparison. Shaded areas represent the 67% confidence intervals.

have a stronger negative effect on impact whereas expansionary shocks have a smaller but more persistent effect on the economy.

5.3 Credit demand and credit supply

In our benchmark specification we found that, under high vulnerability, after an initial expansion, the response of output to credit shocks turns negative. To further explore this result, in this extension we disentangle credit demand from credit supply shocks.

To do that, we modify the previous specifications in two ways. First, we add the mortgage rate to the set of endogenous variables and use it to disentangle credit demand and supply shocks: an expansionary credit demand (supply) shock increases (reduces) the mortgage rate (Table 2). Second, for the sake of parsimony, we follow Furlanetto et al. (2017) and exclude the policy rate from this specification.

Overall, in this specification we find that for both shocks the non-linear

	GDP	Inflation	Inv/Out ratio	Stock prices	Credit/RE ratio	Mortgage rate
AD	+	+	-			
AS	+	-		+		
Investment	+	+	+	-		
Housing	+	+	+	+	-	+
Cred supply	+	+	+	+	+	-
Cred demand	+	+	+	+	+	+

Table 2: The table presents the sign restrictions assumed on the reaction on impact of endogenous variables (column) to identify the structural shocks shocks (row). When the space is empty, the response is left unrestricted.

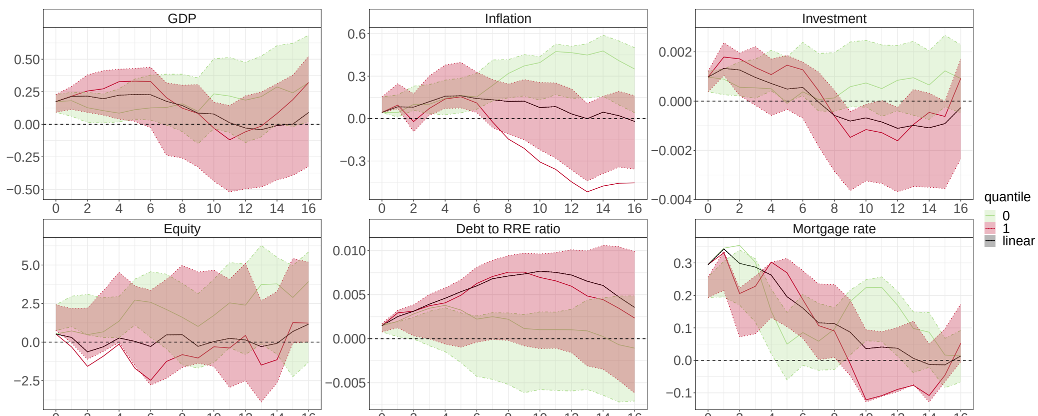


Figure 6: Impulse responses to a credit demand shock.
Note. The responses of output growth and equity growth are cumulated, while the responses for the ratio of investment/output are in levels. The red (green) lines are the impulses when leverage is high (low). Shaded areas represent the 67% confidence intervals.

effects are in line with the ones found for the undistinguished credit shock of the benchmark specification.

In Figure 6 we report the responses of the economy to a credit demand shock. Under high vulnerability, the response of output growth to a credit demand shock is positive and statistically significant on impact, whereas it becomes not statistically significant after six quarters since the arrival of the shock. Besides, investments over output react positively during the first two years, whereas in the second part of the projection, their response turns slightly negative. Instead, under low vulnerability, the effect of credit demand shock in the economy is not statistically significant across the projection horizon, made exception for the first two quarters since the arrival of the shock.

Credit supply shocks, reported in Figure 7, deliver similar non-linear dynamics as the ones found in the benchmark specification for the credit shock. First, the expansionary impact is persistent under low vulnerability. Second, under high vulnerability the expansionary effect on output is limited to the beginning of the projection and the cumulated effect turns negative after three years. Third, the debt to houses value ratio reacts positively under high vulnerability, while it significantly decreases under low vulnerability. As explained discussing the results of the benchmark specification, these important state effects of the debt to houses value ratio and of output are consistent with the role of debt overhang being triggered under high financial vulnerability.

