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Sovereign Uncertainty

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Abstract

This paper investigates the impact and the transmission of uncertainty regarding the future path of government finances on economic activity. I first employ a data-rich approach to extract a novel proxy that captures uncertainty surrounding public finances, which I refer to as *sovereign uncertainty*, and demonstrate that the estimated measure exhibits distinct fluctuations from macro-financial and economic policy uncertainty indices. Next, I analyze the behavior of sovereign uncertainty shocks and detect the presence of significant and long-lasting negative effects in the financial and macroeconomic sectors using state-of-the-art identification strategies, within the context of a Bayesian vector autoregression framework. I show that a shock to sovereign uncertainty differs from a macro-financial uncertainty shock — while the former dampens the economy in the medium-run and points to deflationary dynamics, the latter displays a short-lived response in real activity and generates inflationary pressures. Finally, I study the role of sovereign uncertainty in a New Keynesian dynamic stochastic general equilibrium model augmented with recursive preferences and financial intermediaries. I find that a sovereign uncertainty shock in the model is able to capture the empirical slowdowns in economic aggregates if there is lack of reaction by the monetary authority in the aftermath of the shock. The model also emphasizes the importance of financial frictions in transmitting the effects of sovereign uncertainty shocks and highlights the minor role played by nominal rigidities.

Keywords: Sovereign Uncertainty Index, Government Finances, Economic Activity, Event-based Identification, Bayesian VARs, Non-Linear DSGE Models.

JEL Codes: C32, E32, E44, E60.

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Non-Technical Summary

Since the aftermath of the Great Recession, the solvency of several European governments has again become the focus of attention among economists and policymakers. This situation has resulted in an increase in uncertainty about the outlook for public finances. For example, during the height of the sovereign debt crisis, Spain, Ireland, Portugal and Greece had implement unprecedented economic programs in order to alleviate the uncertainty surrounding the rising bond yield spreads, the high structural deficits and the considerable levels of debt. While a large and growing body of literature has focused on the consequences of overall uncertainty in business cycle fluctuations, evidence on the effects of uncertainty originating from disturbances in the public finances has received less discussion.

In this paper, I contribute to the analysis of the transmission of uncertainty associated with public finances on economic activity. In particular, I present a new uncertainty indicator for public finances, which I refer to as *sovereign uncertainty*, by exploiting a high-information content approach. This framework implies that sovereign uncertainty is a measure of the common variation in uncertainty across a large number of series that affect several aspects of the public finances simultaneously. We can think about the interpretation of the sovereign uncertainty measure as the sum of its risk component, related to rollover (liquidity) and solvency (default) risks, and Knightian uncertainty (ambiguity).

The index identifies important government-related events for the Spanish economy and clearly exhibits independent variations from macro-financial and economic policy uncertainty measures. My research finds that shocks to sovereign uncertainty lead to significant and long-lasting negative effects in the macroeconomy. In addition, I show that a shock to sovereign uncertainty notably differs from a macro-financial uncertainty shock — while the former dampens the economy in the medium-run and points to deflationary dynamics, the latter displays short-lived responses in real activity and generates inflationary pressures.

Finally, I study the transmission of sovereign uncertainty in a standard theoretical model augmented with financial intermediation and recursive preferences. I find that the proposed model captures the empirical slowdown in output, investment and hours worked following a sovereign uncertainty shock and, in a lower proportion, it also accounts for the declines in private consumption and bank lending. This finding is conditional on the lack of reaction by the monetary authority. My theoretical framework also emphasizes the importance of financial frictions in explaining and transmitting the effects of sovereign uncertainty shocks and highlights the minor role played by nominal rigidities.

1 Introduction

Since the aftermath of the Great Recession, the solvency of several European governments has again become the focus of attention among economists and policymakers. This situation has resulted in an increase in uncertainty about the outlook for public finances. For example, during the height of the sovereign debt crisis, Spain, Ireland, Portugal and Greece had to implement unprecedented economic programs in order to alleviate large fluctuations of the bond yield spreads, the high structural deficits and the considerable levels of debt. While a large and growing body of literature has focused on the consequences of overall uncertainty in business cycle fluctuations, evidence on the effects of uncertainty originating from disturbances in the public finances has received less discussion.[1]

In this paper, I contribute to the analysis of the transmission of uncertainty associated with government policy on economic activity. Firstly, I propose a new uncertainty indicator for public finances, which I refer to as *sovereign uncertainty*, by exploiting the high-information content of the forecasting methodology in Jurado et al. (2015). The benefit of using this framework is that changes in sovereign uncertainty capture whether the outlook for government finances has become more or less predictable, and not whether it has become more or less volatile. Moreover, in this approach sovereign uncertainty is a measure of the common variation in uncertainty across a large number of series that affect several aspects of the public finances simultaneously. Following the work by Rossi et al. (2016), we can think about the interpretation of the sovereign uncertainty measure as the sum of its risk component, in this case related to rollover (liquidity) and solvency (default) risks, and its Knightian uncertainty.[2] Secondly, I employ Bayesian vector autoregression (BVAR) techniques to analyze the effects of sovereign uncertainty shocks on key macroeconomic and financial aggregates. These are identified through various identification strategies — recursive schemes and a combination of sign, event-based and ratio restrictions. Finally, I introduce an approximation for sovereign uncertainty in a New Keynesian dynamic stochastic general equilibrium (NK-DSGE) model with recursive preferences and financial intermediaries to rationalize the empirical results.

I conduct this study using Spanish data. In fact, Spain is an economy where the lack of discipline in public finances has been a longstanding issue (see BdE, 2006) and, therefore, the sovereign debt crisis was likely not a unique instance of concern regarding government uncertainty.[3] In order to obtain the sovereign uncertainty index, I use a sample of 31 government-related variables and 93 macro-financial time series. In particular, the former dataset embodies series on bond spreads, securities, loans, revenues, expenditures and taxation. The macro-financial series encompass data on industrial production, prices,

[1] Bloom (2014) and Castelnuovo et al. (2017) are recent surveys on the role played by uncertainty in business cycle fluctuations.

[2] Rossi et al. (2016) show that uncertainty can be decomposed into Knightian uncertainty (ambiguity) and risk. Their paper defines Knightian uncertainty as the one pertaining to situations where the odds and outcomes are not properly known, or even if agents are informed, they disagree on those probabilities. Instead, the measure of risk is the realized volatility, which measures uncertainty about the odds of the outcomes when the probability distribution is known.

[3] Other economies such as Greece or Italy are also informative cases of public uncertainty in recent times. However, in comparison with Spain, lack of (*i*) a large enough number of government finances indicators and (*ii*) a long time-span makes the choice of these countries questionable.

foreign trade, wages, raw materials, surveys, interest rates, exchange rates, credit and private equities. I use the combined datasets to estimate the forecasting model, but calculate sovereign uncertainty only from the aggregation of each individual uncertainty estimate associated with the public finance series. Sovereign uncertainty is then defined as an aggregate proxy that conveys a set of 31 government-related individual uncertainty indices from May 1997 to August 2017.

The estimated measure of sovereign uncertainty, denoted SU subsequently, identifies important government-related events for the Spanish economy. The most important are those related to the concerns prior to joining the European monetary union; the Spanish involvement in Iraq, which implied the use of a sizable amount of public resources to finance the military intervention; the global financial crisis; the Euro Area debt crisis; and the upward trend in sovereign uncertainty from 2015 to 2017, associated with political uncertainty given the difficulties of forming a stable government after two consecutive elections and, consequently, this entailed a freeze in the budget. Furthermore, I show that SU clearly exhibits independent variations from the economic policy uncertainty (EPU) indicator developed by Baker et al. (2016), as well as from a macro-financial uncertainty (MU) index computed again with the Jurado et al. (2015) approach.[4] The difference between the SU index and both the EPU and MU is sizable. The correlation between SU and EPU is only 0.14 for the full sample. This divergence may arise either from the fact that coverage of political events has not always resulted in increased difficulty to predict the path of the government finances, or from the fact that EPU does not explicitly control for a deterioration in expectations of the mean economic outcome when volatility increases, potentially conflating uncertainty shocks and confidence shocks. On the other hand, while SU and MU present a common spike at the height of the Great Recession, MU does not display any other episodes of heightened uncertainty captured by SU.

Next, according to my BVAR analysis, shocks to sovereign uncertainty that are identified through both recursive orderings and a combination of sign, event-based and ratio restrictions lead to economically and statistically significant declines in economic activity, and point to deflationary pressures. First, relative to the recursive identification, I argue under which conditions SU shocks can be considered as unable to contemporaneously respond to developments in the economy and vice versa, showing that the results are robust in both circumstances and, additionally, to an extensive battery of recursive-based robustness checks. Second, the mix of sign, event-based and ratio restrictions confirms, in general, the validity of the previous findings. In this case, I jointly identify a sovereign uncertainty shock and a macro-financial uncertainty shock. The benchmark theoretical restrictions are imposed as follows: (*i*) I assume that SU shocks (MU shocks) rise SU (MU) for the first nine months, whereas the signs of the responses for other macroeconomic and financial variables remain agnostic; (*ii*) I constraint the structural shock series on particular dates (mainly around the Spanish involvement in Iraq, the Lehman Brothers' collapse and the European Stability Mechanism assistance); and (*iii*) it is required that SU (MU) shocks produce, on impact, a response of the SU-MU ratio above (below)

[4] Meinen and Röehe (2017) and Redl (2018) already compute a measure of macroeconomic uncertainty for Spain and other European countries. I compute it here (given my macro-financial dataset) for comparative reasons, particularly, to show that sovereign uncertainty displays autonomous fluctuations from macro-financial uncertainty.

unity. An interesting finding here is that the effects of these two sources of uncertainty are different — while SU shocks perturb the economy in the medium-run, the impact of MU shocks is short-lived and inflationary. Again, I check the robustness of these results by considering other prior beliefs about the narrative of both shocks and accounting for potential omitted variables in the baseline vector of agents' information.

In the theoretical section of the paper, the starting point is a canonical New Keynesian DSGE model augmented with financial intermediation as in Gertler and Karadi (2013) and Epstein-Zin (EZ) preferences. In the extended framework, banks hold government bonds. I explicitly model the real interest rate on these bonds as the sum of return on a perpetuity and an exogenous additive term which is subject to a stochastic volatility shock. The latter is an approximation of a sovereign uncertainty shock. This interpretation follows the extraction of the empirical measure of sovereign uncertainty where the time-varying volatility components are computed by employing an AR(1) stochastic volatility model. Hence, the way I model uncertainty in both parts of the paper is based on the same assumptions. This also allows for a shock to the second moment that is independent of the first moment. In addition, the model is solved by a third-order perturbation method (see Fernández-Villaverde et al., 2011 and Basu and Bundick, 2017) and estimated with a combination of impulse response and moment matching (see Christiano et al., 2005 and Basu and Bundick, 2017). The goal is to minimize the distance between impulse responses implied by the theoretical model and empirical responses generated by the VAR framework, while generating moments consistent with the data.

The main finding here is that the proposed theoretical model captures the empirical slowdown in output, investment and hours worked following a SU shock and, in a lower proportion, it also accounts for the decline in consumption and bank lending while being consistent with the data moments and the empirical path of sovereign uncertainty after the shock. I also find that lack of reaction by the monetary authority when a SU shock hits the economy is crucial to fully reconcile, in magnitude, empirics with theory. One interpretation of the empirical results in the DSGE model is that, after a SU shock, the price of government bonds decline as it now becomes riskier to hold them as banks are exposed to larger fluctuations in the real return on government bonds (either negative or positive). At the same time, heightened sovereign uncertainty affects banks' expectations on firms' claims also causing a fall in the relative price of private capital. The drop in asset prices pulls down bank net worth. Consequently, banks' ability to lend to firms is severely limited since their credit capacity is directly tied to their net worth. Therefore, lack of sufficient bank credit creates scarcity of capital for firms and restricts real economic activity. Moreover, this theoretical framework emphasizes the importance of financial frictions in explaining and transmitting the effects of sovereign uncertainty shocks and highlights the minor role played by nominal rigidities.

My paper relates to several strands of literature. Empirically, I build on the insights of Jurado et al. (2015) and apply their ideas to the measurement of sovereign uncertainty. Born and Pfeifer (2014), Fernández-Villaverde et al. (2015) and Mumtaz and Surico (2018) analyze the effects of second-moment shocks to fiscal and monetary policy, generally finding moderately negative impact on economic activity.[5] In particular, Born and Pfeifer (2014) show that effects of uncertainty about future tax liabilities, government spending, and monetary policy are limited because their shocks are small and lack sufficiently persistency, whereas Fernández-Villaverde et al. (2015) report that only a two standard deviation fiscal volatility shock to the capital income tax rate is able to generate a relevant economic impact. Mumtaz and Surico (2018) argue that solely uncertainty about government debt has significant impact on real activity. A crucial difference with respect to these papers is that my government-related uncertainty measure is based on a high-information content approach and therefore, is intended to capture several aspects of the public finances simultaneously. In fact, the exclusion of this feature could potentially be the reason behind the minor role that their policy uncertainty shocks play in business cycle fluctuations. Another example focusing on policy uncertainty is Baker et al. (2016). In this influential work, the authors exploit information contained in newspapers to extract aggregate and policy-specific uncertainty indices for the U.S., as well as aggregate policy uncertainty measures for 11 other countries, and note a large detrimental impact of economic policy uncertainty. However, as argued before, their approach does not control for a worsening in expectations of the mean economic outcome when volatility rises, possibly combining confidence shocks (first moment) and uncertainty shocks (second moment).

On the theoretical side, this paper first speaks to a large body of literature examining the effects of uncertainty on the macroeconomy. In his seminal article, Bloom (2009) demonstrates through building a model with time-varying second moments that uncertainty shocks generate sharp recessions and recoveries. Fernández-Villaverde et al. (2011) show why an increase in the volatility of the real interest rate at which emerging economies borrow can result in important drops in macroeconomic aggregates. Leduc and Liu (2016) and Basu and Bundick (2017), as well as Born and Pfeifer (2014) and Fernández-Villaverde et al. (2015), contribute to this theoretical literature by investigating the channels under which uncertainty shocks propagate into a New Keynesian economy without financial intermediaries. Regarding the inclusion of a banking sector, several authors are also concerned with the magnifying effects of financial frictions on the real economy after the occurrence of an uncertainty shock, including Christiano et al. (2014), Gilchrist et al. (2014) and Bonciani and van Roye (2016). However, I focus on the transmission of uncertainty about the outlook for public finances and the previous studies investigate the pass-through of overall uncertainty shocks under different banking frameworks.

Finally, this work also links to several theoretical papers in the literature on sovereign default risk (see Uribe, 2006; Arellano, 2008; and Bi, 2012). The closest study related to my theoretical section is Bocola (2016). He examines the effects of shocks to (perceived) sovereign default risk on economic activity through financial intermediaries. In particular, he analyzes two different but complementary channels (liquidity and risk) under which a rise in the probability of default transmits into the financial and real sectors of the Italian economy. In contrast, I do not focus on the probability of default; instead, I distinguish between first and second moment shocks via stochastic volatility (consistent

[5] See also Mumtaz and Zanetti (2013), which preceded the study of Mumtaz and Surico (2018) and formed the basis of it.

with my empirical section). Second, the main objective of my theoretical exercise is to show whether a New Keynesian DSGE model with financial intermediation can effectively match the empirical evidence of an uncertainty shock originating from changes in the public financial sector, and if so, what are the important theoretical assumptions to achieve it. A third reason, is that the probability of default is normally just modelled subject to the level of debt in this theoretical literature. On the contrary, this study aims to capture many aspects of the solvency of a government and can be then used as an empirical test in the analysis on the adverse effects of governments' exposure to risks.

The remainder of the paper is structured as follows. Section 2 describes how to extract the uncertainty indicator for public finances. Section 3 analyzes the effects of the identified sovereign uncertainty shocks through recursive schemes and a combination of sign, event-based and ratio restrictions in a BVAR framework. Section 4 contains a NK-DSGE model with recursive preferences and financial intermediaries to rationalize the empirical results. Section 5 concludes.

2 Measuring Sovereign Uncertainty

To study the transmission of uncertainty surrounding the public finances of the Spanish economy, I first define and compute a novel measure by means of a data-rich approach. In particular, I define a sovereign uncertainty (SU) index as an aggregate proxy that conveys a large set of government-related individual uncertainty indices. These are computed based on the econometric methodology in Jurado et al. (2015). The benefit of using this method is that changes in uncertainty capture whether economic conditions have become more or less predictable, and not whether they have become more or less volatile. This framework implies that any type of uncertainty (e.g. macroeconomic, financial or trade) is not equal to uncertainty in any single time series, but requires the existence of a common variation in uncertainty across a large number of time series. Moreover, common variation in uncertainty is critical because if the variability of an idiosyncratic shock was purely idiosyncratic, it would have no impact on macroeconomic developments. Accordingly, a measure of sovereign uncertainty would also need to entail uncertainty fluctuations that affect several aspects of the public finances of a government at the same time.[6] In what follows, I present a brief description of the key equations. For further details, I refer the reader to Jurado et al. (2015) and references cited therein.

2.1 Econometric Approach

Formally, let $E[y_{j,t+1}|I_t]$ be a forecast for each individual time series included in the following factor augmented forecasting model:

$$y_{j,t+1} = \phi_j^y(L)y_{j,t} + \gamma_j^F(L)\hat{F}_t + \gamma_j^G(L)\hat{G}_t + \gamma_j^W(L)W_t + \nu_{j,t+1}^y, \tag{1}$$

[6] It is important to remark that sovereign uncertainty is not the same as disagreement about future fiscal policy. A good example is Ricco et al. (2016). Their disagreement measure based on professional survey forecasts may reflect differences in opinion rather than of uncertainty. In fact, they show that their measure does not correlate with the aggregate index of Baker et al. (2016) or with its individual sub-components.

where $\phi_j^y(L)$, $\gamma_j^F(L)$, $\gamma_j^G(L)$ and $\gamma_j^W(L)$ are finite-order polynomials; F_t is a set of potential factors drawn from the original data set; G_t entails a set of potential factors drawn from the squares of the original data set; and W_t is comprised of squares of the first principal component in F_t. The selected factors $\hat{F}_t$ and $\hat{G}_t$ are based on their incremental predictive power for each $y_{j,t}$ by using the information criterion in Bai and Ng (2002).[7]

The one-step-ahead prediction error of $y_{j,t+1}$ and of each selected factor exhibits time-varying volatility. For each forecast error, time-varying volatility is computed by employing an AR(1) stochastic volatility model which allows for a shock to the second moment that is independent of the first moment, consistent with theoretical models of uncertainty (see Fernández-Villaverde et al., 2011; Born and Pfeifer, 2014; Fernández-Villaverde et al., 2015; and Basu and Bundick, 2017). Then, uncertainty associated with the variable $y_{j,t}$ at forecast horizon h, denoted as $\mathbb{U}_{j,t}(h)$, is defined as the conditional volatility of its purely unforecastable component of the future value of the series:

$$\mathbb{U}_{j,t}(h) = \sqrt{\mathbb{E}\left[(y_{j,t+h} - \mathbb{E}[y_{j,t+h}|I_t])^2|I_t\right]}, \tag{2}$$

where the expectation $\mathbb{E}(\cdot|I_t)$ is taken with respect to the information I_t available to economic agents at time t. If the expectation today of the squared forecast error rises, uncertainty in the variable increases. As my sovereign uncertainty proxy is a measure of the common variation in uncertainty across many time series related with the Spanish public finances, the index is then constructed by taking an average of $\mathbb{U}_{j,t}(h)$ across all time series:

$$\mathbb{U}_t(h) \equiv plim_{N\to\infty} \sum_{j=1}^{N} \frac{1}{N} \mathbb{U}_{j,t}(h). \tag{3}$$

This is based on equally weighting the individual uncertainty estimates.

2.2 Dataset

I apply the previous framework to Spain using a sample of 31 government-related variables and 93 macro-financial time series. I use the combined dataset to estimate the forecasting factors, but calculate sovereign uncertainty only from the individual uncertainties in the public sector time series. I have conducted further investigations (results available upon request) and find that the estimated sovereign uncertainty indicator does not significantly change with or without including the macro-financial dataset in the forecasting model. Yet, I opt for including it since this provides an estimate of macro-financial uncertainty (MU) that I can directly compare with the SU index and study the differences and similarities of both measures.

I employ monthly data from May 1997 to August 2017. The starting and ending dates are dictated by the availability of the individual time series associated with the Spanish government. The datasets cover a broad spectrum of series: (*i*) the government-related dataset embodies series on bond spreads, securities, loans, revenues, expenditures and taxation, for different maturities and owners where appropriate; (*ii*) the macro-financial series encompass data on industrial production, prices, foreign trade, wages, raw materials, surveys, interest rates, exchange rates, credit and private equities. All data are

[7] Bai and Ng (2002) propose a t-test with a threshold value of $t = 2.575$.

fetched from the Statistical Data Warehouse (SDW), Haver Analytics or Datastream.[8] In general, interest rates and exchange rates are used as levels, survey data is transformed into first differences, and for all other series first (log) differences are applied. A detailed description of data sources and definitions is listed in Appendix A.1.

2.3 An Estimate for Sovereign Uncertainty

Figure 1 depicts the estimated one-month ahead measure of sovereign uncertainty.[9,10] It can be observed that the proxy matches important government-related events for the Spanish economy:

- Prior to joining the European monetary union (EMU), Spain faced a period of sovereign uncertainty (which in fact was not captured by macro-financial uncertainty). At this time, there were concerns about the success of the monetary integration, in particular for economies with weak tradition of macroeconomic discipline (see BdE, 2006).
- In 2003, the Spanish involvement in Iraq implied the use of a sizable amount of public resources to finance the military intervention. The estimated index also presents this situation as a period of heightened sovereign uncertainty.
- Considering the great recession, one can detect the presence of a significant positive spike. This event has been shown as the combination of many factors, and is therefore displayed by both sovereign and macro-financial uncertainties.
- Shortly after the start of global financial crisis in 2008, the spreads on sovereign debt of many eurozone economies (compared with Germany) began climbing and peaked during the Euro Area debt crisis. To put things into perspective, the spread on one-year Spanish bonds during the height of Euro Area debt crisis was around 350 basis points which was 14 times its mean value of 25 basis points (average over the years 1997–2010). Therefore, as Figure 1 reveals, this span constituted another great episode of uncertainty about the outlook for public finances.
- After a lengthy economic downturn from 2008 to 2013, the Spanish economy also experienced other uncertainty episodes. Concretely, we witnessed an upward trend from 2015 to 2017 in sovereign uncertainty, peaking when Spain faced serious concerns to form a government after two consecutive elections. This led to a freeze in the budget and uncertainty surrounding the public finances rose.

One might think that sovereign uncertainty is simply capturing the same uncertainty episodes compared to macro-financial or economic policy uncertainty indicators. However,

[8] There are few exceptions. See Appendix A.1 for further details.

[9] Figure 11 (Appendix A.2) also reports the 12-months ahead sovereign uncertainty. It can be noticed that the variability of sovereign uncertainty decreases as the prediction horizon tends to infinity. Nevertheless, the main events are still matched and several of them reinforced given that the spikes on those episodes are larger.

[10] Figure 12 in Appendix A.3 exhibits the benchmark measure of sovereign uncertainty together with two sub-indices: its price and quantity components. While the former includes uncertainty price-based series from the public finances dataset, the latter follows a similar logic regarding quantity-based indicators. The price-based component is computed by using 10 public series (out of the 31 government-related variables) and the quantity-based component by employing 21. See Appendix A.1 for data description.

I show in Figure 2 that this is not the case.[11] It can be seen that SU and MU only coincide at the spike of the Great Recession in 2009. In fact, the correlation between these two measures is just 0.28 prior to the global recession. Moreover, even after 2008, particularly during the European debt crisis, the narrative also diverges: MU captures two important peaks in July 2010 and August 2012, while SU exhibits just one main episode in December 2011.[12]

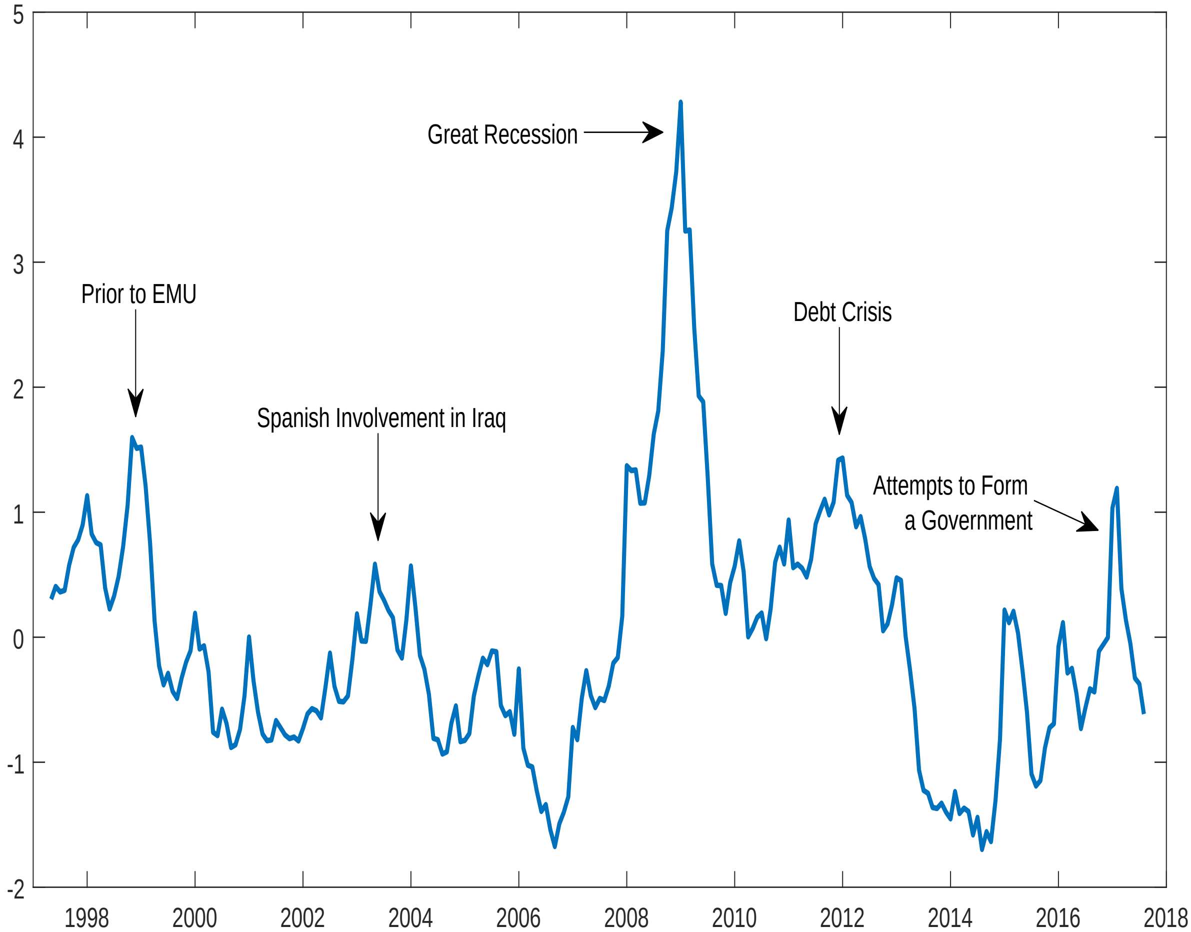

Figure 1: Sovereign Uncertainty (SU) Index

Note: The index represents the one-month ahead uncertainty surrounding the public finances of the Spanish economy. The measure is standardized.

Figure 2 also displays the economic policy uncertainty index (EPU) developed by Baker et al. (2016). The correlation between SU and EPU is just 0.14 for the full sample. This indicates that sovereign uncertainty clearly exhibits independent variation from economic policy uncertainty. This divergence may arise either from the fact that coverage of political events has not always resulted in increased difficulty to predict the path of the govern-

[11] I also provide SVAR evidence in Section 3, where I show that SU and MU shocks produce notably different responses in most of the financial and macroeconomic variables.

[12] Further investigation reveals that if SU is regressed over MU and a dummy variable is introduced that takes a value of one for the period 2008–2009 and zero otherwise, the correlation for the full sample (excluding that period) is around 0.40. If the period 2008–2009 is included, the correlation jumps to 0.69. Consequently, one can notice that only the short span 2008–2009 is responsible for that difference.

ment finances, or from the fact that EPU does not explicitly control for a deterioration in expectations of the mean economic outcome when volatility increases, potentially conflating uncertainty shocks and confidence shocks.[13] Nevertheless, it is important to stress that both indicators feature elevated uncertainty episodes during the attempts to form a government and the Spanish intervention in Iraq.[14]

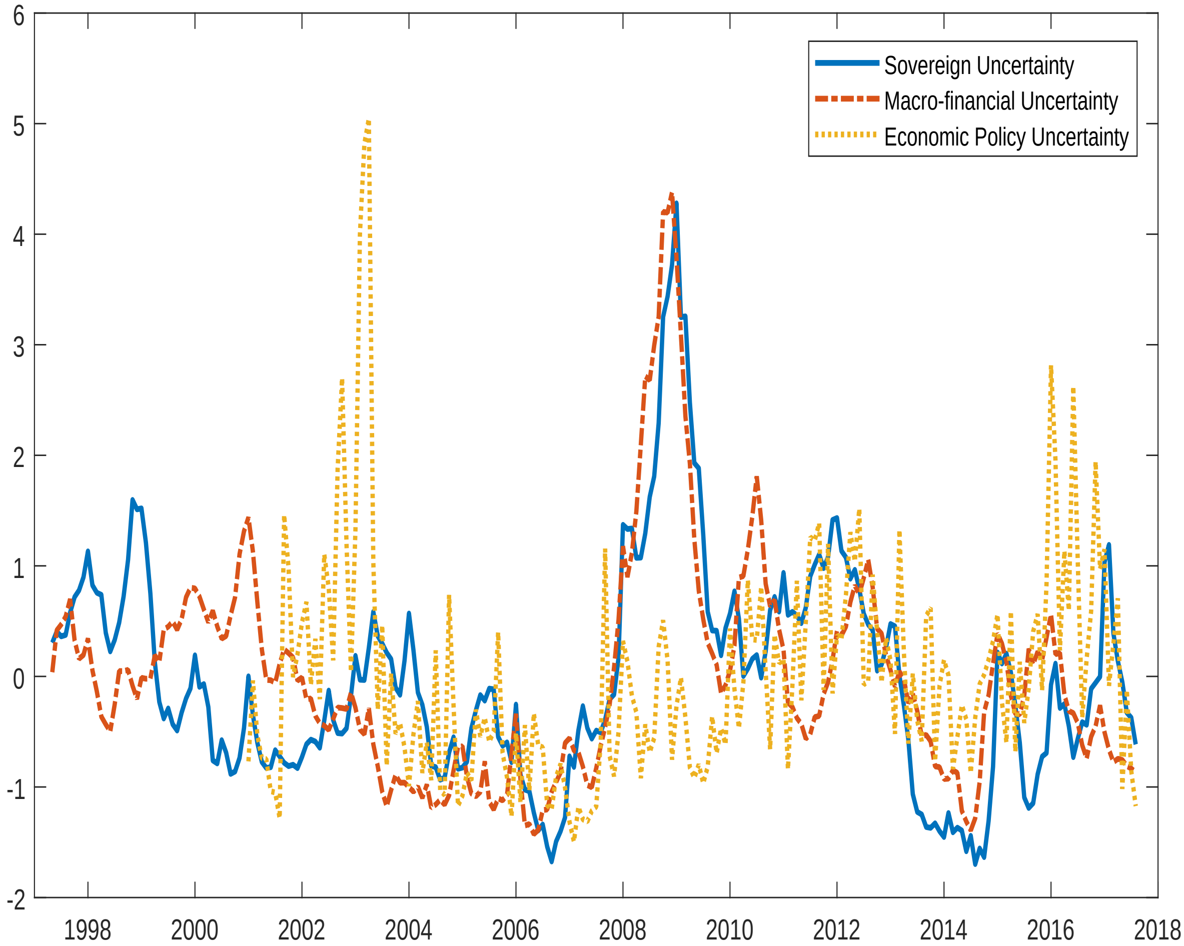

Figure 2: Sovereign Uncertainty, Macro-financial Uncertainty, and EPU

Note: The solid-blue line indicates the estimated sovereign uncertainty; the dash-dot-orange line represents the aggregate macro-financial uncertainty; and the dotted-yellow line exhibits the economic policy uncertainty index from Baker et al. (2016). All measures are standardized.

[13]Figure 13 (Appendix A.4) also reports the economic policy uncertainty index (EPU) developed by Ghirelli et al. (2019). This paper refines the index by Baker et al. (2016) in several dimensions: they expand the headline newspaper coverage from 2 to 7 and use a much richer set of keywords to form the search expressions. The correlation between SU and their EPU is still low at 0.15 for the full sample. Again, this implies that sovereign uncertainty manifests autonomous variation from economic policy uncertainty.

[14]The elevated episode in EPU during the course of 2016 is mainly driving by the Catalan crisis. At this time, Spanish newspapers were reporting daily on the tensions between the central government and the Catalan analogue. This is why high spikes in the EPU index can be observed. On the contrary, the peak in SU is less pronounced. This indicates that the Catalan dispute was not transmitted to the public finance concerns as much as the EPU index reflects, nor to the macro-financial uncertainty.

3 The Macroeconomic Effects of Sovereign Uncertainty Shocks

I now explore the effects of sovereign uncertainty shocks on macroeconomic aggregates using Bayesian vector autoregression (BVAR) methods. I consider a number of alternative identification schemes. In particular, I detail potential recursive orderings and provide robustness evidence. Next, I describe reliable set-identification techniques based on a combination of sign, event-based and ratio restrictions (à la Rubio-Ramírez et al., 2010; Antolín-Díaz and Rubio-Ramírez, 2018; and Ludvigson et al., 2019).

3.1 VAR Model

The benchmark VAR specification is as follows:

$$y_t = c_0 + \sum_{k=1}^{p} \beta_k y_{t-k} + \epsilon_t, \qquad \epsilon_t \sim \mathbb{N}(0,\, Q), \tag{4}$$

where c_0 is a constant, y_t stands for the vector of endogenous variables and ϵ_t is a Gaussian white noise with covariance matrix Q. I employ Bayesian techniques to estimate the model. Specifically, I use a conjugate Normal-inverse Wishart prior, assuming that $vec(B) = (c_0, \beta_1 \ldots, \beta_p)$ is normally distributed and that Q has an inverse Wishart distribution.[15] The prior means of the coefficients on the first lag are set to one for non-stationary variables, and set to zero otherwise. The overall prior tightness is set to 0.10 and the prior on the intercept to 100. These values are standard in the literature.

I use Spanish monthly data in log-levels for all variables except those expressed in rates (see Appendix A.1.3 for data description). The sample is from May 1997 to August 2017 and the baseline model features nine lags.[16] The starting and ending dates are dictated by the availability of the sovereign uncertainty measure (see subsection 2.2).

Recursive schemes. I first identify the shocks recursively based on a Cholesky decomposition of the variance-covariance matrix of the reduced-form residuals. The observables are (in this order) stock market (IBEX-35), bank loans, price level, unemployment rate, industrial production, 10-years government bond rate, public debt and sovereign uncertainty. While the extant literature has debated the exogeneity/endogeneity of uncertainty measures — Ludvigson et al. (2019) find that financial uncertainty is exogenous and macroeconomic uncertainty is not, whereas Carriero et al. (2018) claim the opposite — these studies are actually referring to other types of uncertainty with respect to the one considered here. My chosen recursive identification scheme is motivated by following the

[15] The Normal-inverse Wishart prior takes the following general form:

$$vec(B)|Q \sim \mathcal{N}\big(vec(\underline{B}), Q \otimes \underline{\Phi}\big)$$

and

$$Q \sim \mathcal{IW}\big(\underline{S}, \underline{\alpha}\big),$$

where $\underline{B}$, $\underline{\Phi}$, $\underline{S}$ and $\underline{\alpha}$ are functions of hyperparameters.

[16] The literature normally chooses twelve lags for monthly data. Nevertheless, results are robust to reasonable variations of the number of lags in the VAR framework.

theoretical literature on sovereign risk where concerns about the sustainability of a government are often treated as endogenous drivers (see Uribe, 2006; Arellano, 2008; and Bi, 2012).[17] By ordering sovereign uncertainty last, I am able to model the possibility of other shocks in the system contemporaneously affecting the dynamics of sovereign uncertainty shocks. Nevertheless, I also test the assumption that macroeconomic uncertainty can be considered as a more exogenous component of the economy, and hence, ordered first. This recursive ordering will also permit the clear isolation of the economic mechanisms driving the propagation of sovereign uncertainty in the theoretical model. To empirically motivate this exogeneity one could rely on Longstaff et al. (2011) who investigate credit default swaps for 26 economies and find that country spreads are driven more by forces exogenous to the economy than the local forces. Further support for this position comes from Uribe and Yue (2006) who show that innovations exogenous to the local conditions can explain up to two-thirds of movement in country spreads. To be clear, these two papers do not focus on sovereign uncertainty, but investigate how different factors (internal or external) affect a specific component of the public finances. However, I consider both studies able to provide some validation for the potential exogeneity of the government's exposure to risks.[18]

Sign, event-based and ratio restrictions. Set-identified methods have become a popular and relevant alternative to the recursive approach (see Faust, 1998; Canova and Nicolo, 2002; Uhlig, 2005; Rubio-Ramírez et al., 2010; Mumtaz and Zanetti, 2012; Antolín-Díaz and Rubio-Ramírez, 2018; and Ludvigson et al., 2019, among others). While recursive schemes are justified by economic theory in some cases, they are often inconsistent with theoretical models. The literature on set-identified restrictions proposes to employ prior information on the signs of the impact of certain shocks, combined with narrative and ratio constraints, which is normally extracted from DSGE models and/or specific economic events that have altered the dynamics of the economy. This leads to set-identified responses which are only based on imposing weak assumptions at the considered timing. Therefore, identification is less restrictive than that achieved through the traditional approach of a recursive ordering of the variables that implicitly involves the knowledge of the timing of each variable to all shocks in the system.

In order to transform the reduced-form errors, ϵ_t, into fundamental innovations, $e_t = A\epsilon_t$, it is necessary to place theoretical restrictions to recover the structural shocks. Following Rubio-Ramírez et al. (2010) for the case of sign restrictions, the procedure is to (i) obtain the estimates of the reduced-form elements B and Q; (ii) orthogonalize the innovations using a Cholesky decomposition and compute the consequent impulse responses; (iii) draw a matrix P from a *QR-decomposition* of a random standard normal matrix such that $A = \tilde{A}P$, where $\tilde{A}\tilde{A}' = Q$; and (iv) check whether the imposed signs are matched on the impulse responses (calculated with the ones obtained in the second step and P).

[17] However, it is important to stress that my measure of sovereign uncertainty is aimed to capture several aspects regarding the public sustainability of a country, whereas the theoretical literature on sovereign risk mainly focuses on the probability of default which normally just depends on the level of debt or/and productivity. In other words, we are not exactly measuring the same concepts but they can be potentially linked.

[18] Exogenous elements might relate to risk appetite which may change independent of how the public finances of a particular country evolve, while endogenous would reflect developments in the government finances.

If these are not fulfilled, redraw P until they are met. In addition, the inclusion of event-based (narrative) restrictions requires that the structural shock series is constrained on particular dates. Then, following Antolín-Díaz and Rubio-Ramírez (2018) and Ludvigson et al. (2019), the draws are just kept if the narrative is satisfied.

Previously, I have justified the differences between the SU and MU measures by showing the time series were different. Moreover, I have shown that the inclusion of macro-financial uncertainty does not erase the effects of SU shocks under recursive identification schemes. But do the impulse response functions (IRFs) to shocks to both indices look different? If the two measures are really capturing different things, then, the responses should differ in the structural VAR setting. Consequently, I jointly identify a sovereign uncertainty shock and a macro-financial uncertainty shock by considering the following prior information:

- First, I implement simple and agnostic *sign restrictions*: SU shocks (MU shocks) rise SU (MU) for the first nine months.[19] The signs of the responses for other macroeconomic and financial variables remain agnostic.
- I add now the following *event-related (narrative)* and *ratio constraints*:
  (a) Motivated by the Spanish involvement in Iraq, which implied the use of a sizable amount of public resources to finance the military intervention, SU shocks are required to be positive in the aftermath of the Iraq war (March-April 2003); and negative in April 2004, where the Prime Minister of Spain pulled Spanish troops out of Iraq. In contrast, MU shocks are non-positive in March-April 2003. The choice of this narrative is driven by two crucial reasons: (i) following Ramey and Shapiro (1998) and Ramey (2011), the presence of this war in the SU index creates an event that is exogenous to the current state of the economy; and (ii) one can notice that the SU index rises during this narrative and it declines for the case of MU.[20] As it is displayed in Figure 3, this is evident for each uncertainty indicator at short and long forecasting horizons. Therefore, the aforementioned narrative imposes the minimum restrictions required to identify these two shocks.

  (b) SU and MU shocks must be positive during the Lehman Brothers' collapse (September 2008). This episode triggered uncertainty in many sector of the U.S. economy and it propagated to the Euro Area and the rest of the world.[21]

  (c) SU and MU shocks are positive in June 2012. This is an interesting event be-

[19]In practice, the half-life of sovereign uncertainty is estimated to be around 23 months (based on estimates from a univariate AR(1) model for the series) and 27 months for macro-financial uncertainty. Consequently, this can justify the election of the minimal sign restrictions during 9 months. Further investigations (available from the author upon request) reveal that when the range is diminished to six months or augmented to twelve months, the responses are consistent with the original findings. In particular, when I consider spans longer than nine months, the previous results are strongly reinforced. In this case, it implies that the economy simply responds as if a larger temporary shock had occurred. This corroborates the findings in Bloom (2009), Fernández-Villaverde et al. (2011) and Basu and Bundick (2017), where uncertainty is also explored as a large temporary phenomenon.

[20]Macro-financial uncertainty is normally linked to periods of economic slowdown (see e.g. Jurado et al., 2015). During the Iraq war episode, the Spanish economy was not in recession according to the historical archive of the Spanish Business Cycle Dating Committee.

[21]Nonetheless, around this event, there was already a substantial amount of uncertainty in the Spanish economy due to its housing market crash and the upcoming restructuring of its banking sector.

cause it represented the moment when the European Stability Mechanism (ESM) made available to Spain up to €100 billion in assistance (it is important to note that the country only needed €41.3 billion). Interestingly, this financial support was counted specifically as further sovereign debt. Thus, it could had directly affected the stability of its public finances.[22] If one follows the decomposition of uncertainty by Rossi et al. (2016), we could see a scenario where markets first experience low sovereign Knightian uncertainty but a high risk of default because turmoil is market-driven. Then, when the ESM financial package arrives, the risk of fragmentation in the Euro Area disappears but sovereign Knightian uncertainty increases due to the political process of determining the terms and conditions of the assistance.

(d) Finally, SU (MU) shocks produce, upon impact, a response of the SU-MU ratio above (below) one. The rationale is that events inducing sovereign uncertainty may also increase macro-financial uncertainty, but have larger effects on sovereign uncertainty itself on impact. As time goes by, the SU-MU ratio is endogenously determined and, consequently, it is not constrained.[23]

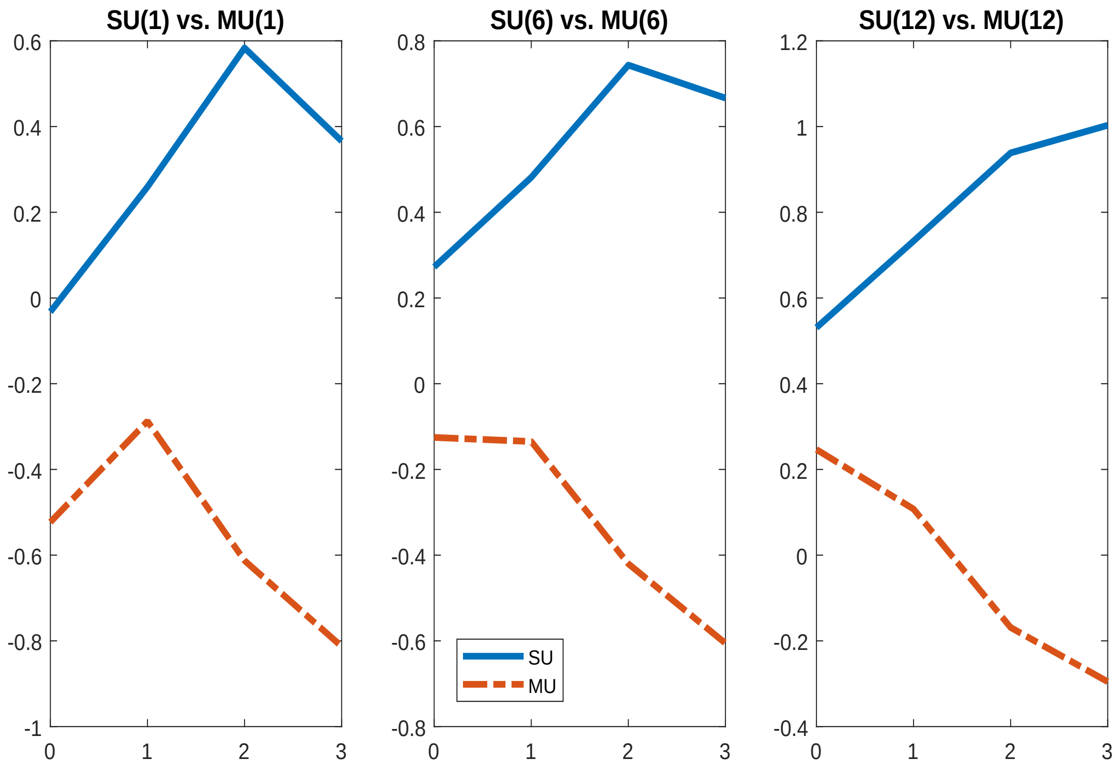

Figure 3: Narrative around the Iraq War: $t = 0$ is March 2003

Note: The figure exhibits the estimated 1-month, 6-months and 12-months ahead uncertainties for both SU (solid-blue lines) and MU (dash-dot-orange) indices. All measures are standardized.

[22]While this constraint in June 2012 could be justified in the case of sovereign uncertainty, I cannot rule out the possibility that this event also impacted overall economic uncertainty. This is the reason why I assume that both SU and MU shocks are non-negative during this month.

[23]Ratio restrictions, in general, are also considered in Furlanetto et al. (2019) and Caggiano et al. (2020).

3.2 VAR Results

In this section, I first examine the findings employing the recursive identification and then continue with those obtained through sign, event-based and ratio restrictions. Exhaustive robustness checks for both identification strategies are also explored.

3.2.1 Findings under Recursive Identification

Figure 4 plots the impulse responses to a one standard deviation shock to sovereign uncertainty in the recursive identification. One can observe that all the variables decline except unemployment rate and government debt. The impact on the long-term rate is inconclusive. It seems to fall in the short-run but this effect is barely significant.[24] In detail: industrial production begins to decline and does not hit the bottom until 15 months later, when it reaches its lowest value of nearly -0.6%. The stock market index and overall price level follow similar paths and take 20 and 30 months before approaching their lowest points of around -0.8% and -0.1%, respectively. Bank lending by roughly -1.5%, whereas unemployment rate and government debt rise, respectively, by almost 0.25% and 0.70% at their maximum levels. These results potentially suggest that an increase in sovereign uncertainty operates as a negative demand shock. In the theoretical section, I will examine how a sovereign uncertainty shock can be transmitted to the real economy. Now, I compare my empirical findings with previous studies on uncertainty shocks. However, it is important to note that these concern the role of different types of uncertainty and none specifically focus on sovereign uncertainty shocks.