5.4 Sensitivity analysis

We run a series of robustness checks. In all these exercises, results remain qualitatively and quantitatively similar to what found for the benchmark specification. The main robustness exercises are reported in the Appendix.

First we used two alternative econometric methods. We run the Smooth Local Projections developed by Barnichon and Brownlees (2018) to efficiently estimate local projections coefficients by using B-spline and ridge regressions. Using this method, we found very similar quantitative and qualita-

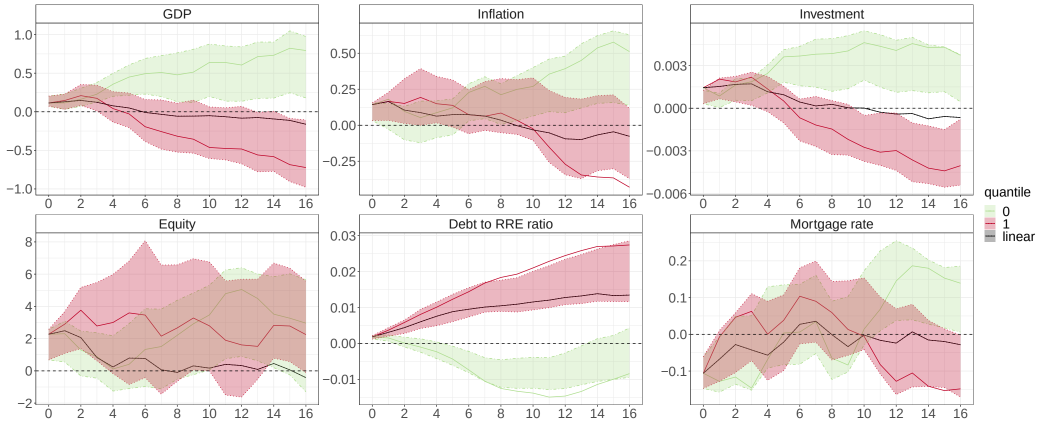


Figure 7: Impulse responses to a credit supply shock.
Note: The responses of output growth and equity growth are cumulated, while the responses for the ratio of investment/output are in levels. The red (green) lines are the impulses when leverage is high (low). Shaded areas represent the 67% confidence intervals.

tive results. We also implement the bootstrap-after-bootstrap bias-correction method, which only marginally affect results.

Second, in terms of modelling choice, we run the regressions with three lags, instead of the two lags used in the baseline. Besides, we use other calibrations for smoothing transition parameter $\theta = 1.5, 5$.

Third, in order to test the results to different transformations of our state variable, we use different transformations of the DSR. We use the 2 and 4-year difference instead of the 3-year one. Alternatively, we use the DSR expressed in levels: results are qualitatively similar to the ones found in the benchmark specification. Finally we use as an alternative source the DSR provided by the Federal Reserve.

Fourth, our results are robust to the use of different measures for our regressors. We use the mortgage debt, instead of total debt, to compute the debt to house ratio. Besides, we use alternative inflation measures (Core CPI quarterly variation, GDP deflator quarterly variation). Finally, we use as alternative measures for the policy rate the Fed Fund Rate and the one-year government bond rate[13].

[13]The last one is supposed to include also information on the forward guidance and is less affected by the materialization of the Zero Lower Bound, see Gertler and Karadi

6 Discussion

In this section we resume our main results and discuss them in light of the findings of macroeconomic theoretical works studying the propagation of financial shocks.

Not all financial shocks propagate in the same way: housing shocks are more persistent. This finding recalls Justiniano et al. (2015) who assess whether the observed credit boom bust cycle over the Great Recession is related to a a credit shock or to housing shocks. In their model, only housing shocks can produce a sensible variation in collateral prices and, consequently, trigger the financial accelerator.[14] This difference between the two shocks in triggering the collateral channel could rationalize our result.

Overall recessionary shocks are stronger than expansionary ones. In line with the most theoretical results (Guerrieri and Iacoviello (2017); Jensen et al. (2020)) recessionary shocks have overall stronger effects in absolute terms. According to their findings, a weaker role of the collateral channel after expansionary shocks is at the origin of this asymmetry detected in the business cycle.