The rise in unemployment is in line with the theoretical predictions of Leduc and Liu (2016) following a TFP uncertainty shock. They show that search frictions give rise to a real option-value effect that is contractionary. This is so given that a job match in their model represents a long-term employment contract that is irreversible. This follows the same logic as in the model of irreversible investment outlined in Bernanke (1983), where agents postpone their investment decisions until business conditions become clearer. The decline in prices also supports the findings in Leduc and Liu (2016), as well as in Christiano et al. (2014) and Basu and Bundick (2017). This contrasts with the theoretical results of Born and Pfeifer (2014) and Fernández-Villaverde et al. (2015), who find that policy uncertainty shocks imply an upward pricing bias channel where firms end up setting prices higher than they would otherwise do. Nonetheless, Fernández-Villaverde et al. (2015) also show that when the model allows the monetary authority to react to policy uncertainty, the theory matches the observed evidence. Concerning the banking sector, the drop in lending is consistent with the work of Bonciani and van Roye (2016). They argue that banking frictions in credit supply amplify the effects of a volatility shock to households' preferences on economic activity. Finally, the decline in industrial production is recognized in Jurado et al. (2015) for the U.S. economy, and in Meinen and Röehe (2017) for Spain, both employing aggregate measures of macroeconomic uncertainty.

Robustness of recursive identification. As I have discussed previously, sovereign uncertainty could be affected by more international factors as compared to domestic factors. In this regard, Figure 5 displays the robustness of the baseline findings when SU is

[24] I have also checked (not shown) that the benchmark results do not change when substituting the 10-years government bond rate for its spread with respect to German counterpart.

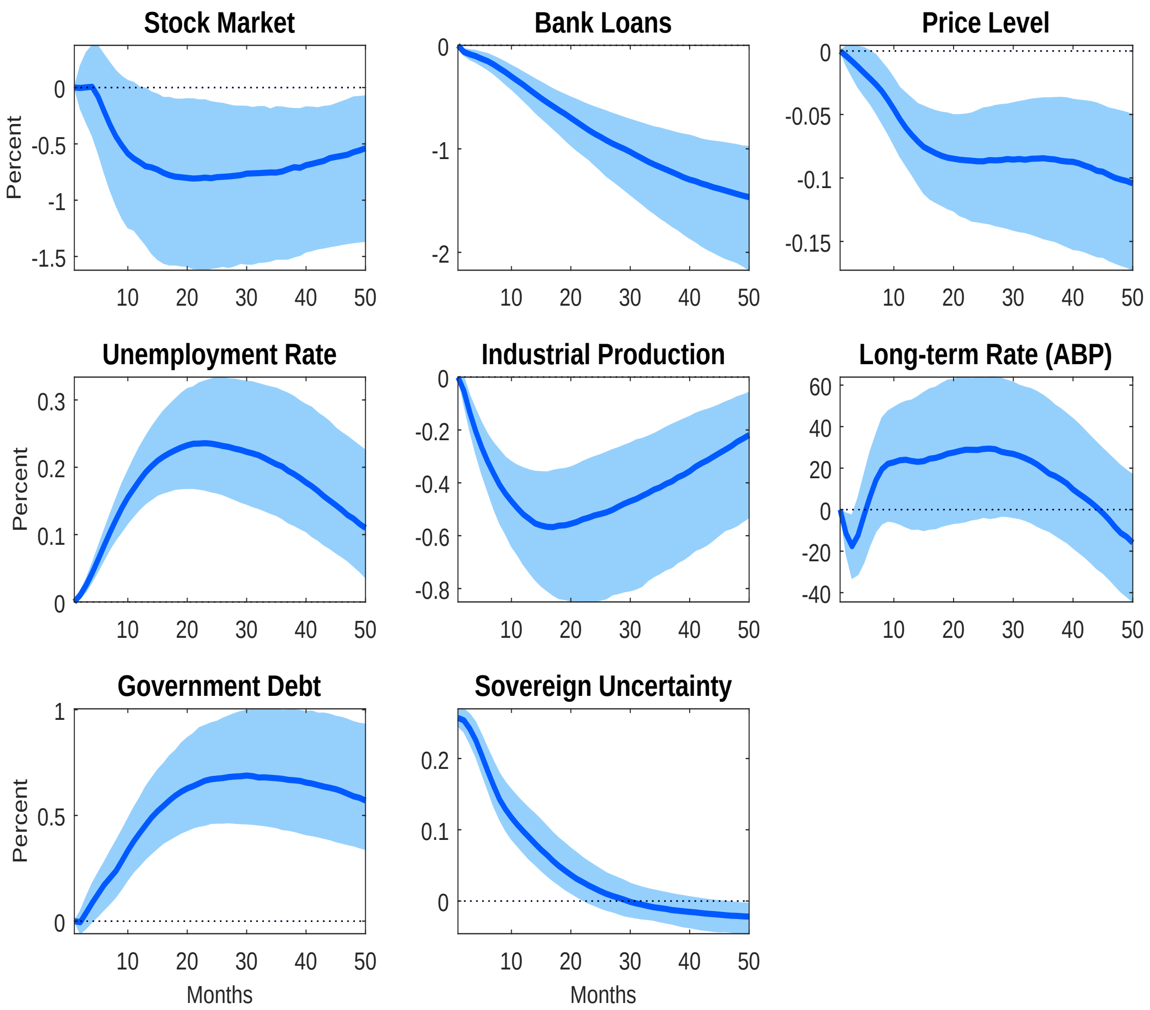

Figure 4: IRFs to One Standard Deviation Shock to Sovereign Uncertainty: Baseline Recursive Ordering

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

ordered first.[25] Qualitatively the results are similar but they are now larger in magnitude and the response of the stock market index is already negative on impact. Figure 5 shows further checks with respect to the baseline specification, principally, regarding the presence of potential omitted variables.[26] The inclusion of both consumer and industrial confidence is made to disentangle the effects of confidence shocks from uncertainty shocks. As it is normally argued in the literature, uncertainty could arise from information-noisy news. Thus, there may exist a link between them when agents receive bad news about the future and the economy is stuck in an elevated uncertainty state. To this end, I test that SU shocks do not resemble negative confidence shocks by individually

[25] See Appendix A.5.1 for the complete set of median IRFs with their respective confidence bands.

[26] The inclusion of more variables in the system can help to disentangle the "correct" decisions of the different agents in the economy. In other words, the econometrician has access to a larger set of information in the extended model and thus the dynamics can vary with respect to the baseline case.

including consumer and industrial confidence first in the VAR model. Additionally, I consider fundamental to further scrutinize the effects of sovereign uncertainty by taking into account the presence of overall macro-financial uncertainty. Despite I have previously shown that my sovereign uncertainty index is weakly correlated with macro-financial uncertainty prior to the great recession and that they only share a common spike in this period, the lack of inclusion of overall uncertainty could produce upper-biased estimates in the aftermath of a sovereign uncertainty shock. I then include macro-financial uncertainty last in the baseline specification following Ludvigson et al. (2019). The vector featuring MU predicts somewhat milder responses with respect to the baseline case. Nevertheless, this scenario still confirms the sizable and long-lived effects of SU shocks. Figure 5 also reports the results when varying the lag order.

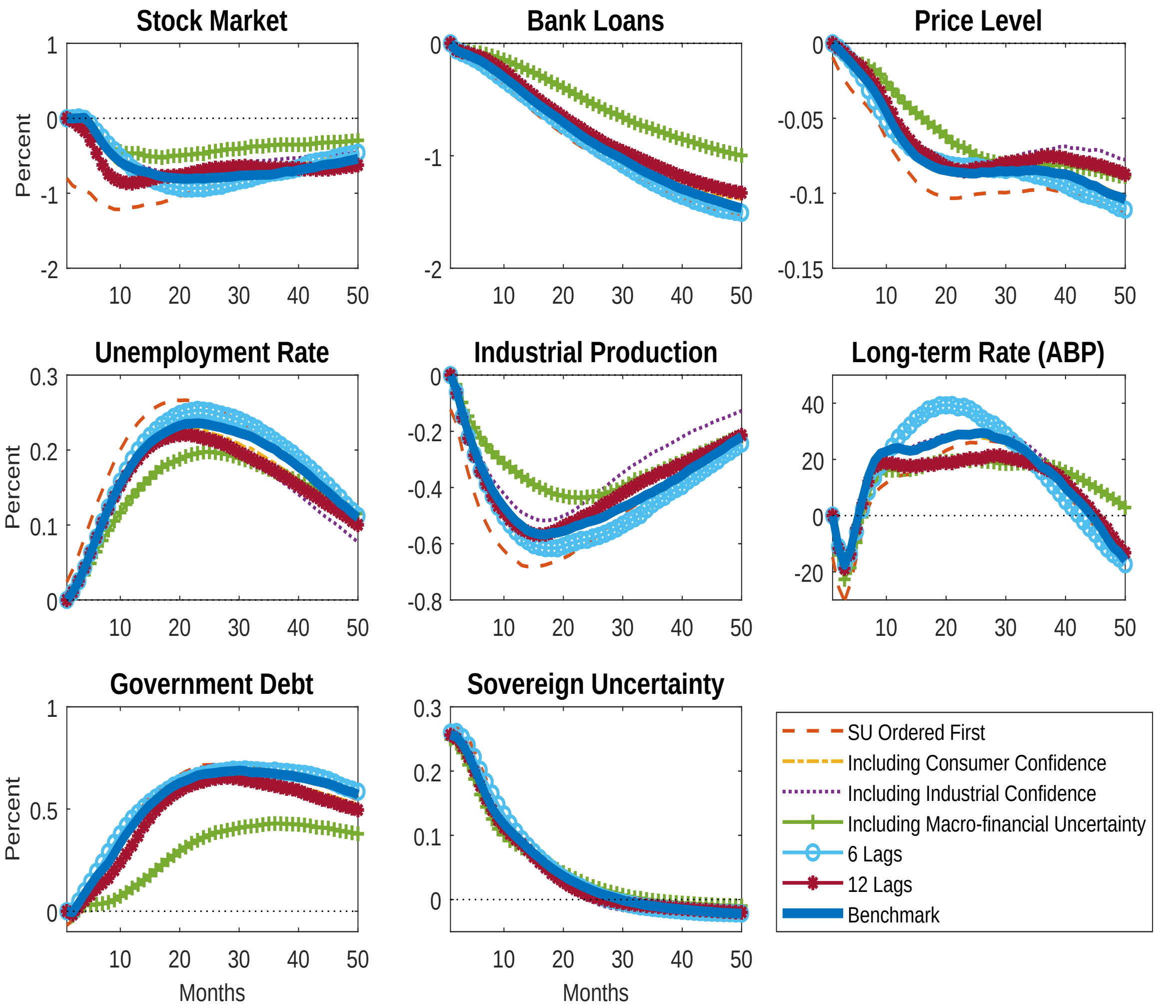

Figure 5: IRFs to One Standard Deviation Shock to Sovereign Uncertainty: Recursive Robustness Checks

Note: Each entry shows the median responses (see Appendix A.5.1 for the complete set of IRFs with their respective confidence bands). All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

Next, what is the potential relevance of the data-rich approach? As noted earlier, a crucial difference with respect to Born and Pfeifer (2014) or Fernández-Villaverde et al. (2015) is that my government-related uncertainty measure is based on a high-information content approach. The exclusion of this feature could potentially be the reason behind the minor role played by their policy uncertainty shocks. Hence, I could construct an alternative measure of sovereign uncertainty by just employing data from a single time series and check how the results would change. For example, one can analyze the time-varying volatility of the unexpected component of public debt. Figure 28 and Figure 29 in Appendix A.5.3 show that the impact on the real economy is clearly reduced when this individual measure of uncertainty is imposed (both for short-term and long-term measures of debt). It can be observed that unemployment rate and industrial production are not significantly affected in the case of long-term debt uncertainty. These findings confirm the importance of a rich-information strategy when measuring the effects of sovereign uncertainty shocks.

Finally, does the transmission of sovereign uncertainty rely exclusively on periods of economic slowdown? It could be also assumed that the negative and persistent effects of sovereign uncertainty shocks are only driven by the Great Recession or the European debt crisis. To assess this question, I consider a threshold VAR model to account for the presence of potential non-linearities. The importance of non-linearities when analyzing the effects of uncertainty shocks has been recently stressed by the literature (see Auerbach and Gorodnichenko, 2012; Caggiano et al., 2014; Caggiano et al., 2017; Liu et al., 2019 and Alessandri and Mumtaz, 2019). Appendix A.6 details the estimation strategy and confirms that the effects of sovereign uncertainty shocks during recessions are indeed stronger, especially in the short-run. However, contrary to the findings of other studies in the U.S. using measures of macroeconomic or economic policy uncertainty, the effects in booms found here are sizable (see Figure 37). This implies that economic downturns are not the sole drivers of the detrimental consequences of sovereign uncertainty shocks.

3.2.2 Findings under Identification with Sign, Event-based and Ratio Restrictions

I turn now to discuss the empirical findings when a combination of sign, event-based and ratio restrictions is employed. Figure 6 reports the baseline effects of a one standard deviation shock to SU.[27] I found, in general, similar results as in the case where the sovereign uncertainty shocks are identified with a Cholesky decomposition. In particular, the responses of bank loans, unemployment rate, industrial production, price level and government debt are qualitatively the same. However, some differences emerge when I consider the stock market. Without imposing any prior beliefs on the response of this variable, it is not clear whether it significantly declines as a consequence of a sovereign uncertainty shock or not.[28] As I show later in Appendix A.5.2, this pattern is also present

[27] Figure 30 in Appendix A.5.4 reports forecast error variance decomposition for selected variables (the ones that produce statistically significant IRFs) attributable to SU shocks. I find that this source of perturbation plays an important role in business cycle fluctuations. I have also performed a historical decomposition analysis to see how important any of the uncertainty indicators are in historical period (Appendix A.5.5).

[28] Although the mass of the distribution of the response is inclined toward the negative plane as time goes by.

sometimes in prices after conducting several robustness checks. So, the "definite" evidence gathered with the previous identification strategy about the dynamics of the price level is questionable when one is agnostic on its potential reaction. This consequently does not always confirm the behavior of sovereign uncertainty shocks as pure demand shocks (although it does not support the supply narrative either).

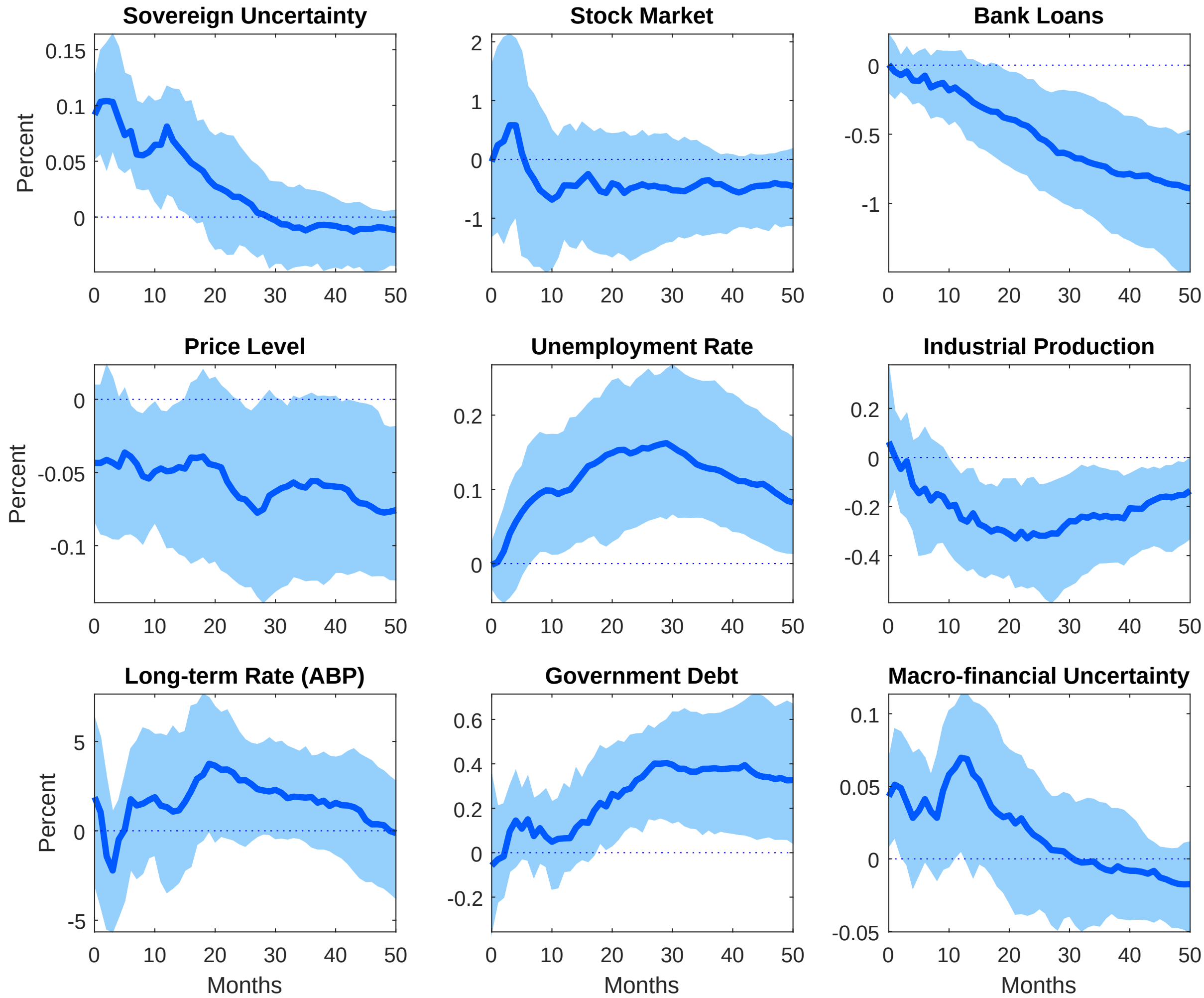

Figure 6: IRFs to One Standard Deviation Shock to Sovereign Uncertainty: Baseline Identification with Sign, Event-based and Ratio Restrictions

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

Regarding MU shocks, it can be seen from Figure 7 that the results support the previous evidence, i.e., the effects of SU and MU shocks respectively differ. While the former perturb the economy in the medium-run, the latter display short-lived responses in real activity. The implication of this finding for policymakers is that if they are about to assess the possible impact of their indecision on the private sector, they must be mindful that this impact may vary across both sources of uncertainty. Concretely, industrial production and unemployment rate react persistently more after a SU shock. Bank lending declines shortly after impact in the aftermath of a MU shock, whereas it strongly decreases after 20 months following a SU shock. A similar pattern emerges with the response of government debt. Finally, different from SU disturbances, MU shocks increase prices upon impact. This will presumably imply that MU shocks are more prone to reflect a supply-driven mechanism, again confirming the diverse nature of both types of uncertainty shocks.

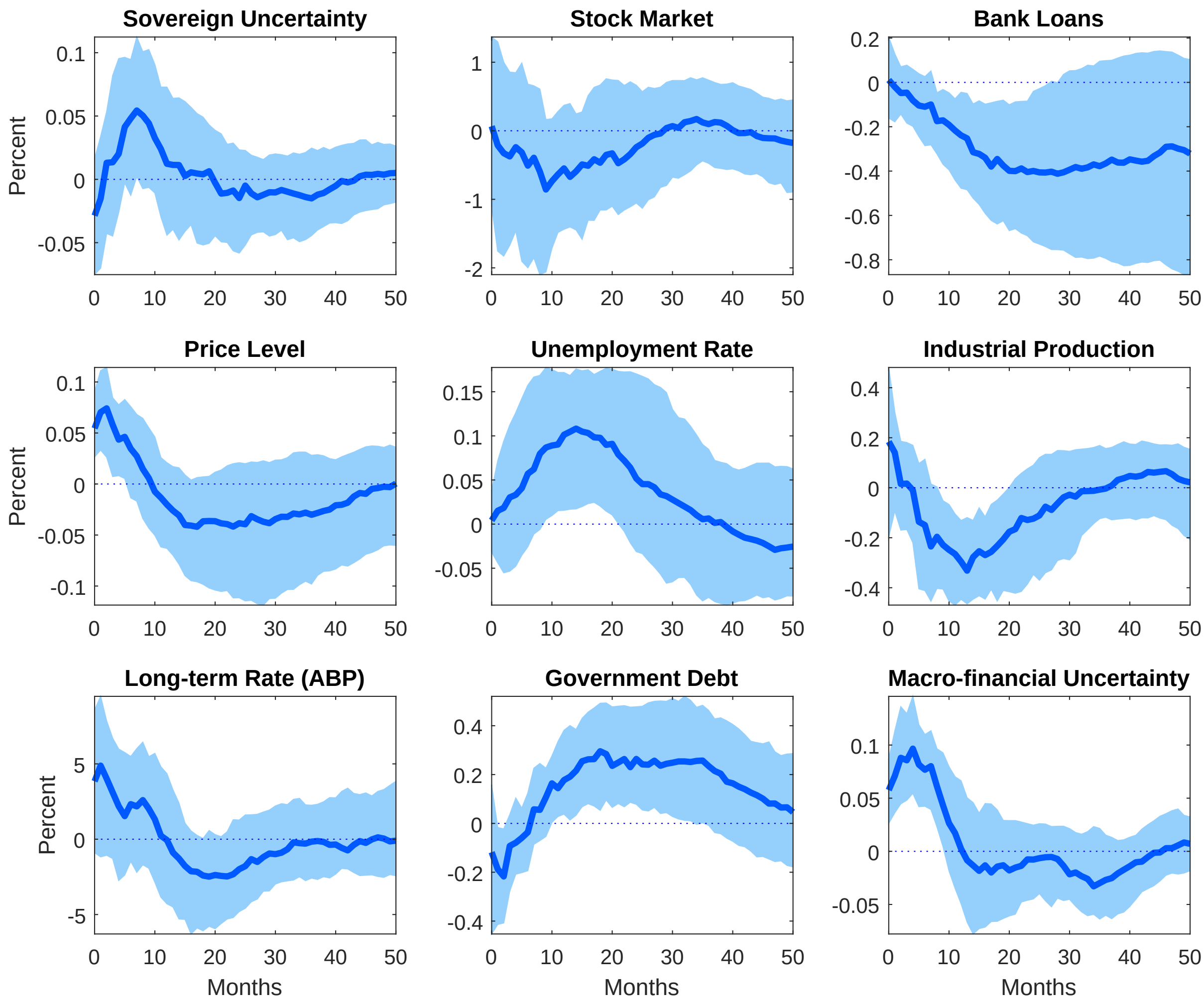

Figure 7: IRFs to One Standard Deviation Shock to Macro-financial Uncertainty: Baseline Identification with Sign, Event-based and Ratio Restrictions

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

Robustness of identification through sign, event-based and ratio restrictions. How decisive are the previous restrictions in order to identify a sovereign uncertainty shock? I propose the following set of robustness checks under this type of identification: (i) considering other prior beliefs about the narrative of SU and MU shocks; and (ii) accounting for potential omitted variables in the baseline vector of agents' information.

First, one could expect that the initial restrictions imposed are crucial or necessary for the identification of the structural shocks of interest. I study two variants of the benchmark event-based identification strategy — I drop from the set of narrative information the Lehman Brothers' collapse and I eliminate the ESM constraint (one at a time). Figure 20,

Figure 21, Figure 22 and Figure 23 in Appendix A.5.2 prove that it is possible to obtain results analogous to the ones reported in Figure 6 and Figure 7 by just imposing a different combination of narrative restrictions.[29]

As in the recursive identification scheme, I consider now the presence of potential omitted variables in the model to purge the effect of a sovereign uncertainty shock and a macro-financial uncertainty shock. That is, I control for both confidence about the future and global economic policy uncertainty (GEPU).[30] As previously noted for the former case, this inclusion is important given that there exist several studies who clearly show that news and uncertainty shocks are interconnected (see e.g. Forni et al. 2017; Cascaldi-García and Galvão 2018; and Lagerborg et al. 2019). Next, it is also relevant to confirm that shocks to SU and MU still survive in the presence of global uncertainty (see e.g. Berger et al. 2016 and Cesa-Bianchi et al. 2019). To this end, I impose an extra restriction assuming that GEPU does not react on impact in the aftermath of a SU or a MU shock. Figure 24, Figure 25, Figure 26 and Figure 27 in Appendix A.5.2 certify the stability of the baseline results with clearer deflationary pressures after SU shocks.

Altogether, regardless of the identification strategy, sovereign uncertainty shocks have significant and persistent negative effects on bank lending. The effects of these shocks are translated to the larger economy leading to a prolonged and significant downturn in industrial production, with several evidences of deflationary pressures. At the same time, they are accompanied by significant rises in unemployment rate and government debt. Finally, to show that these findings are indeed stable, I have performed a battery of robustness checks. For the rest of macroeconomic aggregates — stock market index and long-term interest rate — the results are more ambiguous.

4 Theoretical Framework

In this section, I introduce an approximation for sovereign uncertainty in a DSGE model with recursive preferences and financial intermediaries to rationalize my empirical results. In particular, the objective is to investigate whether the model can effectively match the empirical evidence of an uncertainty shock originating from changes in the public financial sector, and if so, which important theoretical assumptions are necessary to achieve it.

4.1 A New Keynesian DSGE Model with Sovereign Uncertainty, EZ Preferences, and Banking Sector

The starting point is a canonical New Keynesian DSGE model augmented with financial intermediation as in Gertler and Karadi (2013) and Epstein-Zin (EZ) preferences. In the extended framework, banks hold government bonds. I explicitly model the real interest

[29] In July 2012, former European Central Bank (ECB) President Mario Draghi pronounced his famous "whatever it takes". This event is generally considered as a turning point because it reverted the negative situation around the European public finances. In other words, it can be treated as a positive outcome. Then, one may assign a positive sign to the SU shock occurring in July 2012. This extra restriction does not alter the baseline IRFs (results are available upon request).

[30] The GEPU index is a GDP-weighted average of national EPU indices for 21 countries and it is obtained from `www.PolicyUncertainty.com`.

rate on these bonds as the sum of return on a perpetuity and an exogenous additive term which is subject to a stochastic volatility shock. I will refer to the latter as an approximation for sovereign uncertainty. I postpone a full justification for this choice to the end of section. In addition, the model is solved by a third-order perturbation method (Fernández-Villaverde et al., 2011 and Basu and Bundick, 2017) and estimated with a combination of impulse response and moment matching (see Christiano et al., 2005 and Basu and Bundick, 2017). The goal here is to minimize the distance between impulse responses implied by the theoretical model and empirical responses generated by the VAR system, while being consistent with the data moments and the empirical path of sovereign uncertainty after the shock.

The whole economy is populated by households, banks, intermediate producers, retail goods firms, capital goods producers and a monetary authority. The central bank's actions can be directly affected by sovereign uncertainty shocks in an augmented Taylor rule. The following sections detail the agents' decision problems.

4.1.1 Households

There is a continuum of identical households of unity mass. Each household is composed by a fraction f of bankers and a fraction $1-f$ of workers. Each banker manages a financial intermediary and returns earnings to the household. Workers supply labor and similarly transfer their wages back to the household. Additionally, there is perfect consumption insurance within the family.

The problem of the household is formalised as follows:

$$V_t = max\left[(1-\beta)(C_t^{\nu}(1-H_t)^{1-\nu})^{\frac{1-\sigma}{\theta_V}} + \beta(\mathbb{E}_t V_{t+1}^{1-\sigma})^{\frac{1}{\theta_V}}\right]^{\frac{\theta_V}{1-\sigma}}, \tag{5}$$

where C_t denotes consumption, H_t is labor supply, β is the discount factor, ν controls labor supply, σ governs risk aversion, and $\theta_V = (1-\sigma)/(1-(1/\psi))$. The latter is an index of the deviation with respect to the CRRA utility function where ψ regulates household's elasticity of intertemporal substitution (EIS). When $\theta_V = 1$, the recursive preferences collapse to the CRRA case and the inverse of the EIS and risk aversion coincide.

The maximisation problem is subject the household's budget constraint:

$$D_t + C_t = R_{t-1}D_{t-1} + W_t H_t + T_t + \Pi_t, \tag{6}$$

where D_t refers to deposits in intermediaries that the household does not own, receiving the real interest rate R_t. Moreover, it supplies labor for the real wage W_t and pays lump-sum taxes T_t. Through its ownership of goods and capital producing firms, the household receives the profit Π_t.

Denoting by ϱ_t the Lagrange multiplier associated with the resource constraint, the optimality conditions for the household's maximization problem with respect to deposits, labor and consumption are:

$$1 = \mathbb{E}_t \Lambda_{t,t+1} R_{t+1}, \tag{7}$$

$$W_t = \frac{(1-\nu)}{\nu}\frac{C_t}{(1-H_t)}, \tag{8}$$

$$\varrho_t = \frac{\nu(C_t^{\nu}(1-H_t)^{1-\nu})^{\frac{1-\sigma}{\theta_U}}}{C_t}(1-\beta)U_t^{1-\frac{1-\sigma}{\theta_U}}, \tag{9}$$

where

$$\Lambda_{t,t+1} = \beta\left(\frac{C_{t+1}^{\nu}(1-H_{t+1})^{1-\nu}}{C_t^{\nu}(1-H_t)^{1-\nu}}\right)^{\frac{1-\sigma}{\theta_V}}\left(\frac{C_t}{C_{t+1}}\right)\left(\frac{V_{t+1}^{1-\sigma}}{\mathbb{E}_t V_{t+1}^{1-\sigma}}\right)^{1-\frac{1}{\theta_V}}. \tag{10}$$

The last equation represents the stochastic discount factor $\Lambda_{t,t+1}$ (between periods t and $t+1$) implied by the Epstein-Zin preferences. From now on, one period corresponds to one-quarter.

4.1.2 Intermediate Goods Producers

The intermediate goods firms produce their output following a Cobb-Douglas production function using capital, K_t, and labour, H_t:

$$Y_t = A_t K_t^{\alpha} H_t^{1-\alpha}, \quad 0 < \alpha < 1, \tag{11}$$

where α is output elasticity with respect to capital, $1-\alpha$ is labour elasticity, and A_t is total factor productivity (TFP) with the following law of motion:

$$A_t = \rho_A A_{t-1} + u_{A,t}, \text{ with } u_{A,t} \sim \mathbb{N}\big(0, \sigma_A^2\big). \tag{12}$$

In order to finance the capital acquisition, the firm must obtain funds from a financial intermediary. It therefore issues securities, S_t, equal to number of units of capital it acquires, K_{t+1}, pricing each claim at the unit price of capital, Q_t. Letting P_{mt} be the relative price of intermediate goods at time t and assuming the firm makes zero profits every period, the rate of return to the bank on the loan, R_{t+1}^k, is given by:

$$R_{t+1}^k = \frac{\xi_{t+1}[P_{m,t}\frac{\alpha Y_{t+1}}{K_{t+1}} + (1-\delta)Q_{t+1}]}{Q_t}, \tag{13}$$

where δ is the gross depreciation rate and ξ_t is a capital quality shock whose law of motion is given as:

$$\xi_t = \rho_\xi \xi_{t-1} + u_{\xi,t}, \text{ with } u_{\xi,t} \sim \mathbb{N}\big(0, \sigma_\xi^2\big). \tag{14}$$

The capital stock for $t+1$ evolves according to:

$$K_{t+1} = \xi_{t+1}[I_t + (1-\delta)K_t], \tag{15}$$

and the firms' demand for labour is equal to the marginal productivity of labour:

$$W_t = P_{m,t}(1-\alpha)\frac{Y_t}{H_t}. \tag{16}$$

4.1.3 Capital Goods Producers

Capital producers use final output as an input to make new capital. They sell this capital to investing firms at the price Q_t. Capital goods producers choose I_t that maximizes the expected lifetime profits given by:

$$\max\ \mathbb{E}_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau}\left\{Q_\tau I_\tau - \left[1 + f\left(\frac{I_\tau}{I_{\tau-1}}\right)\right] I_\tau\right\}, \tag{17}$$

where investment adjustment costs have the following functional form:

$$f\left(\frac{I_t}{I_{t-1}}\right) = \frac{\vartheta}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2. \tag{18}$$

The resulting first-order condition indicates that the price of capital goods equals the marginal cost of investment goods production:

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}}\right) - E_t \Lambda_{t,t+1}\left(\frac{I_{t+1}}{I_t}\right)^2 f'\left(\frac{I_{t+1}}{I_t}\right). \tag{19}$$

Profits arising outside the steady state are rebated to households in lump-sum fashion.

4.1.4 Retail Firms

There exists a unit continuum of monopolistic firms who repackage the intermediate output. Final output, Y_t, is a CES aggregator of differentiated retailers output, $Y_t(i)$, given by:

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}}, \tag{20}$$

where ϵ is the elasticity of substitution between different retail goods. The demand curve for each good is thus given by:

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} Y_t. \tag{21}$$

Monopolistic retailers convert one-to-one the intermediate output into the final good. The marginal cost is therefore the relative intermediate output price $P_{m,t}$. I introduce nominal rigidities following Rotemberg (1982). In particular, the retailer i maximizes:

$$\mathbb{E}_t \sum_{j=0}^{\infty} \Lambda_{t+j} \left(\frac{P_{t+j}(i) - P_{m,t}}{P_{t+j}} Y_{t+j}(i) - \frac{\phi_P}{2}\left(\frac{P_{t+j}(i)}{P_{t+j-1}(i)} - \pi\right)^2 Y_{t+j}\right), \tag{22}$$

subject to the demand function in Equation (21).

4.1.5 Banks

The modeling of financial intermediaries draws from Gertler and Karadi (2013). Nonetheless, I describe here their main choices and interactions with the real economy for the sake of completeness. Accordingly, banks finance their operation by obtaining deposits from households, D_t, and through their own net worth, N_t. Moreover, they lend to non-financial firms and invest in government bonds, B_t. Their balance sheet is then given by:

$$Q_t S_t + Q_t^B B_t = N_t + D_t, \tag{23}$$

where S_t is the quantity of financial claims on non-financial firms that the intermediary holds, and the relative prices of private claims and government bonds are Q_t and Q_t^B, respectively.

The law of motion for the net worth of banks is given by the combination of the balance sheet and the flow of funds:

$$N_t = (R_t^k - R_t)Q_{t-1}S_{t-1} + (R_t^B - R_t)Q_{t-1}^B B_{t-1} + R_t N_{t-1}. \tag{24}$$

The bankers objective is to maximize the present value of their terminal wealth discounted with the household's intertemporal marginal rate of substitution, $\Lambda_{t,t+i}$. Each banker transfers the remaining net worth to its household as a lump-sum payment and exits the market with probability $1-\theta$. Formally, the maximization problem can be expressed as:

$$V_t = \mathbb{E}_t \sum_{i=1}^{\infty} \Lambda_{t,t+i}(1-\theta)\theta^{i-1} N_{t+i}. \tag{25}$$

As in Gertler and Karadi (2013), in order to motivate a limit on bank's ability to expand its assets indefinitely by accepting more deposits, it is assumed that a bank is able to divert a proportion λ of funds back to its own household at the end of every period. Therefore, the incentive to default reduces the amount that depositors are willing to lend to the banks. In this framework, it is also assumed that it is easier for a bank to divert a higher proportion of private loans than diverting funds from government bonds. Concretely, λ is the diverted fraction of private assets and $\lambda\Delta$ of government bonds with $0 \leq \Delta < 1$. This difference can be easily motivated by the lower monitoring ability of deposit holders. Accordingly, the incentive constraint is given as:

$$V_t \geq \lambda(Q_t S_t + \Delta Q_t^B B_t). \tag{26}$$

Solving the banker's problem by maximizing Equation (25) subject to Equation (23), Equation (24), and Equation (26), yields the following inequality restriction holding with equality:

$$Q_t S_t + \Delta Q_t^B B_t \leq \phi_t N_t, \tag{27}$$

where time-varying leverage is written as:

$$\phi_t = \frac{\mathbb{E}_t \tilde{\Lambda}_{t,t+1} R_{t+1}}{\lambda - \mathbb{E}_t \tilde{\Lambda}_{t,t+1}(R_{t+1}^k - R_{t+1})}, \tag{28}$$

and with $\tilde{\Lambda}_{t,t+1}$ being the bank's stochastic discount factor augmented by the multiplier Ω_{t+1}:

$$\tilde{\Lambda}_{t,t+1} \equiv \Lambda_{t,t+1} \cdot \Omega_{t+1}. \tag{29}$$

The weight Ω_{t+1} reflects the shadow value of a unit of net worth to the bank at $t+1$ and is given by:

$$\Omega_{t+1} = 1 - \theta + \theta \mathbb{E}_t \tilde{\Lambda}_{t,t+1}[(R_{t+1}^k - R_{t+1})\phi_t + R_{t+1}]. \tag{30}$$

Moreover, expected excess returns on banks assets must satisfy the following arbitrage condition:

$$\mathbb{E}_t \tilde{\Lambda}_{t,t+1}(R_{t+1}^B - R_{t+1}) = \Delta \mathbb{E}_t \tilde{\Lambda}_{t,t+1}(R_{t+1}^k - R_{t+1}). \tag{31}$$

Total net worth evolves as the sum of retained earnings by the surviving fraction θ of the bankers and the transfers that new bankers receive:

$$N_t = \theta \left[\frac{(R_t^k - R_t)Q_{t-1}S_{t-1}}{N_{t-1}} + \frac{(R_t^B - R_t)Q_{t-1}^B B_{t-1}}{N_{t-1}} + R_t \right] N_{t-1} + TR_t, \tag{32}$$

where

$$TR_t = \omega(Q_{t-1}S_{t-1} + Q_{t-1}^B B_{t-1}). \tag{33}$$

4.1.6 Securities Holdings by Households

Following Gertler and Karadi (2013), I now permit direct household participation in asset markets and assume that a household pays a cost equal to the percentage $\frac{1}{2}\kappa(S_t^h - \bar{S}^h)^2/S_t^h$ of the value of its portfolio for $S_t^h \geq \bar{S}^h$. Similarly, there is a holding cost for government bonds which equals the percentage $\frac{1}{2}\kappa(B_t^h - \bar{B}^h)^2/B_t^h$ of the total value of government bonds for $B_t^h \geq \bar{B}^h$. This assumption captures in a parsimonious way limited participation in financial markets by households.

After allowing households to directly hold private securities and government bonds, the initial budget constraint becomes:

$$\begin{aligned} D_t + C_t + &Q_t \left[S_t^h + \frac{1}{2}\kappa(S_t^h - \bar{S}^h)^2/S_t^h\right] + Q_t^B \left[B_t^h + \frac{1}{2}\kappa(B_t^h - \bar{B}^h)^2/B_t^h\right] \\ =&R_{t-1}D_{t-1} + R_t^k S_{t-1}^h + R_t^B B_{t-1}^h + W_t H_t + T_t + \Pi_t. \end{aligned} \tag{34}$$

Resolving the household's optimization problem leads to the same firs-order conditions for deposits, labor supply and consumption as before. The optimality conditions for private securities and government bonds are given by:

$$S_t^h = \bar{S}^h + \frac{\mathbb{E}_t \Lambda_{t,t+1}(R_{t+1}^k - R_{t+1})}{\kappa}, \tag{35}$$

$$B_t^h = \bar{B}^h + \frac{\mathbb{E}_t \Lambda_{t,t+1}(R_{t+1}^B - R_{t+1})}{\kappa}. \tag{36}$$

It can be noted that when marginal costs go to zero, excess returns disappear and households are able to engage in frictionless arbitrage of security returns. On the contrary, when marginal costs grow to infinity, households demand their respective frictionless values.

In this extended case, the equilibrium conditions in the markets for loans and government bonds read now as:

$$S_t = S_t^b + S_t^h, \tag{37}$$

$$B_t = B_t^b + B_t^h, \tag{38}$$

where S_t^h and B_t^h are, respectively, household holdings of private securities and government bonds, while S_t^b and B_t^b are the amounts held by banks.

4.1.7 An Approximation for Sovereign Uncertainty

Every government bond is a perpetuity and pays one euro per period indefinitely. In order to introduce sovereign uncertainty in the model, I assume that the real interest rate on the bond is given by the sum of return on a perpetuity and an exogenous additive term which is subject to a stochastic volatility shock:

$$R_t^B = \frac{(1/P_{t-1} + Q_t^B)}{Q_{t-1}^B} + \nu_{RB,t}, \tag{39}$$

where P_{t-1} is the overall price level in period $t-1$ and $\nu_{RB,t}$ is a shock to the realized return on government bonds. The law of motion for the latter evolves as:

$$\nu_{RB,t} = \rho_{RB}\nu_{RB,t-1} + e^{\sigma_{RB,t}} u_{RB,t}, \tag{40}$$

where $u_{RB,t}$ is a normally distributed shock with mean zero and unitary variance. Its standard deviation, $\sigma_{RB,t}$, obeys the following mean-reverting process:

$$\sigma_{RB,t} = (1 - \rho_{\sigma_{RB}})\sigma_{RB} + \rho_{\sigma_{RB}}\sigma_{RB,t-1} + \eta u_{\sigma_{RB,t}}. \tag{41}$$

In the previous equation, the shock $u_{\sigma_{RB,t}}$ is normally distributed with zero mean and unitary variance. This is what I refer to as a sovereign uncertainty shock. The parameters σ_{RB} and η control, respectively, the degree of mean volatility and stochastic volatility.

As introduced before, this approximation for sovereign uncertainty deserves to be discussed. It is clear that the previous equations do not look as if they model the possibility of a default by the government. In that case, there would simply be a binary variable multiplying the excess return. This is something in line with Bocola (2016), who studies the effect of shocks to (perceived) sovereign default risk on economic activity. Instead, I have opted for the stochastic volatility narrative of the exogenous additive term in the realized return on government debt for the following reason. As mentioned previously, during the extraction of the empirical measure of sovereign uncertainty, the one-step-ahead prediction error of each time series and of each selected factor in the FAVAR model exhibited time-varying volatility, where the latter was computed (for each forecast error) by employing an AR(1) stochastic volatility model. This feature allowed for a shock to the second moment that is independent of the first moment. Consequently, the way I model uncertainty in both sections is based on the same assumptions.[31] It is true, however, that the large set of information available in the empirical counterpart is not present here. I am thus constrained to simplify the diverse data-oriented stochastic volatility processes into a single stochastic volatility entity.

Summing up, the larger potential fluctuations in the real interest rate on sovereign bonds (either negative or positive) serve as a theoretical approximation for the data-driven sovereign uncertainty index. In this way, uncertainty about future movements related to the real return on government bonds affect agents' expectations and is able to generate fluctuations in nominal and real variables.

4.1.8 Monetary Policy and Equilibrium

The monetary authority sets the nominal interest rate following a simple Taylor rule:

$$\left(\frac{i_t}{i}\right) = \left(\frac{\pi_t}{\pi}\right)^{\kappa_\pi} \times \left(\frac{Y_t}{Y}\right)^{\kappa_Y} \times e^{\upsilon_{i,t}}, \tag{42}$$

where i_t is the net nominal interest rate, i the steady state nominal interest rate and Y stands for output in steady state. The monetary policy shock, $\upsilon_{i,t}$, is given as:

$$\upsilon_{i,t} = \rho_i \upsilon_{i,t-1} + u_{i,t}, \text{ with } u_{i,t} \sim \mathbb{N}(0, \sigma_i^2). \tag{43}$$

To fully reflect the view that the ECB will not change its nominal target by only observing the economic developments of the Spanish economy, one should take into account the

[31] Further investigation (not shown) reveals that if I model sovereign uncertainty by simply considering a binary variable multiplying the excess return as in the literature on government default, this does not deliver hump-shaped responses in economic activity, which are observed in the empirical contribution of the paper after a sovereign uncertainty shock.

Spanish contribution to Euro Area output and inflation. In the calibration part, I will then set the parameter governing the reaction to output growth close to zero. However, in a NK-DSGE model with a small weight on inflation the indeterminacy region can be large. This is the reason why the latter will be set to a standard value in the literature.

The following Fisher equation relates the nominal and the real interest rates:

$$1 + i_t = \mathbb{E}_t R_{t+1} \frac{P_{t+1}}{P_t}. \tag{44}$$

In addition, I consider that monetary policy decisions can be directly influenced by sovereign uncertainty shocks and augment the previous simple Taylor rule as follows:

$$\left(\frac{i_t}{i}\right) = \left(\frac{\pi_t}{\pi}\right)^{\kappa_\pi} \times \left(\frac{Y_t}{Y}\right)^{\kappa_Y} \times \left(\frac{e^{\sigma_{RB,t}}}{e^{\sigma_{RB}}}\right)^{\kappa_{\sigma_{RB}}} \times e^{\upsilon_{i,t}}. \tag{45}$$

This modification follows Fernández-Villaverde et al. (2015) who also extend their model by allowing that the Federal Reserve is directly affected by fiscal volatility shocks. In this paper, the motivation is that the ECB has explicitly mentioned sovereign risk or fiscal uncertainty as a consideration for monetary policymaking during both the global financial crisis and the European debt crisis. Consequently, the previous specification allows for a smaller monetary policy easing than the one expected in an environment with no uncertainty about the future path of public finances. As demonstrated later, the inclusion of this feature will help to better quantitatively match the empirical IRFs. However, I will also show that a different estimation of the model (consistent with the empirical moments) where the ECB is not allowed to react directly to sovereign uncertainty still produces sizable effects.

It is worth mentioning that the assumption that the ECB's response can be altered in some circumstance due to SU shocks in Spain is not so restrictive. For instance, it is likely that the peak in the SU measure during the sovereign debt crisis is more due to global (European) factors than domestic (Spanish) factors. Therefore, the reaction of the ECB is more justified if one thinks on this specific episode.

Finally, the aggregate resource constraint is given by the following expression:

$$Y_t = C_t + \left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] I_t + \frac{\phi_P}{2}\left[\frac{P_t}{P_{t-1}} - \pi\right]^2 Y_t. \tag{46}$$

The supply of long-term bonds is fixed by the government:

$$B_t = \bar{B}. \tag{47}$$

Labor market equilibrium requires that labor supply equals labor demand:

$$\frac{(1-\nu)}{\nu}\frac{C_t}{(1-H_t)} = P_{m,t}(1-\alpha)\frac{Y_t}{H_t}. \tag{48}$$

And the supply of firm's securities at the end of period t evolves as:

$$S_t = I_t + (1-\delta)K_t. \tag{49}$$

4.2 Solving the Model, Calibration, and Estimation

The model is solved by means of a third-order perturbation method. As explained in the study by Fernández-Villaverde et al. (2011), a third-order approximation to the equilibrium conditions of the model is required in order to allow that stochastic volatility shocks enter as independent arguments into the policy functions with coefficients different from zero.[32]

I divide the calibration of the model's parameters into two groups. In the first group, parameters are calibrated using results from the literature or steady state relationships. For the second group, I estimate them using a combination of impulse and moment matching which I will detail later. Table 1 lists the parameters taken from both groups.[33]

I set the values of some parameters drawing upon Gertler and Karadi (2013): capital share in production for intermediate goods firms, α; proportional advantage in seizure rate of government bonds, Δ; capital holdings of households, S^h/S; and portfolio adjustment cost, κ. Transfer to new bankers, ω, is 0.001 (a small value similar to Gertler and Karadi, 2011). The parameter for elasticity of demand, ϵ, comes from Burriel et al. 2010, who estimate it for the Spanish economy in particular. The risk aversion parameter, γ, and the intertemporal elasticity of substitution parameter, ψ, are obtained from van Binsbergen et al. (2012) and Caldara et al. (2012), respectively. Price adjustment cost, ϕ_P, is chosen to be 100 so that in a first-order equivalent Calvo (1983) setup, prices are fixed for four quarters on average. The household discount factor, β, is given a standard value of 0.992. The share of bond holdings by households, $\bar{B}^h/\bar{B}$, is set to 0.70 as observed in the data (see Merler and Pisani-Ferry, 2012). Government bond supply, $\bar{B}$, is set to hit the ratio of government debt to output (around 0.60, average 1997–2017). For monetary policy, the value for $\kappa_\pi = 1.50$ is standard and largely used in the literature, and $\kappa_y = 0.05$ as argued before. The values for the autocorrelation of the shock to the approximation process of sovereign uncertainty, $\rho_{\sigma_{RB}}$, and its stochastic volatility component, η, are set from the estimated VAR.[34]

Before proceeding with the matching estimation, I specify the empirical IRFs and moments to match. Regarding the IRFs, I re-consider the VAR estimation in previous sections since the DSGE model is designed in quarterly terms. For conciseness, I only examine here the recursive identification (results for sign, event-based and ratio restrictions are available upon request). Figure 39 in Appendix B.1 displays three variants of the quarterly VAR. The benchmark vector includes the stock market index, overall confidence, bank loans, output, consumption, investment, price level, employment level, long-term interest rate on government bonds and sovereign uncertainty. This resembles the baseline recursive ordering in the previous empirical exercise (solid-blue lines). Furthermore, I also consider sovereign uncertainty as a more exogenous driver (marked-red lines) and the scenario where both sovereign and macro-financial uncertainties are present (dash-dot-purple lines). While the second recursive setup permits clear isolation of the economic

[32]The non-linear solution of the model is conducted with Dynare (Adjemian et al. 2011). The pruning algorithm described in Andreasen et al. (2018) is used to account for non-explosive simulations.