(2015)

[14]Justiniano et al. (2015) use a macroeconomic model featuring an asymmetric collateral constraint on households: when collateral decreases, agents are forced to reduce the new debt flows but not the outstanding debt. This modelling choice is key to match an observed feature of the data in that after crisis, the ratio between credit/real estate does not decrease and actually spikes. First, they identify the housing shock as the main driver of the fluctuations, since in their model housing shock deliver an increase in the credit/house prices ratio as observed during the crisis. Second, they find that a shock on the credit side generates a variation in house prices value that is not strong enough to generate a big amplification spiral. In fact, credit shocks trigger an increase in willingness to buy houses for borrowers but not for savers. Since these two effects partially offset each other, the positive effect on houses is smaller, triggering a smaller collateral channel. Instead, housing shocks affect both savers and borrowers willingness to buy houses, triggering a stronger increase in house prices and triggering a stronger effect on debt. Third, they do not find significantly strong effects on output growth. This can also be related to the fact that the financial friction is applied only to the households and not to other agents (as banks or firms).

Housing shocks are amplified under vulnerability. This result can be interpreted in light of the models studying the role of financial accelerator, from the seminal paper by Kiyotaki and Moore (1997), to the recent stream of papers following the GFC (among others, Liu et al. (2013, 2016)). In those models, households can borrow up to a fraction of their collateral, so housing shocks affecting collateral prices directly modify agents' borrowing capacity, potentially amplifying the initial fluctuations. Our results suggest that this effect is stronger after a large increase in the DSR. One explanation for this amplification could be provided by the fact that while the DSR informs on the income buffer of the borrower, and thus her Probability of Default, the collateral value captures the payoff of the lender in case of default, i.e. the Loss Given Default. A large increase is the former is likely to make lenders more sensitive to the latter, amplifying the financial accelerator effect.

When recessionary, amplification of housing shocks is even stronger. To this extent, Guerrieri and Iacoviello (2017) build a DSGE model where the presence of occasionally binding constraints causes a strong sign effect in the propagation of the housing shock. Drops in collateral prices *forces* agents to deleverage to get back to the new borrowing constraint. On the contrary, an increases of the same size *allow* them to borrow more. They may use some of that financial slack for intertemporally substitution, but without expanding their debt as much as they could.

Under high vulnerability, expansionary credit shocks determine a positive effect at the beginning but are less persistent. This overshooting featuring the response of output to credit shock is also found in Gambetti and Musso (2017) and Furlanetto et al. (2017). Our non-linear specification seems to suggest that debt overhang, originated under high vulnerability, can be responsible for the overturn of the effect after the first year since the arrival of the shock. Indeed, a debt overhang effect is more likely to occur after a credit supply shock when debt was already originally high.

Vulnerability makes recessionary credit shocks stronger on impact Jensen et al. (2020) find this same type of results thanks to the role of occasionally binding constraints: expansionary shocks allow agents (in their case entrepreneurs) to inter-temporally postpone their spending, making the effects of the shocks less strong on impact with respect to recessionary shocks, which force agents to deleverage, amplifying the initial negative fluctuation.

7 Conclusion

In this paper we find that households' debt burden features important non-linear effects on the transmission of financial shocks. First, we detect that financial vulnerability: i) amplifies and makes more persistent housing shocks, ii) makes expansionary credit shocks less persistent and overturn their initial effects. At the origin of this difference lies the possible presence of debt overhang or a weaker collateral channel concerning the transmission of the credit shocks. Second, recessionary shocks are overall stronger on impact.

If overall we find results in line with the findings of models with occasionally binding constraints, the asymmetric propagation between housing and credit is in contrast to what usually found in this literature, where housing and credit shocks usually feature very similar amplification mechanisms. This result suggests to better take into account the asymmetries related to the propagation of housing and credit shocks, in the spirit of what done by Justiniano et al. (2015).

Our results have key implications for policy makers. On the positive side, they call for the monitoring of macrofinancial indicators of households vulnerability. On the normative side, they highlight the importance of macroprudential policies preventing the excessive build-up of such financial vulnerability.

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