[33]Christiano et al. (2005) and Basu and Bundick (2017) use a similar estimation approach.

[34]Notice that the path of the model's sovereign uncertainty process after the shock must be comparable to one obtained in the VAR analysis. For that reason, the parameters governing the stochastic process of sovereign uncertainty are set from the VAR evidence.

Table 1: Model Parameters

		Firms	
ϑ	Investment adjustment cost	35.27	Target
δ	Gross depreciation rate	0.02	Standard
α	Capital share in production	0.33	Gertler and Karadi (2013)
ϵ	Elasticity of demand	9	Burriel et al. (2010)
ϕ_P	Price adjustment cost	100	Price stickiness of 0.75
		Banks	
λ	Fraction of divertible capital	0.342	Target
ω	Transfer to new bankers	0.001	Small value
θ	Survival rate of bankers	0.965	Target
Δ	Seizure rate of gov. bonds	0.50	Gertler and Karadi (2013)
		Households	
β	Discount rate	0.992	Standard
γ	Risk aversion	60	van Binsbergen et al. (2012)
ψ	Inter. elasticity of substitution	0.50	Caldara et al. (2012)
$\bar{B}^h/\bar{B}$	Bond holdings by households	0.70	Data
$\bar{S}^h/\bar{S}$	Capital holdings of households	0.50	Gertler and Karadi (2013)
κ	Portfolio adjustment cost	1	Gertler and Karadi (2013)
		Monetary Policy and Bond Supply	
κ_π	Inflation coefficient TR	1.50	Standard
κ_y	Output coefficient TR	0.05	Low value
$\kappa_{\sigma_{RB}}$	Sov. uncertainty coefficient TR	0.007	Target
$\bar{B}$	Government bond supply	1.40	Data ($B/Y = 0.60$)
		Shocks	
$\rho_{\sigma_{RB}}$	Autocorrelation parameter of σ_{Rb}	0.80	VAR evidence
η	Stochastic volatility parameter	0.33	VAR evidence
ρ_{RB}	Autocorrelation parameter of Rb	0.956	Target
σ_{RB}	Degree of mean volatility	-7.89	Target
ρ_A	TFP autocorrelation	0.963	Target
σ_A	Standard deviation of TFP	0.250	Target
ρ_ξ	Capital quality autocorrelation	0.923	Target
σ_ξ	S.D. of capital quality shock	0.036	Target
ρ_i	Taylor rule autocorrelation	0.578	Target
σ_i	Taylor rule standard deviation	0.351	Target

mechanisms driving the propagation of sovereign uncertainty, the third accounts for this isolation and at the same time permits the purging of the effects of sovereign uncertainty shocks. I believe that, for the same reasons outlined in the previous sections, the last variation of the quarterly VAR is the most accurate representation, and therefore chose it as the group of IRFs to match the DSGE model. The selected vector of variables, whose IRFs are employed in the estimation, is formed by bank loans, output, consumption, investment and hours worked. Moreover, the same array is selected to match the standard deviations of the model-based series.

As discussed, for the second group of parameters I employ a combination of impulse response and moment matching. Specifically, I define the estimator j as:

$$j = \min_{\gamma} [\hat{\psi} - \psi(\gamma)]' V^{-1} [\hat{\psi} - \psi(\gamma)] + \zeta [\hat{\Xi} - \Xi(\gamma)]' W^{-1} [\hat{\Xi} - \Xi(\gamma)], \tag{50}$$

where $\hat{\psi}$ denotes the impulse responses obtained from the VAR, $\psi(\gamma)$ represents the selected model responses to a sovereign uncertainty shock and γ is the vector of estimated parameters. I refer to their estimated values as "target" in Table 1. V is a diagonal matrix with the variances of the empirical impulse responses. $\hat{\Xi}$ and $\Xi(\gamma)$ are the vectors that contain, respectively, the unconditional standard deviations of the selected variables in the data and in the model. W is a diagonal matrix that incorporates the empirical unconditional variances of the economic aggregates. The parameter ζ is set to 100, roughly equalizing the weight on matching the unconditional moments and the impulse response functions.

Table 2: Business Cycle Statistics: Model versus Data

Unconditional Volatility	Percent		Relative to Output	
	Model	Data	Model	Data
Targeted Variables				
Output	1.53	1.34	1	1
Consumption	1.35	1.50	0.88	1.12
Investment	3.97	3.87	2.59	2.88
Hours Worked	2.19	1.65	1.43	1.23
Bank Lending	2.48	3.42	1.62	2.55
Non-Targeted Variables				
Inflation	0.46	0.52	0.30	0.39
Nominal Rate	0.35	0.44	0.23	0.33
Credit Spread	1.63	0.96	1.07	0.72
Bond Spread	0.96	1.15	0.63	0.86

Note: The empirical sample period is 1997–2017. *Non-Targeted Variables* are the ones that are not included in the matching estimation. See Appendix A.1.3 and A.1.4 for data description and sources.

To compute the model-based moments, I first simulate the DSGE model for 20,000 periods (quarters). After an initial burn-in period, I use the last 20 years of simulated data to compute model moments and repeat this procedure 250 times to take the mean of the moments of the simulation. For constructing data moments, I apply the HP filter to the log of each empirical time series with a smoothing factor of 1600.

As a diagnosis of the model fit, Table 2 shows the moments observed in the data and those that are obtained from the model. Undoubtedly, the model does a good job at matching the empirical moments. The standard deviations of output, consumption and investment in the model are 1.53, 1.35 and 3.97, respectively, which are close to the values 1.34, 1.50 and 3.87 produced by the data. I obtain a less optimal, but still good fit for hours worked and bank loans. Moreover, Table 2 displays the standard deviations of the non-targeted variables in the model. Again, the theoretical framework is also able to reasonably match the standard deviations implied by the data.

4.3 Results

How well do the model-generated impulse responses match those from the empirical counterpart? Figure 8 exhibits the matched IRFs to a one standard deviation shock to sovereign uncertainty.[35] Looking at the theoretical responses, output, consumption, investment, hours worked and bank lending fall persistently. Furthermore, the model is capturing the empirical slowdown in output, investment and hours worked, and in a lower proportion, it also accounts for the declines in consumption and bank lending while being consistent with the data moments (see Table 2) and with the empirical path of sovereign uncertainty after a shock to it. It is worth noting that for consumption and bank lending their respective theoretical responses lie inside the confidence bands of the VAR framework for most of the quarters after the shock.

One interpretation of these results is that, after a sovereign uncertainty shock, the price of government bonds decline because now it becomes riskier to hold them as banks start to be exposed to larger fluctuations in the real return on government bonds (either negative or positive). At the same time, two more facts emerge: (*i*) heightened sovereign uncertainty affects banks' expectations on firms' claims causing a fall in the relative price of private capital too, and (*ii*) since banks are facing tighter funding constraints, the marginal value of wealth is higher. The two forces together with the decline in the price of bonds amplify the drop in bank net worth. Consequently, banks' ability to lend to firms is severely limited since their credit capacity is directly tied to their net worth. Therefore, lack of sufficient bank credit creates scarcity of capital for firms and restricts real economic activity. Figure 9 (solid-purple lines) accounts for the previous dynamics and also shows that net worth recovers faster than bank assets, generating a slow recovery in real variables. Then, as already noted in Gertler and Karadi (2011), the need for deleveraging can delay the recovery of the economy.

Motivated by the slow recovery observed in the benchmark findings, I explore what the main drivers are that give rise to the persistence of the responses. I conduct three different experiments. First, I reconsider the matching estimation and set the reaction parameter to SU shocks in the Taylor rule to zero. In this way, the monetary policy decisions are not directly influenced by SU shocks. Figure 9 (dashed-black lines) shows the IRFs under this alternative estimation, which delivers a new set of estimated parameters and model-implied standard deviations consistent with those seen in the data (see Table 7 and Table 8 in Appendix B.2). As it can be seen, the results are qualitatively the same but the size of the responses is now smaller and the dynamics are less persistent. Nevertheless, the magnitudes are still substantial. For example, output falls by around -0.15% and investment by -0.40%.

[35] The theoretical IRFs are expressed in percent deviation from the stochastic steady state of the model. To construct these responses, I follow Basu and Bundick (2017) by setting the exogenous shocks in the model to zero and iterating the third-order solution forward. After a sufficient number of periods, the variables in the model converge to a fixed point, which is denoted as the stochastic steady state. Then, the economy is hit with only a one standard deviation SU shock and the IRFs are computed as the percent deviation between the equilibrium responses and the pre-shock stochastic steady state.

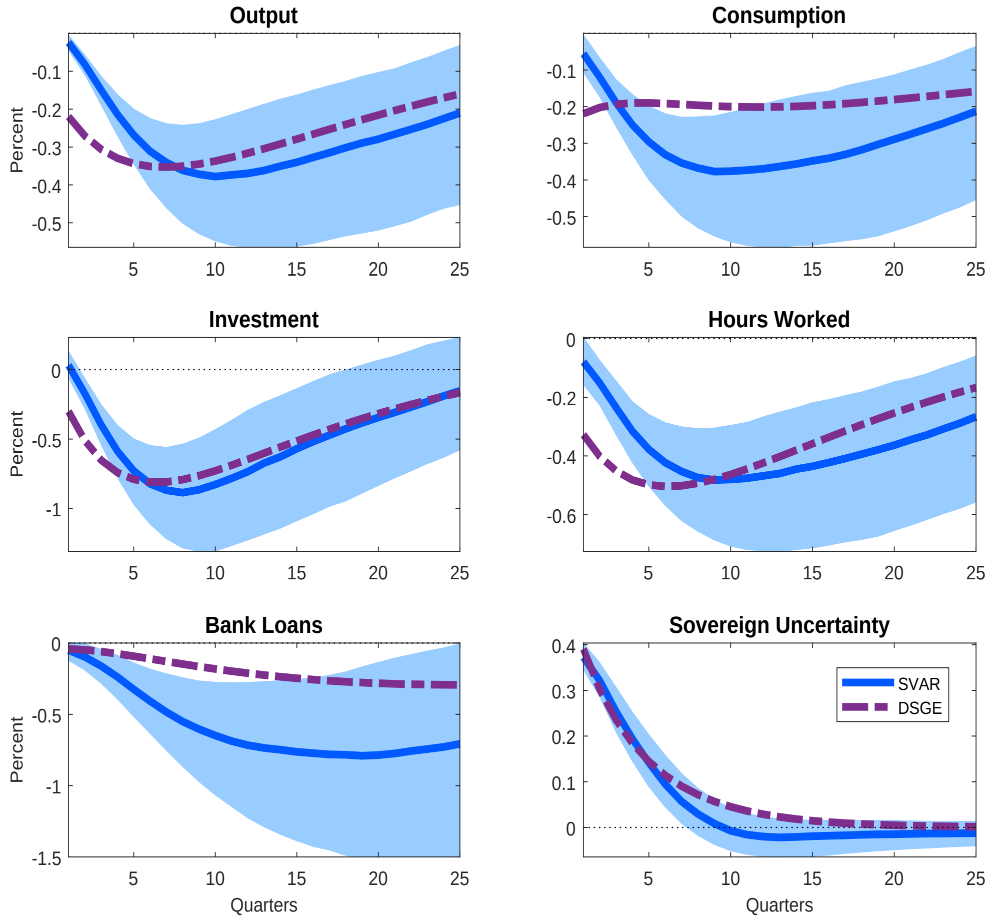

Figure 8: Quarterly IRFs to One Standard Deviation Shock to Sovereign Uncertainty: Model vs Data

The intuition of this experiment is as follows: if the reaction parameter to a SU shock in the Taylor rule is set from the estimated value of 0.007 to zero, the monetary authority will decrease the nominal interest rate more than it would otherwise do so.[36] This additional decrease in the nominal rate will then alleviate the initial negative effects of sovereign uncertainty and it will also reactivate the economy to return faster to its equilibrium. Another consequence related with the lack of persistence is that it generates an overshooting effect in investment which has been detected in other theoretical and empirical studies (see Bloom, 2009 and Caggiano et al., 2014). This feature comes from the dynamics of net worth, bank lending and the relative prices of the different assets in the model: they return to equilibrium much faster than before with clear rebounds in the responses of net worth and bank lending. Then, firms build up their demand for capital and labour once uncertainty has started to shrink in the financial sector.

[36]In contrast, when one does not impose a restriction on the potential value of the central bank's reaction parameter to SU shocks, $\kappa_{\sigma_{RB}}$, the model estimation implies that the monetary authority has to react less in the aftermath of a SU shock in order to obtain the more persistent empirical responses. Consequently, the benchmark estimation delivered a positive value for $\kappa_{\sigma_{RB}}$ (keeping fixed the other parameters governing the Taylor rule). As stated before, the monetary authority will react by decreasing the nominal interest rate after this adverse shock, but it will potentially do so more cautiously (smaller easing) given the presence of higher uncertainty in the economy.

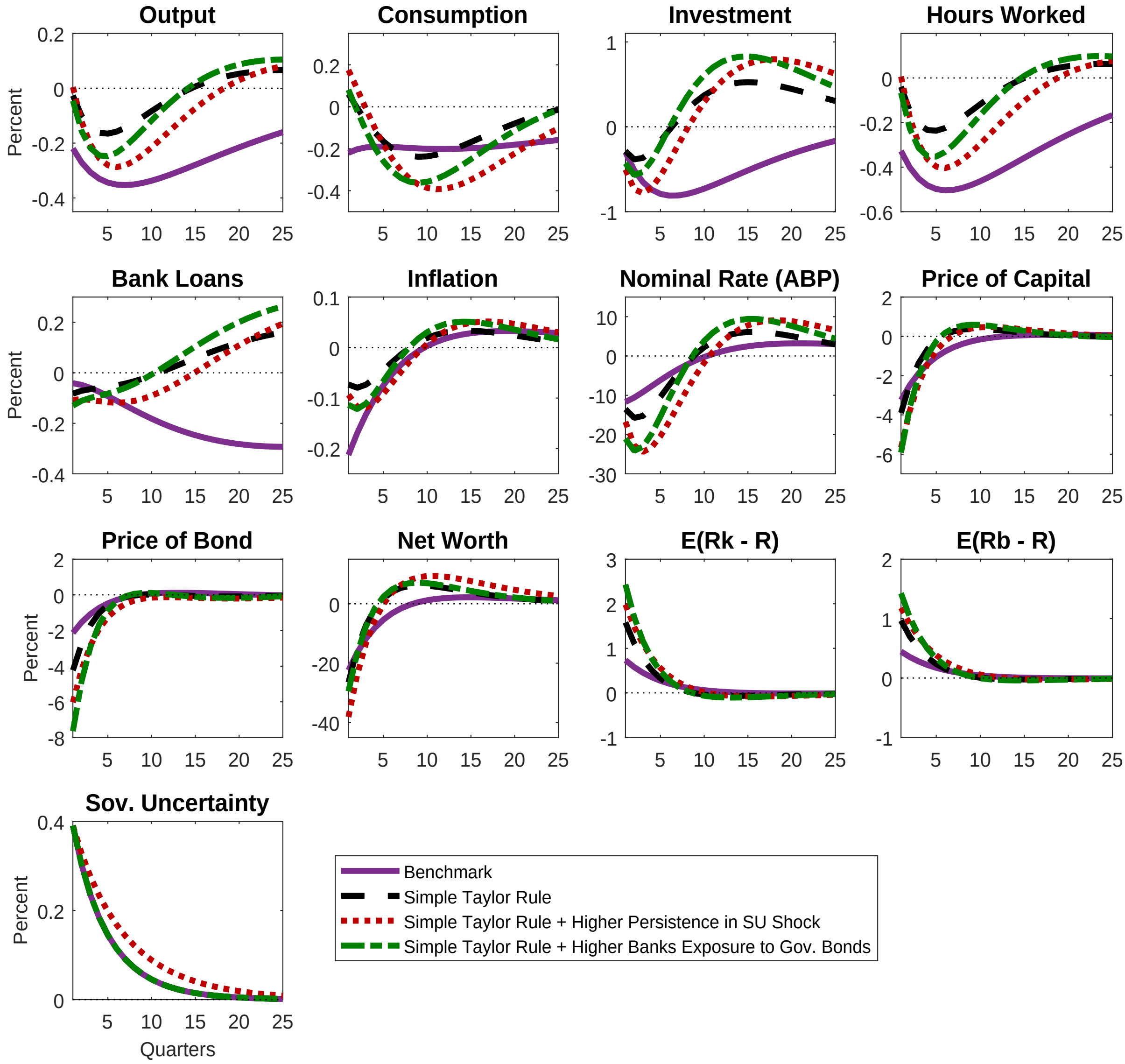

Figure 9: Quarterly IRFs to One Standard Deviation Shock to Sovereign Uncertainty: DSGE Model

Note: All responses are in quarterly percent deviations from the stochastic steady state, except for inflation and the nominal interest rate, which are expressed in quarterly percentage points and annualized basis points (ABP), respectively.

In what follows, the second experiment consists of slightly increasing the persistence of the SU shock from 0.80 to 0.86 under a simple Taylor rule (dotted-red lines in Figure 9). This rise does not much change the model moments and clearly produce larger responses. On the one hand, the effects in output, consumption, hours worked and investment are now more similar to the ones under the benchmark estimation. On the other hand, even if this small change in the persistence of the shock does not perturb the standard deviations of the selected variables in the model, it does affect the theoretical path of sovereign uncertainty after the shock, falling certainly outside the empirical 68% confidence bands.[37] Additionally, the overshooting effect in investment is still present although the short-run

[37]On the contrary, at the 90% or 95%, it would be falling inside.

(within five quarters) responses to SU shocks are again sizable and comparable with the baseline economy.

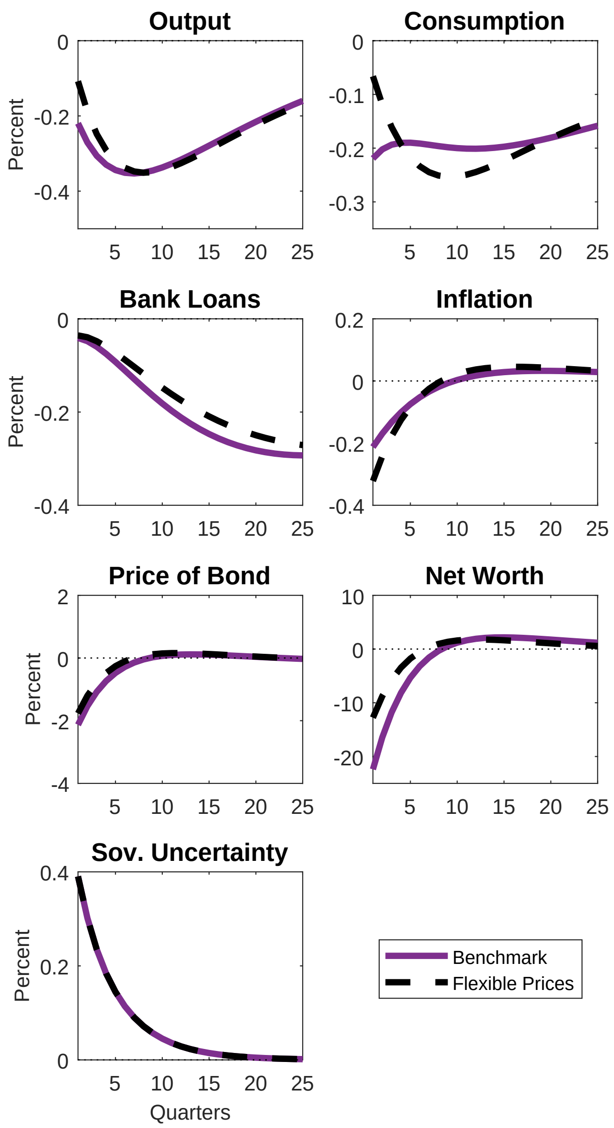

Figure 10: Quarterly IRFs to One Standard Deviation Shock to Sovereign Uncertainty: Flexible Prices

Note: All responses are in quarterly percent deviations from the stochastic steady state, except for inflation and the nominal interest rate, which are expressed in quarterly percentage points and annualized basis points (ABP), respectively.

The third exercise focuses on higher banks' exposure to government bonds under the simple Taylor rule and the original persistence of the shock. In particular, Figure 9 (dash-dot-green lines) shows the implications of a SU shock when banks hold 40% of total government bonds ($\bar{B}^h/\bar{B} = 0.60$) instead of 30% ($\bar{B}^h/\bar{B} = 0.70$). As it can be observed, the responses are larger and similar to those in the previous experiment. The results are basically larger because now the holding of government bonds represents a higher share in banks' portfolio, and in the aftermath of a SU shock, banks are then more exposed to uncertain fluctuations in the real return on these bonds. This implies more impaired balance sheets and banks reduce lending further. However, regardless of a higher bank exposure to government bonds or a more (credible) persistent shock, a larger response of the monetary authority to SU shocks prevents to completely restore the observed persistence in the data.

Finally, I conduct an additional exploration: I investigate the role that nominal rigidities play in explaining the detrimental effects of sovereign uncertainty shocks. Figure 10 shows that the results under flexible prices ($\phi_P = 0$) are definitely smaller that in the baseline case ($\phi_P = 100$). Yet, this difference is much less pronounced than in the previous literature where, in the absence of nominal rigidities, the effects in economic activity are negligible (see Bloom, 2009 and Basu and Bundick, 2017). The intuition is that this literature has generally focused on uncertainty shocks arising from the real economy (second moment shocks to households' preferences or to total factor productivity) and in a framework that abstracts from financial intermediaries. In this paper, the source of uncertainty is originating from government finances and in an environment with financial frictions. Consequently, this result implies that the presence of financial frictions can be enough to account for large declines in economic aggregates. A recent paper by Gilchrist et al. (2014) raises this point, indicating that financial frictions are a powerful conduit through which uncertainty shocks affect economic activity.[38]

5 Conclusion

Several recent episodes in Europe have stressed again that the outlook for government finances is far from being certain. In this paper, I first present a new uncertainty indicator for public finances, which I refer to as *sovereign uncertainty* (SU), by exploiting a high-information content approach. The estimated measure identifies important government-related events for the Spanish economy and is distinct from macro-financial and economic policy uncertainty indices.

Next, I empirically assess the implications of unexpected increases in sovereign uncertainty on economic activity. According to my BVAR analysis, shocks to SU that are identified through both recursive orderings and a combination of sign, event-based and ratio restrictions lead to economically and statistically significant negative effects in the financial and macroeconomic sectors. In addition, I show that the effects of sovereign uncertainty and macro-financial uncertainty shocks are different — while the former perturb the economy in the medium-run with evidence of deflationary pressures, the latter exhibit limited impact and generate inflationary dynamics.

Finally, I study the transmission of sovereign uncertainty in a canonical New Keynesian DSGE model augmented with financial intermediation and Epstein-Zin preferences. I find that the proposed theoretical model captures the empirical slowdown in output, investment and hours worked following a SU shock and, in a lower proportion, it also accounts for the declines in consumption and bank lending while being consistent with

[38] Bonciani and van Roye (2016) also highlight the importance of financial frictions. However, given that their uncertainty shock is coming from the real sector — a volatility shock to households' preferences — the negative co-movement between output, consumption and investment is not longer present under flexible prices.

the data moments and with the empirical path of sovereign uncertainty after a shock to it. In order to achieve this full matching, lack of reaction by the monetary authority is pivotal. However, a substantial matching is still obtained in the presence of a larger response by the central bank. My theoretical framework also emphasizes the importance of financial frictions in explaining and transmitting the effects of sovereign uncertainty shocks and highlights the minor role played by nominal rigidities.

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Supplementary Material for "Sovereign Uncertainty"

[For Online Publication]

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A Empirical Section

A.1 Data definitions and sources

This section presents the datasets used to compute sovereign uncertainty and macro-financial uncertainty, as well as the data employed in the VAR analysis.

A.1.1 Macro-financial Dataset

Table 3: Macro-financial Series (1)

Description	Mnemonic	Transformation
IP in manufacturing	sts.m.es.y.prod.2c0000.3.000	$\Delta log(x_t)$
IP in construction (buildings)	sts.m.es.y.prod.cc1000.3.000	$\Delta log(x_t)$
IP in construction (civil engineering)	sts.m.es.y.prod.cc2000.3.000	$\Delta log(x_t)$
IP consumer goods	sts.m.es.y.prod.ns0080.3.000	$\Delta log(x_t)$
IP non-durable consumer goods	sts.m.es.y.prod.ns0070.3.000	$\Delta log(x_t)$
IP intermediate goods	sts.m.es.y.prod.ns0040.3.000	$\Delta log(x_t)$
IP investment goods	sts.m.es.y.prod.ns0050.3.000	$\Delta log(x_t)$
IP energy	sts.m.es.y.prod.ns0091.3.000	$\Delta log(x_t)$
Car registrations:		
- Passenger cars	sts.m.es.y.creg.pc0000.3.abs	$\Delta log(x_t)$
- Commercial vehicles	sts.m.es.y.creg.cv0000.3.abs	$\Delta log(x_t)$
- Heavy	sts.m.es.y.creg.cvh000.3.abs	$\Delta log(x_t)$
- Light	sts.m.es.y.creg.cvl000.3.abs	$\Delta log(x_t)$
Unemployment rate, total	sts.m.es.s.uneh.rtt000.4.000	$\Delta log(x_t)$
Unemployment rate, under 25	sts.m.es.s.uneh.ryt000.4.000	$\Delta log(x_t)$
Unemployment rate, total, male	sts.m.es.s.uneh.rtm000.4.000	$\Delta log(x_t)$
Unemployment rate, total, female	sts.m.es.s.uneh.rtf000.4.000	$\Delta log(x_t)$
Producer price inflation:		
- Manufacturing	sts.m.es.n.prin.2c0000.3.000	$\Delta log(x_t)$
- Total industry, excl. construction	sts.m.es.n.prin.ns0020.3.000	$\Delta log(x_t)$
- Intermediate goods	sts.m.es.n.prin.ns0040.3.000	$\Delta log(x_t)$
- Capital goods	sts.m.es.n.prin.ns0050.4.000	$\Delta log(x_t)$
- Durable consumer goods	sts.m.es.n.prin.ns0060.4.000	$\Delta log(x_t)$
- Consumer goods	sts.m.es.n.prin.ns0080.4.000	$\Delta log(x_t)$
Indicator of negotiated wages	sts.m.es.n.inwr.000000.5.anr	$\Delta log(x_t)$
Harmonised competitiveness indicator	exr.m.e8.esp.nn00.a	$\Delta log(x_t)$

Note: When required, non-seasonally adjusted series are seasonally adjusted using US Census Bureau's X-12 ARIMA.

Table 4: Macro-financial Series (2)

Description	Mnemonic	Transformation
World market price of raw materials:		
- Total	rmp.m.5a.0100.e	$\Delta log(x_t)$
- Total excl. energy	rmp.m.5a.0200.e	$\Delta log(x_t)$
- Industrial raw materials	rmp.m.5a.0900.e	$\Delta log(x_t)$
- Coal	rmp.m.5a.1900.e	$\Delta log(x_t)$
- Crude oil	rmp.m.5a.2000.e	$\Delta log(x_t)$
Securities:		
- Total	sec.m.es.1000.f33000.n.1.z01.e.z	$\Delta log(x_t)$
- MFIs	sec.m.es.12a0.f33000.n.1.z01.e.z	$\Delta log(x_t)$
- OFIs	sec.m.es.1235.f33000.n.1.z01.e.z	$\Delta log(x_t)$
- NFC	sec.m.es.1100.f33000.n.1.z01.e.z	$\Delta log(x_t)$
Shares:		
- Total	sec.m.es.1000.f51100.m.1.eur.e.z	$\Delta log(x_t)$
- MFIs	sec.m.es.1220.f51100.m.1.eur.e.z	$\Delta log(x_t)$
- Non-MFI corporations	sec.m.es.1610.f51100.m.1.eur.e.z	$\Delta log(x_t)$
- NFC	sec.m.es.1100.f51100.m.1.eur.e.z	$\Delta log(x_t)$
- OFIs	sec.m.es.1235.f51100.m.1.eur.e.z	$\Delta log(x_t)$
- OFIs excl. pension funds	sec.m.es.1230.f51100.m.1.eur.e.z	$\Delta log(x_t)$
Industrial survey:		
- Production trend over recent months	sur.m.es.s.ecfin.man001.tt	Δx_t
- Assessment of order-book levels	sur.m.es.s.ecfin.man002.tt	Δx_t
- Assessment of export order-book levels	sur.m.es.s.ecfin.man003.tt	Δx_t
- Assessment of stocks of finished products	sur.m.es.s.ecfin.man004.tt	Δx_t
- Production expectations	sur.m.es.s.ecfin.man005.tt	Δx_t
- Price expectations	sur.m.es.s.ecfin.man006.tt	Δx_t
- Employment expectations	sur.m.es.s.ecfin.man007.tt	Δx_t
- Industrial confidence indicator	sur.m.es.s.ecfin.man099.tt	Δx_t
Consumer survey:		
- Consumer confidence	sur.m.es.s.ecfin.cns099.tt	Δx_t
- Financial situation	sur.m.es.s.ecfin.cns001.tt	Δx_t
- Financial expectations	sur.m.es.s.ecfin.cns002.tt	Δx_t
- Economic situation	sur.m.es.s.ecfin.cns003.tt	Δx_t
- Economic expectations	sur.m.es.s.ecfin.cns004.tt	Δx_t
- Past inflation	sur.m.es.s.ecfin.cns005.tt	Δx_t
- Expected inflation	sur.m.es.s.ecfin.cns006.tt	Δx_t
- Unemployment expectations	sur.m.es.s.ecfin.cns007.tt	Δx_t
- Past major purchases	sur.m.es.s.ecfin.cns008.tt	Δx_t
- Expected major purchases	sur.m.es.s.ecfin.cns009.tt	Δx_t
- Expected savings	sur.m.es.s.ecfin.cns011.tt	Δx_t
- Financial situation of household	sur.m.es.s.ecfin.cns012.tt	Δx_t
Construction survey:		
- Trend of activity	sur.m.es.s.ecfin.con001.tt	Δx_t
- Limits to production - none	sur.m.es.s.ecfin.con02a.tt	Δx_t
- Limits to production - insufficient demand	sur.m.es.s.ecfin.con02b.tt	Δx_t
- Limits to production - weather conditions	sur.m.es.s.ecfin.con02c.tt	Δx_t
- Limits to production - shortage lab. force	sur.m.es.s.ecfin.con02d.tt	Δx_t
- Limits to production - shortage material	sur.m.es.s.ecfin.con02e.tt	Δx_t
- Limits to production - other factors	sur.m.es.s.ecfin.con02f.tt	Δx_t
- Limits to production - fin. constraints	sur.m.es.s.ecfin.con02g.tt	Δx_t
- Assessment of order books	sur.m.es.s.ecfin.con003.tt	Δx_t
- Employment expectations	sur.m.es.s.ecfin.con004.tt	Δx_t
- Price expectations	sur.m.es.s.ecfin.con005.tt	Δx_t
- Confidence	sur.m.es.s.ecfin.con099.tt.tt	Δx_t

Note: When required, non-seasonally adjusted series are seasonally adjusted using US Census Bureau's X-12 ARIMA.

Table 5: Macro-financial Series (3)

Description	Mnemonic	Transformation
Retail trade survey:		
- Present business situation	sur.m.es.s.ecfin.ret001.tt	Δx_t
- Assessment of stocks	sur.m.es.s.ecfin.ret002.tt	Δx_t
- Orders placed with suppliers	sur.m.es.s.ecfin.ret003.tt	Δx_t
- Expected business situation	sur.m.es.s.ecfin.ret004.tt	Δx_t
- Employment expectation	sur.m.es.s.ecfin.ret005.tt	Δx_t
- Business confidence	sur.m.es.s.ecfin.ret099.tt	Δx_t
- Share price index	bism.d.esha.es.02	Δx_t
Real exports of goods	cpb.m.es.x.vol.e	$\Delta log(x_t)$
Real imports of goods	cpb.m.es.m.vol.e	$\Delta log(x_t)$
Export prices	cpb.m.es.x.pcx.e	$\Delta log(x_t)$
Import prices	cpb.m.es.m.pcx.e	$\Delta log(x_t)$
Terms of trade	cpb.m.es.x.pcx.e/cpb.m.es.m.pcx.e	x_t
Global trade	cpb.m.w1.m.vol.e	$\Delta log(x_t)$
Global export prices	cpb.m.w1.x.pcx.e	$\Delta log(x_t)$
Global import prices	cpb.m.w1.m.pcx.e	$\Delta log(x_t)$
Export competitiveness	cpb.m.es.x.pcx.e/cpb.m.w1.x.pcx.e	x_t
Consumer Price Index	icp.m.es.n.000000.4.inx	$\Delta log(x_t)$
Loans to NFCs	$repmiss(bism.m.cofa.es.l1)	$\Delta log(x_t)$
Credit to households	bism.m.cpva.es.04	$\Delta log(x_t)$
Stock Market Index	www.bolsasymercados.es	$\Delta log(x_t)$
Nominal Effective Exchange Rate	x184dnn@intwkly	x_t
3-Months interbank rate	ir3tib01esm156n	x_t

Note: When required, non-seasonally adjusted series are seasonally adjusted using US Census Bureau's X-12 ARIMA.

A.1.2 Government Finances Dataset

Table 6: Government Series

Description	Mnemonic	Transformation
Taxes under common regime	esnfeta@spain	$\Delta log(x_t)$
Revenue cash basis deficit state resources and uses according to the national accounts:		
- Revenues	esnfprev@spain	$\Delta log(x_t)$
- Expenditures	esnfpexp@spain	$\Delta log(x_t)$
Marketable state debt	esnfdh@spain	$\Delta log(x_t)$
Treasury bills	esnfdb@spain	$\Delta log(x_t)$
Unstripped bonds	esnfdhu@spain	$\Delta log(x_t)$
Regional government bonds	esnfdob@spain	$\Delta log(x_t)$
Treasury bills outstanding by holder:		
- MFIs excluding money market funds	esofdbb@spain	$\Delta log(x_t)$
- Money market funds and other FIs	esofdfb@spain	$\Delta log(x_t)$
- Nonfinancial corporations	esofdcb@spain	$\Delta log(x_t)$
- Households and NPISHs	esofdhb@spain	$\Delta log(x_t)$
- Rest of the world	esofdab@spain	$\Delta log(x_t)$
Unstripped bonds and stripped principal by holder:		
- MFIs excluding money market funds	esofdbfd@spain	$\Delta log(x_t)$
- Money market funds and other FIs	esofdbod@spain	$\Delta log(x_t)$
- Nonfinancial corporations	esofdbnd@spain	$\Delta log(x_t)$
- Households and NPISHs	esofdhb@spain	$\Delta log(x_t)$
- Rest of the world	esofdbwd@spain	$\Delta log(x_t)$
General government debt at different maturities:		
- Short term debt	esmf1gss@spain	$\Delta log(x_t)$
- Long term debt	esmf1gsl@spain	$\Delta log(x_t)$
- Short term loans	esmf1gls@spain	$\Delta log(x_t)$
- Long term loans	esmf1gll@spain	$\Delta log(x_t)$
Interest rates on government bonds at different maturities:		
- 1 year interest rate	gves03(cm01)	x_t
- 5 years interest rate	gves03(cm05)	x_t
- 10 years interest rate	gves03(cm10)	x_t
FTSE WGBI 1-3 years: bond return index	esmf1gss@spain	$\Delta log(x_t)$
FTSE WGBI +5 years: bond return index	esmf1gss@spain	$\Delta log(x_t)$
FTSE WGBI +10 years: bond return index	esmf1gss@spain	$\Delta log(x_t)$
FTSE WGBI all maturities: bond return index	esmf1gss@spain	$\Delta log(x_t)$
FTSE WGBI +5 years: debt market value	esmf1gss@spain	$\Delta log(x_t)$
FTSE WGBI +10 years: debt market value	esmf1gss@spain	$\Delta log(x_t)$
FTSE WGBI all maturities: debt market value	esmf1gss@spain	$\Delta log(x_t)$

Note: When required, non-seasonally adjusted series are seasonally adjusted using US Census Bureau's X-12 ARIMA.

A.1.3 VAR Data

The following monthly variables are used in the BVAR and T-BVAR exercises. The sample is from May 1997 to August 2017. The starting and ending dates are dictated by the availability of the sovereign uncertainty measure:

- *Industrial Production* is production of total industry (seasonally adjusted), obtained from the OECD (retrieved from FRED). Mnemonic: ESPPROINDMISMEI.
- *Unemployment* is total harmonized unemployment rate (seasonally adjusted), obtained from the OECD (retrieved from FRED). Mnemonic: LRHUTTTTESM156S.
- *Price Level* is the non-seasonally adjusted consumer price index (all items), obtained from the OECD (retrieved from FRED). It is seasonally adjusted using US Census Bureau's X-12 ARIMA. Mnemonic: ESPCPIALLMINMEI.
- *Bank loans* is nominal non-seasonally adjusted bank lending to NFIs, obtained from Datastream. Mnemonic: ESBANKLPA. It is seasonally adjusted using US Census Bureau's X-12 ARIMA. It is also divided by CPI to express it in real terms.
- *Long-term rate* is defined as the return on the 10-years Spanish government bonds, obtained from Datastream. Mnemonic: GVES03(CM10).
- *Government Debt* is central government marketable debt, obtained from Haver Analytics. It is seasonally adjusted using US Census Bureau's X-12 ARIMA. Mnemonic: ESNFD@SPAIN.
- *Stock Market* is the IBEX-35 market index extracted from `www.bolsasymercados.es`.
- *Confidence* is overall consumer and industrial sentiments, obtained from the Statistical Data Warehouse (ECB). Mnemonic: for consumer, sur.m.es.s.ecfin.cns099.tt and for industrial, sur.m.es.s.ecfin.man099.tt.
- *Sovereign and Macro-financial Uncertainties* are computed as explained in section 2.

For the IRF-matching estimation of the DSGE model, the following variables are employed in the quarterly VAR:

- *Output* is seasonally adjusted real GDP, obtained from Haver Analytics. Mnemonic: S184NGPC@G10.
- *Consumption* is seasonally adjusted real personal consumption expenditures, obtained from Haver Analytics. Mnemonic: S184NCPC@G10.
- *Investment* is seasonally adjusted real gross fixed capital formation, obtained from Haver Analytics. Mnemonic: S184NFC@G10.
- *Hours Worked* is seasonally adjusted total hours worked (employment), obtained from the SDW (ECB). Mnemonic: mna.q.y.es.w2.s1.s1z.emp.z.t.z.hw.z.n.
- *Price Inflation* is growth rate of the seasonally adjusted GDP implicit price deflator, obtained from Haver Analytics. Mnemonic: S025NGPJ@G10.
- The successive variables, which are also included in the quarterly VAR, are just the quarterly aggregation of the previous monthly series: *stock market index, government*

debt, long-term interest rate on government bonds, bank loans, confidence, macro-financial uncertainty and sovereign uncertainty.

A.1.4 Additional Data

Finally, some extra variables from which their respective business cycle statistics are extracted for Table 2 and Table 8:

- *Nominal Interest Rate* is the 3-months money market interest rate (EA11-19, AVG), obtained from Haver Analytics. Mnemonic: I023M@EUDATA.
- *Credit Spread* is the credit risk indicator for non-financial corporations in Spain, obtained from Gilchrist and Mojon (2018).
- *Bond spread* is defined as return on one year Spanish government bonds net return on one year German government bonds, obtained from Datastream. Mnemonic: GVES03(CM01) for Spain and GVBD03(CM01) for Germany.

A.2 Comparison with 12-months ahead Sovereign Uncertainty

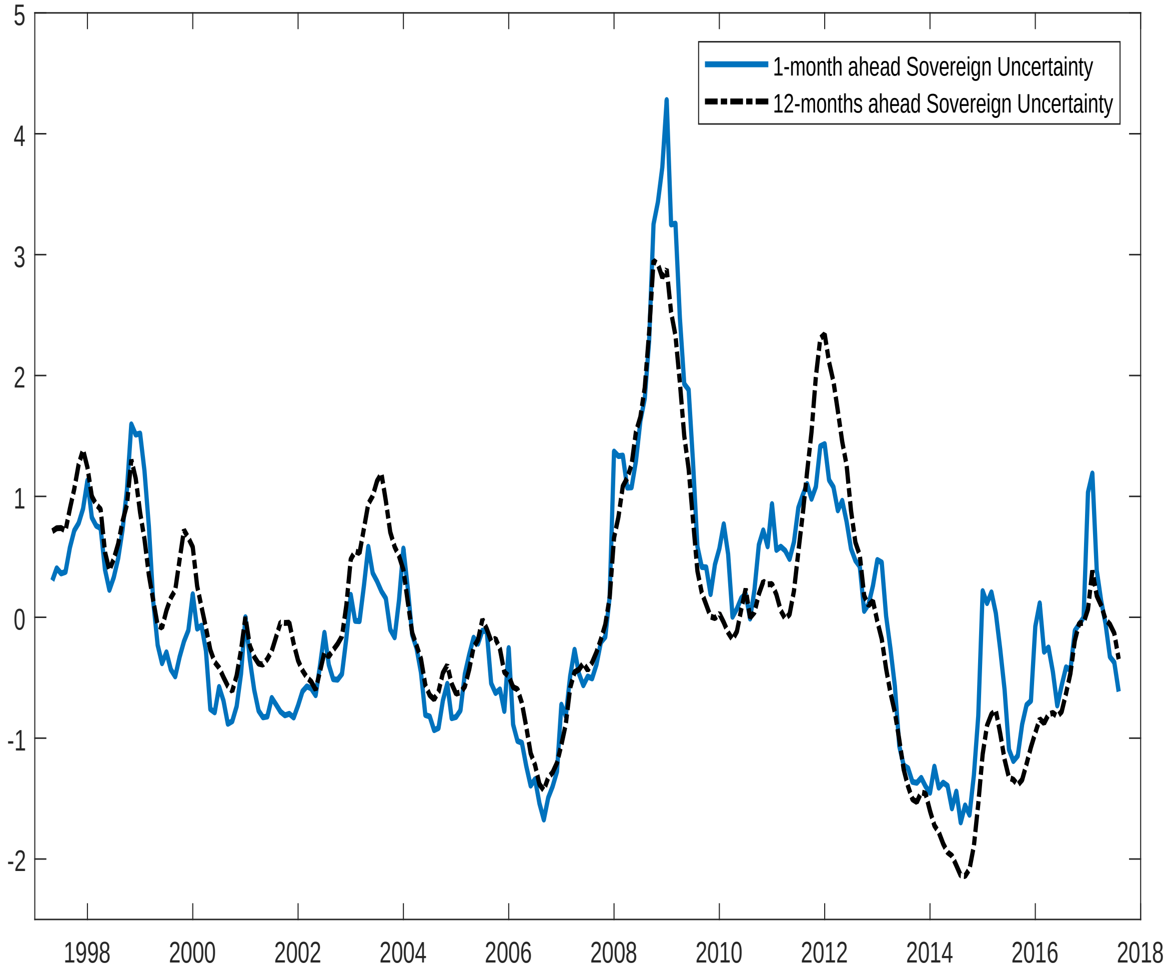

Figure 11: Sovereign Uncertainty at Different Forecast Horizons

Note: The solid-blue and dash-dot-black lines indicate the estimated 1-month and 12-months ahead sovereign uncertainty, respectively. Both measures are standardized.

A.3 Decomposition of SU: Prices vs. Quantities

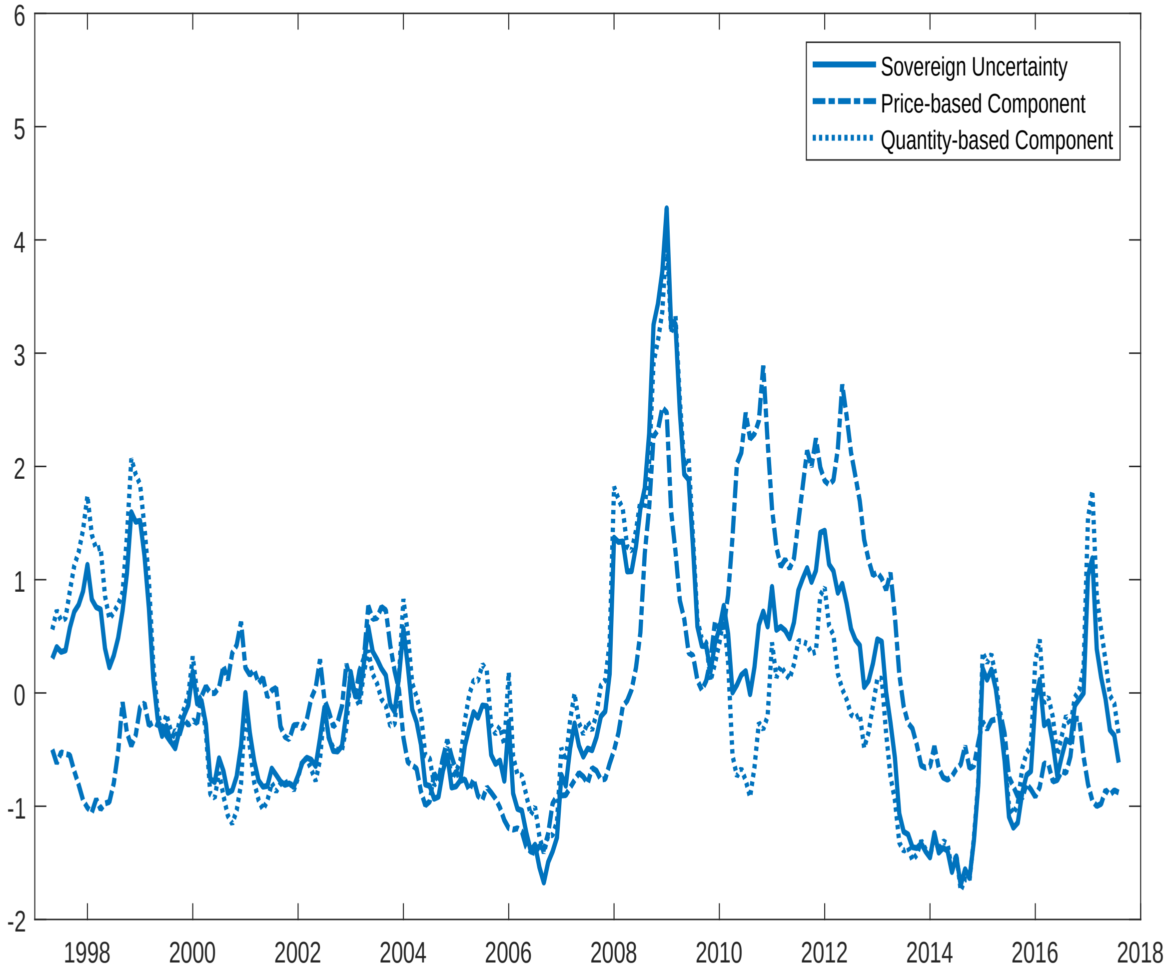

Figure 12: Sovereign Uncertainty: Prices vs. Quantities

Note: The solid line indicates the estimated sovereign uncertainty; the dash-dot line represents the price-based component of sovereign uncertainty; and the dotted line exhibits the quantity-based component of sovereign uncertainty. All measures are standardized.

A.4 Comparison with EPU from Ghirelli et al. (2019)

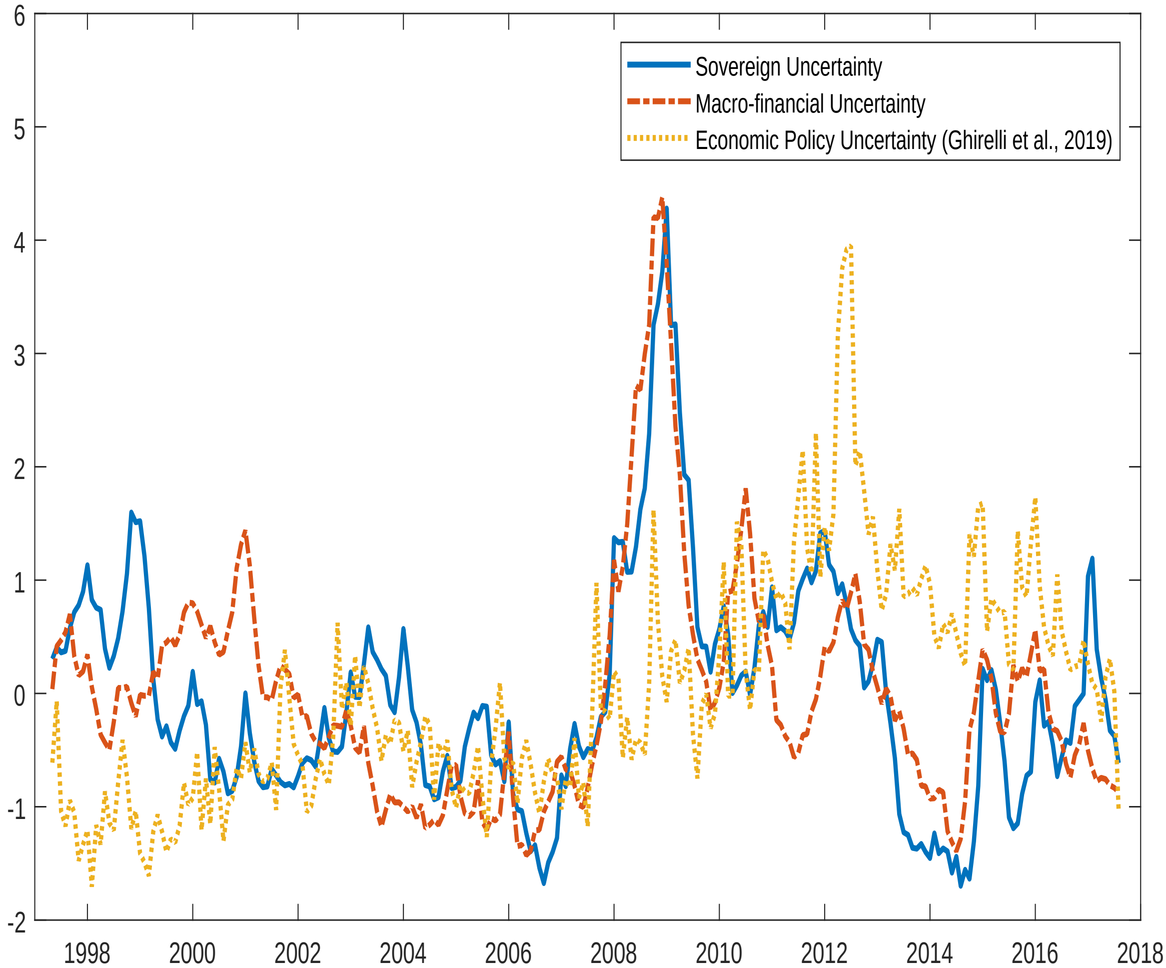

Figure 13: Sovereign Uncertainty, Macro-financial Uncertainty, and EPU

Note: The solid-blue line indicates the estimated sovereign uncertainty; the dash-dot-orange line represents the aggregate macro-financial uncertainty; and the dotted-yellow line exhibits the economic policy uncertainty index from Ghirelli et al. (2019). All measures are standardized.

A.5 VAR Robustness Checks and Additional Results

This section presents the complete figures of the robustness checks under both identification strategies employed in the paper: recursive schemes (A.5.1) and a combination of sign, event-based and ratio restrictions (A.5.2). It also documents the relevance of the data-rich approach (A.5.3), the contribution of sovereign uncertainty shocks by performing a forecast error variance decomposition exercise (A.5.4) and a historical decomposition analysis to see how important any of the uncertainty indicators are in historical period (A.5.5).

A.5.1 Recursive Identification

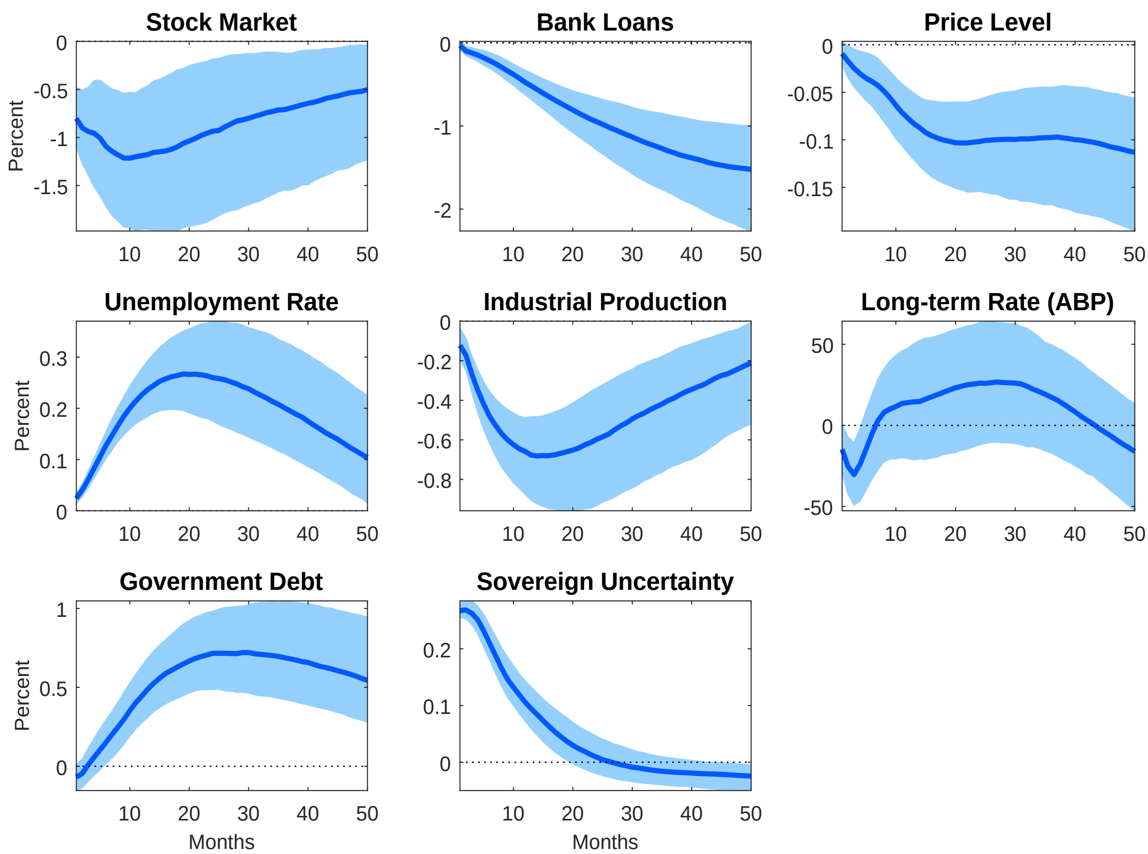

Figure 14: IRFs to One Standard Deviation Shock to Sovereign Uncertainty: SU Ordered First

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

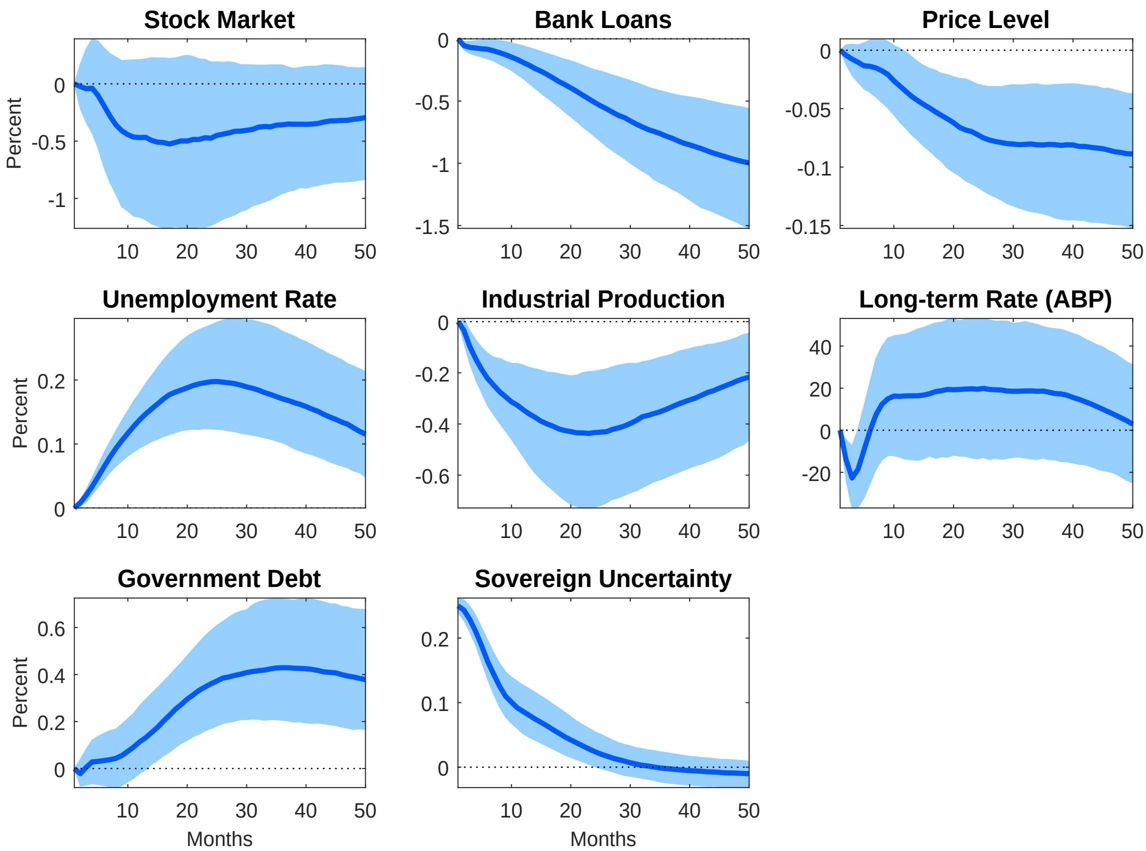

Figure 15: IRFs to One Standard Deviation Shock to Sovereign Uncertainty: Controlling for Macro-financial Uncertainty

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

Figure 16: IRFs to One Standard Deviation Shock to Sovereign Uncertainty: Controlling for Consumer Confidence

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

Figure 17: IRFs to One Standard Deviation Shock to Sovereign Uncertainty: Controlling for Industrial Confidence

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

Figure 18: IRFs to One Standard Deviation Shock to Sovereign Uncertainty: VAR with 6 Lags

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

Figure 19: IRFs to One Standard Deviation Shock to Sovereign Uncertainty: VAR with 12 Lags

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

A.5.2 Sign, Event-based and Ratio Restrictions

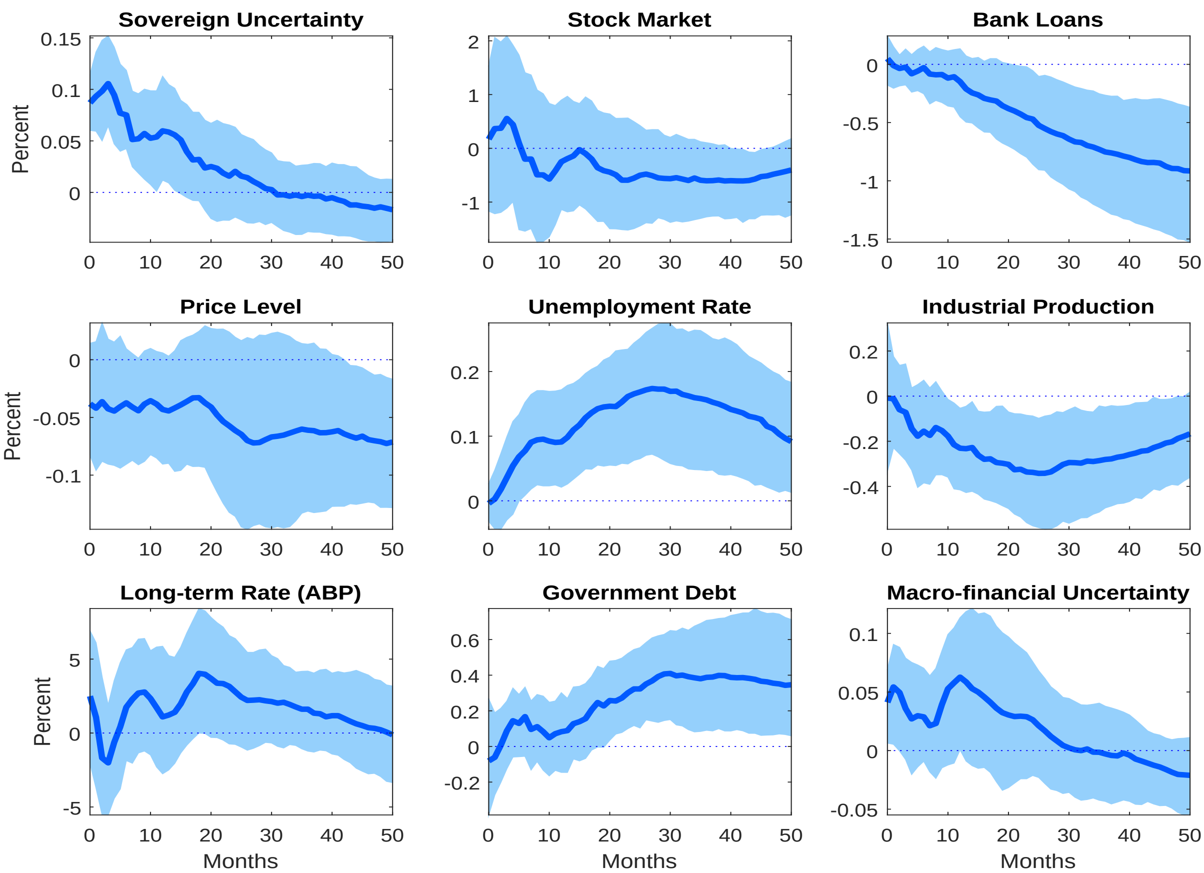

Figure 20: IRFs to One Standard Deviation Shock to Sovereign Uncertainty. Identification with Sign, Event-based and Ratio Restrictions: Excluding the Lehman Brothers' Collapse

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

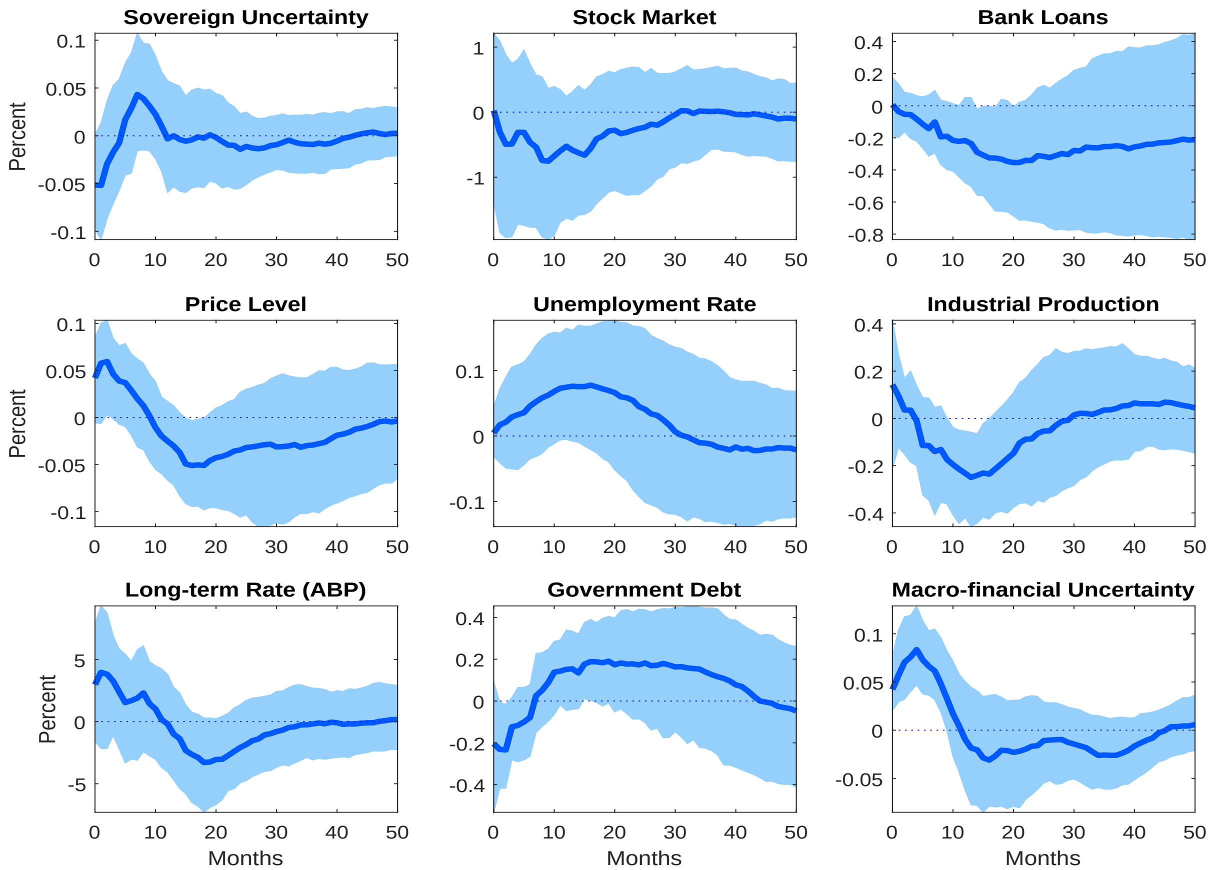

Figure 21: IRFs to One Standard Deviation Shock to Macro-financial Uncertainty. Identification with Sign, Event-based and Ratio Restrictions: Excluding the Lehman Brothers' Collapse

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

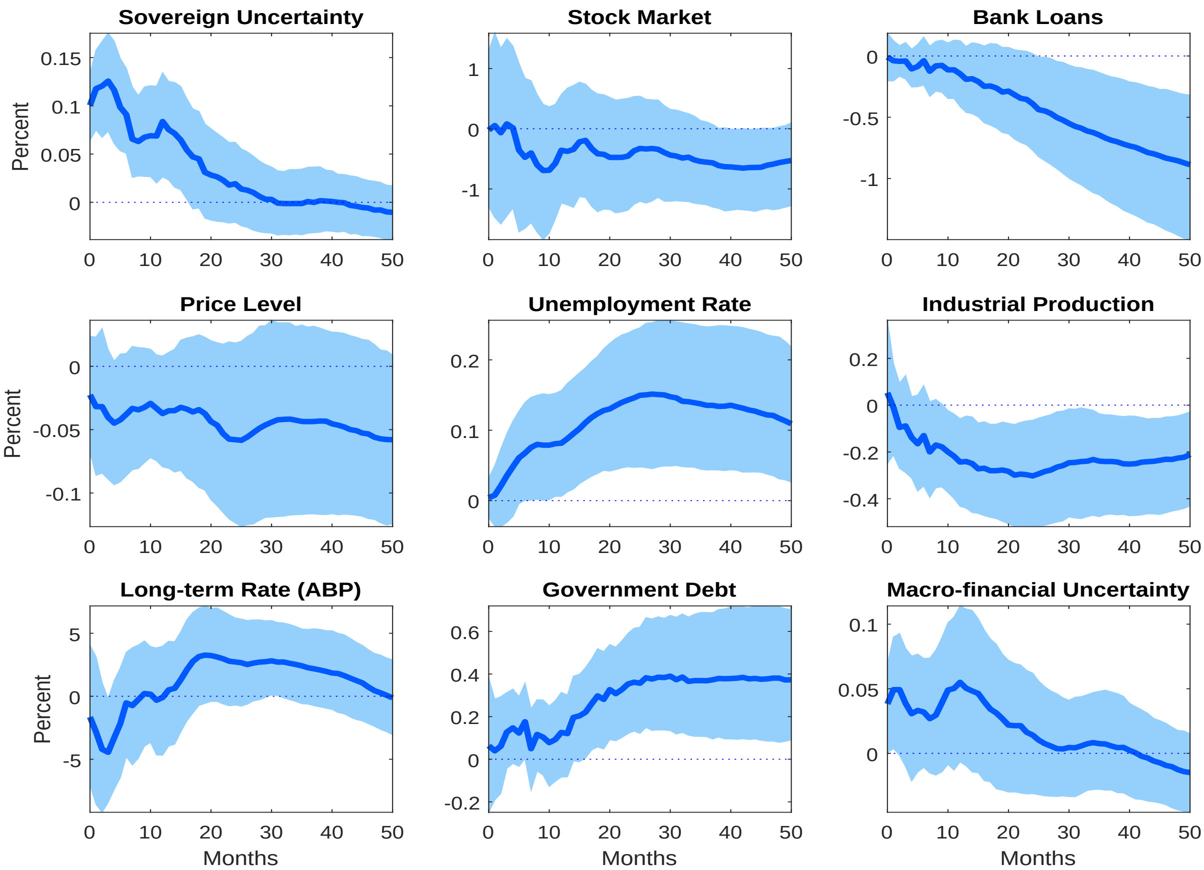

Figure 22: IRFs to One Standard Deviation Shock to Sovereign Uncertainty. Identification with Sign, Event-based and Ratio Restrictions: Excluding the ESM Assistance

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

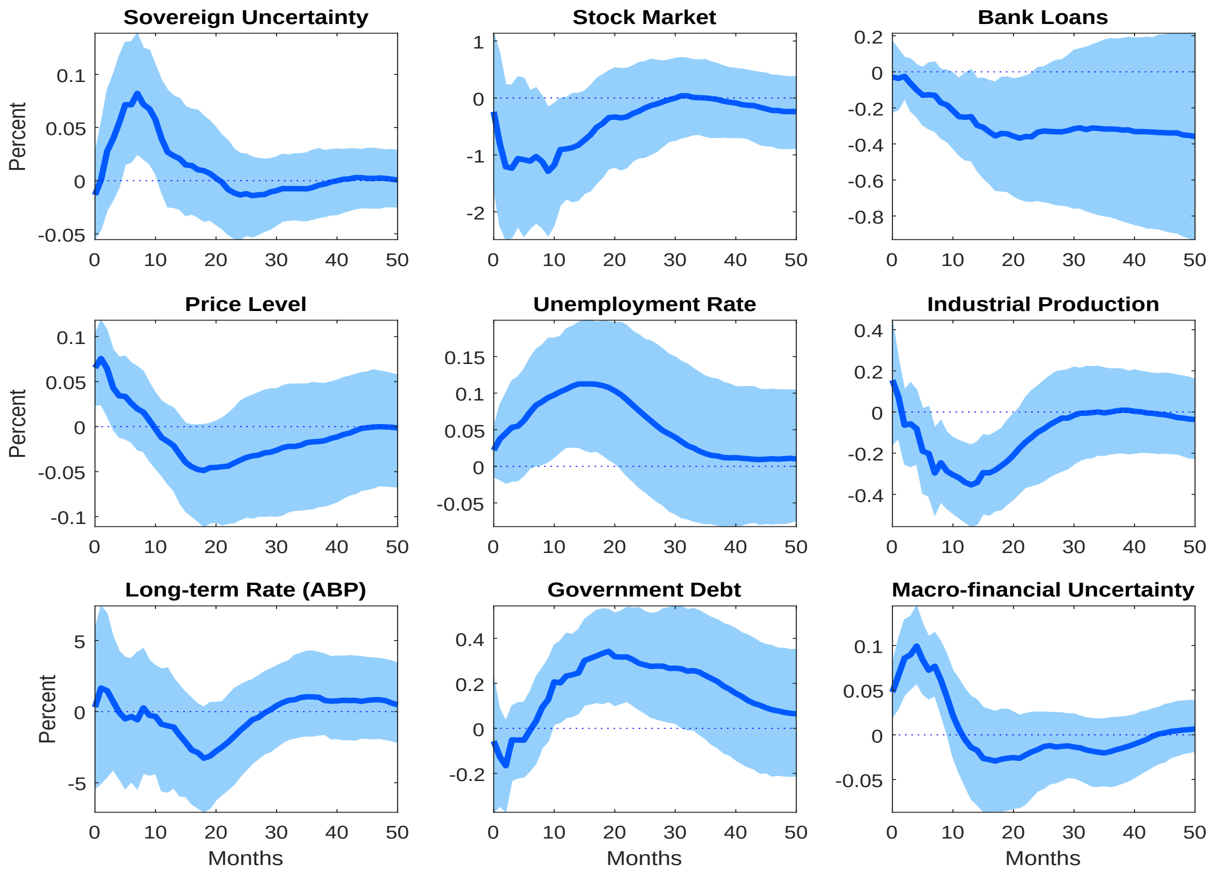

Figure 23: IRFs to One Standard Deviation Shock to Macro-financial Uncertainty. Identification with Sign, Event-based and Ratio Restrictions: Excluding the ESM Assistance

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

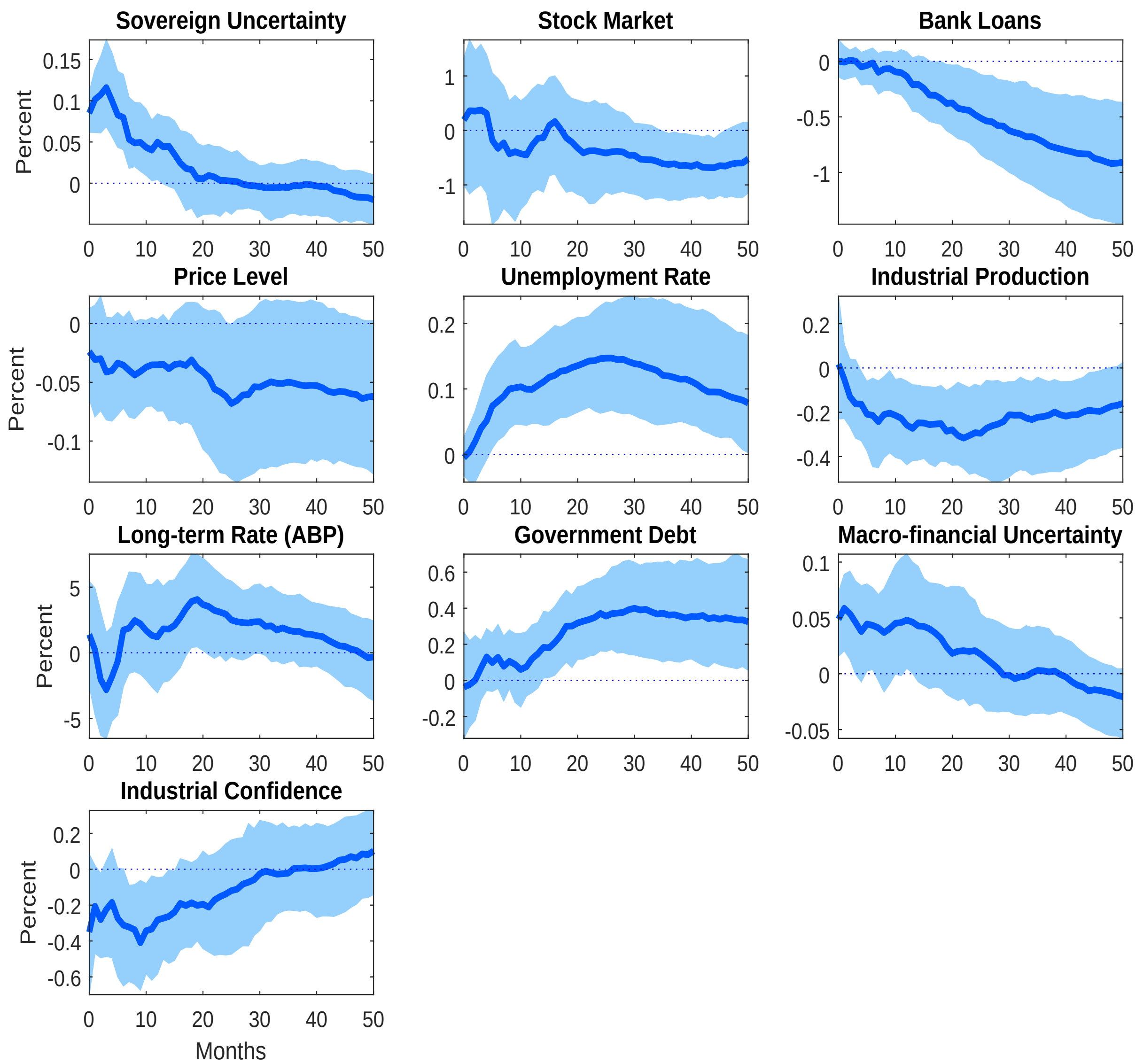

Figure 24: IRFs to One Standard Deviation Shock to Sovereign Uncertainty. Identification with Sign, Event-based and Ratio Restrictions: Controlling for Industrial Confidence

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

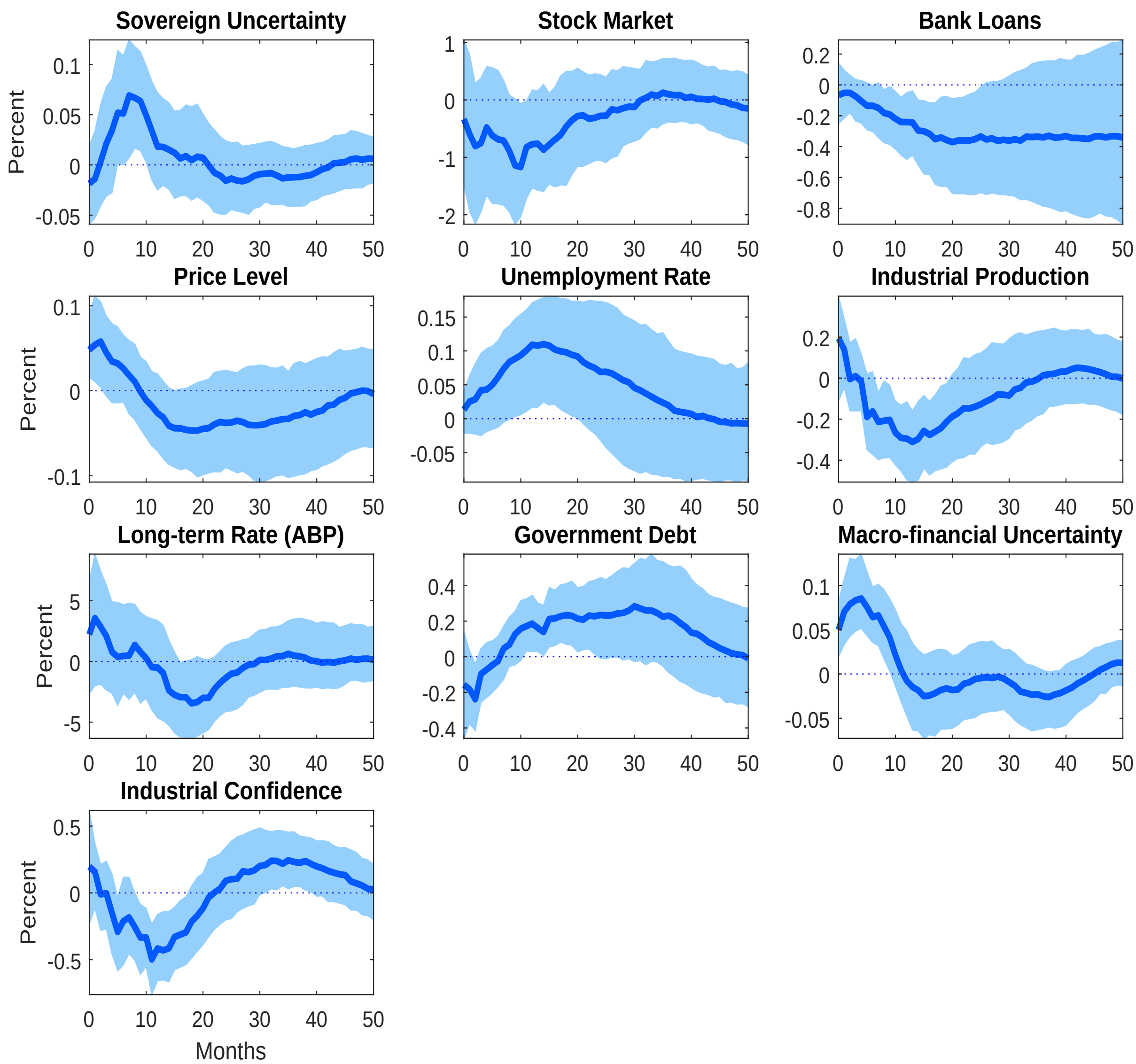

Figure 25: IRFs to One Standard Deviation Shock to Macro-financial Uncertainty. Identification with Sign, Event-based and Ratio Restrictions: Controlling for Industrial Confidence

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

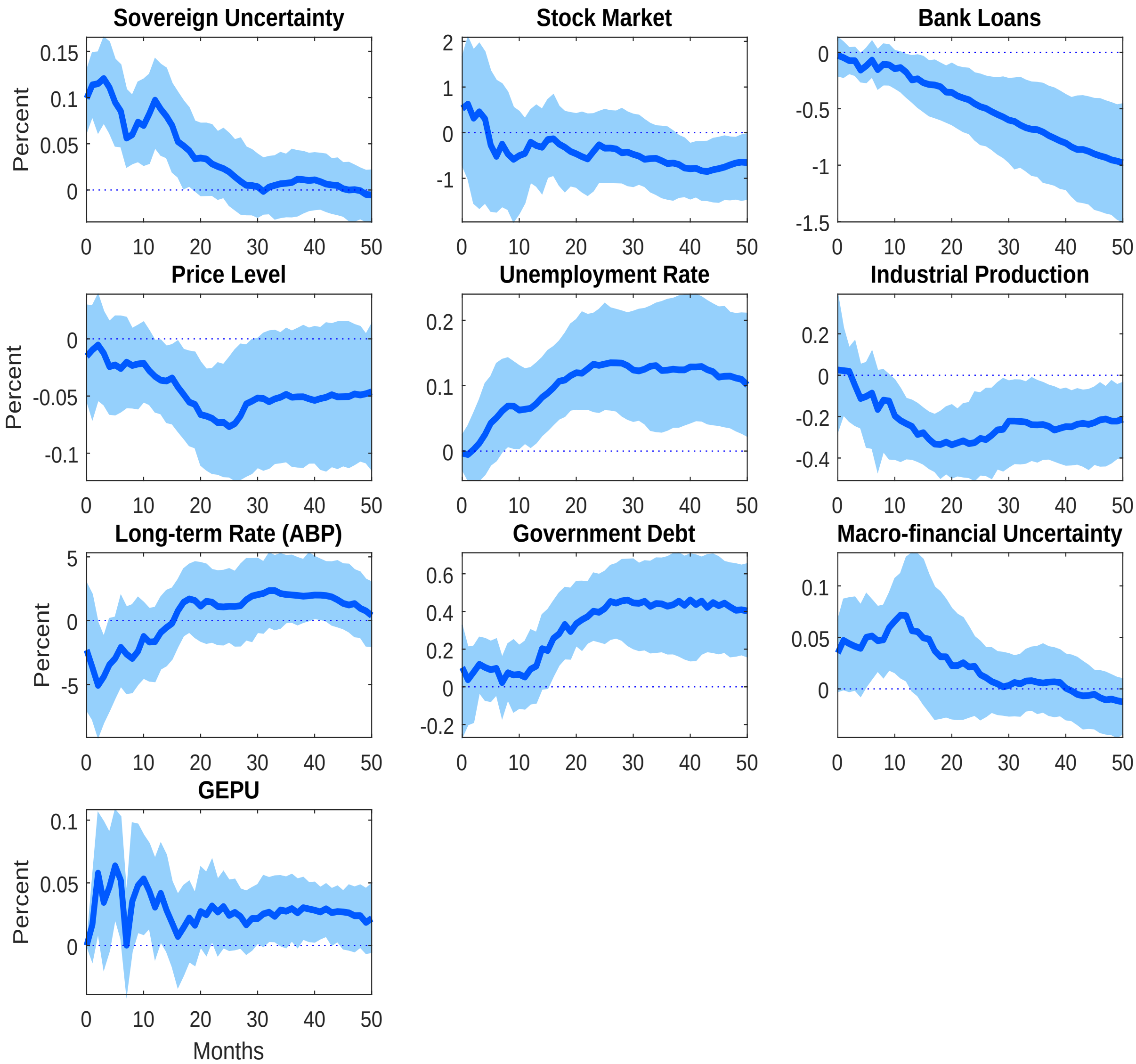

Figure 26: IRFs to One Standard Deviation Shock to Sovereign Uncertainty. Identification with Sign, Event-based and Ratio Restrictions: Controlling for GEPU

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

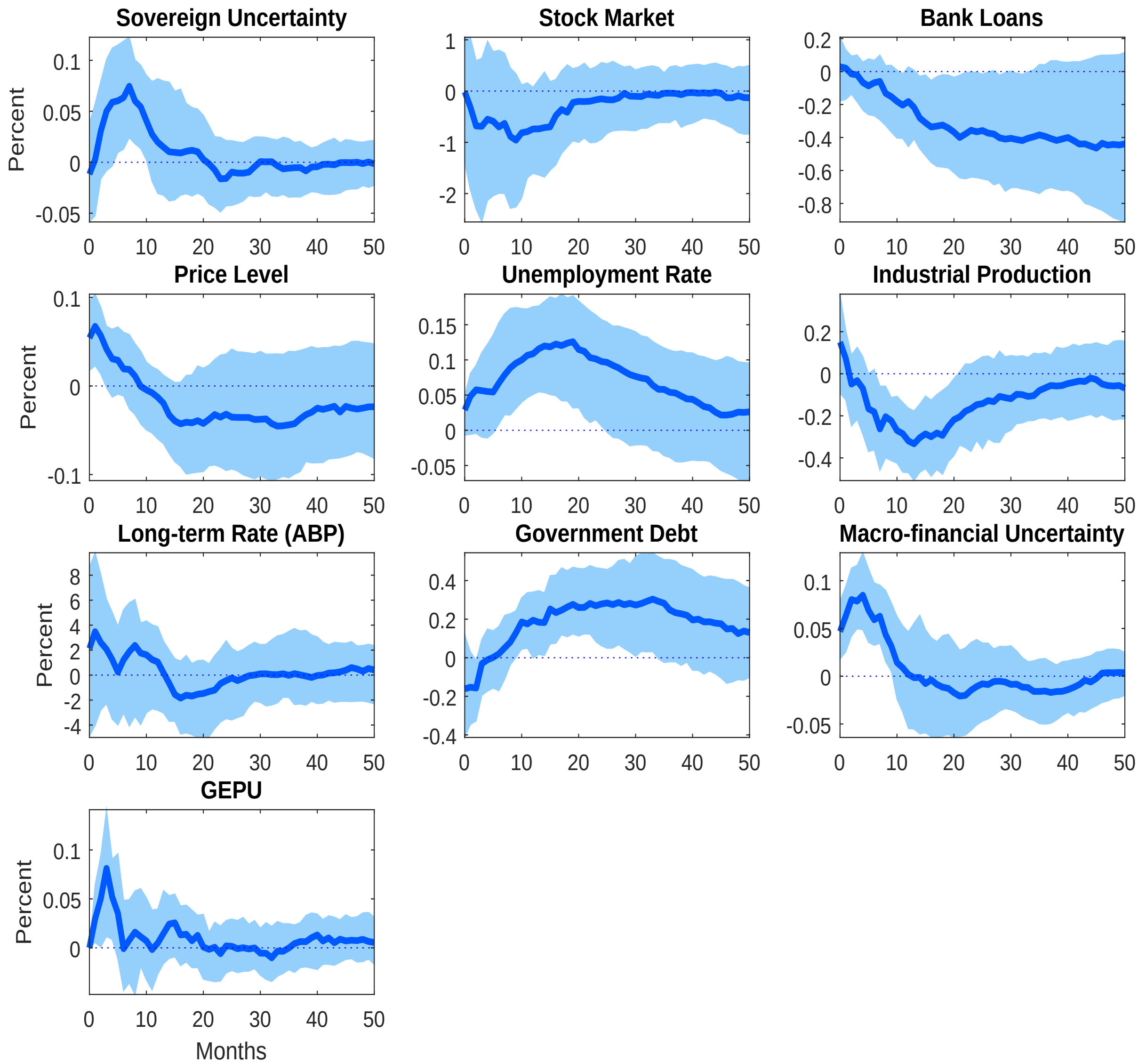

Figure 27: IRFs to One Standard Deviation Shock to Macro-financial Uncertainty. Identification with Sign, Event-based and Ratio Restrictions: Controlling for GEPU

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

A.5.3 Relevance of the Data-rich Approach

Figure 28: IRFs to One Standard Deviation Shock to Short-term Debt Uncertainty

Note: Each entry shows the median and the 68% confidence bands under the baseline recursive identification scheme. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

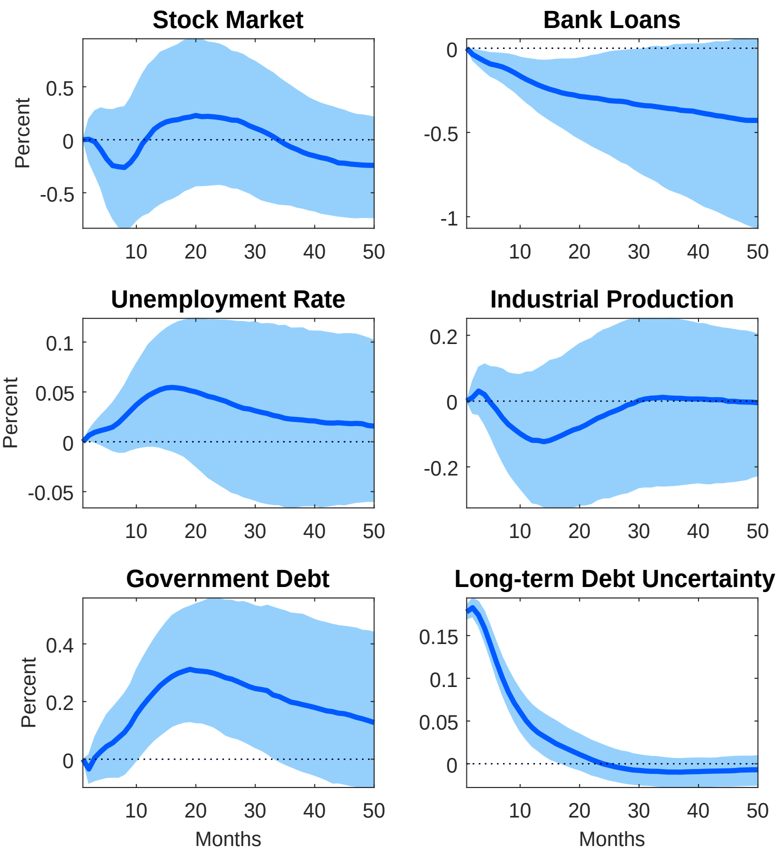

Figure 29: IRFs to One Standard Deviation Shock to Long-term Debt Uncertainty

Note: Each entry shows the median and the 68% confidence bands under the baseline recursive identification scheme. All responses are in monthly percent deviations from trend, except for the unemployment rate and the long-term rate, which are expressed in monthly percentage points and annualized basis points (ABP), respectively.

A.5.4 Forecast Error Variance Decomposition

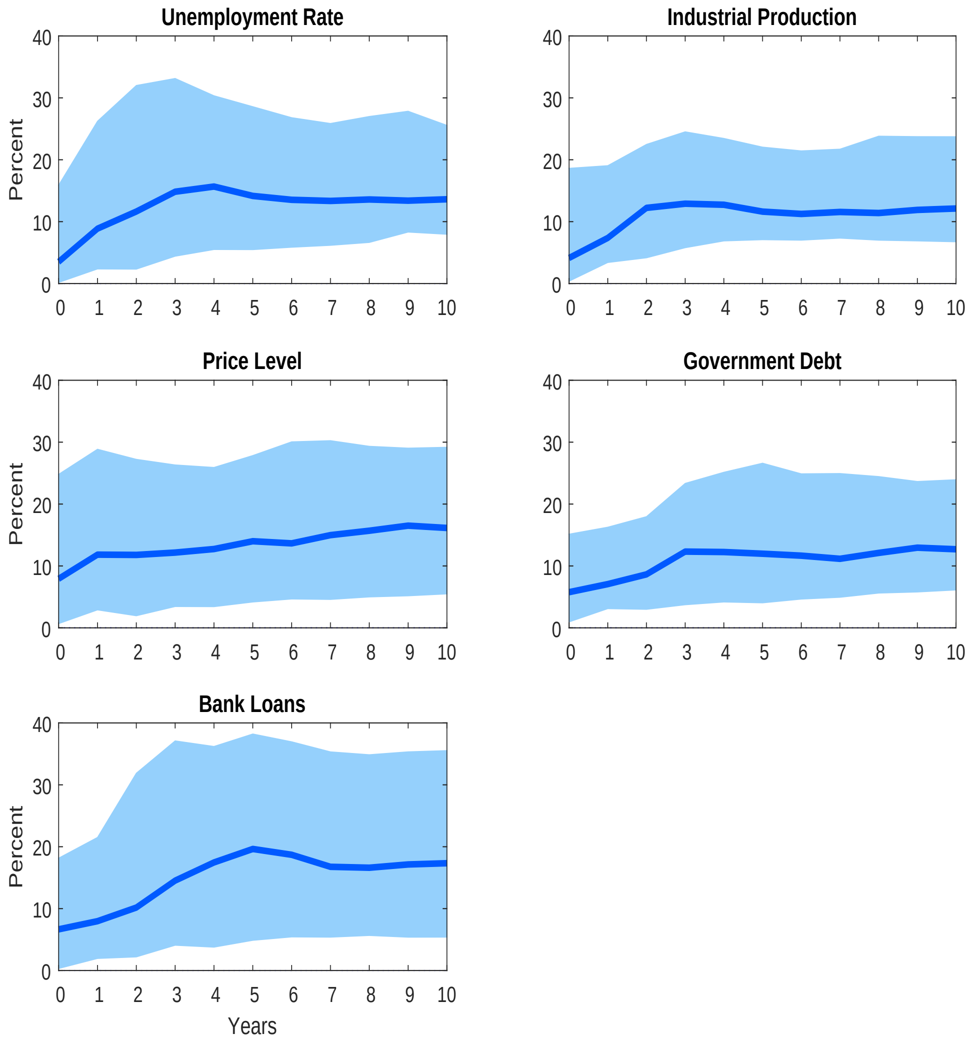

Figure 30: Decomposition of Variance

Note: Variance decomposition in selected variables due to sovereign uncertainty shocks under the baseline identification with sign, event-based and ratio restrictions. Figures are expressed in percent for each VAR forecast horizon (up to 10 years). Each entry shows the median and the 68% confidence bands of the FEVD distribution. The empirical sample is from May 1997 to August 2017.

A.5.5 Historical Decomposition

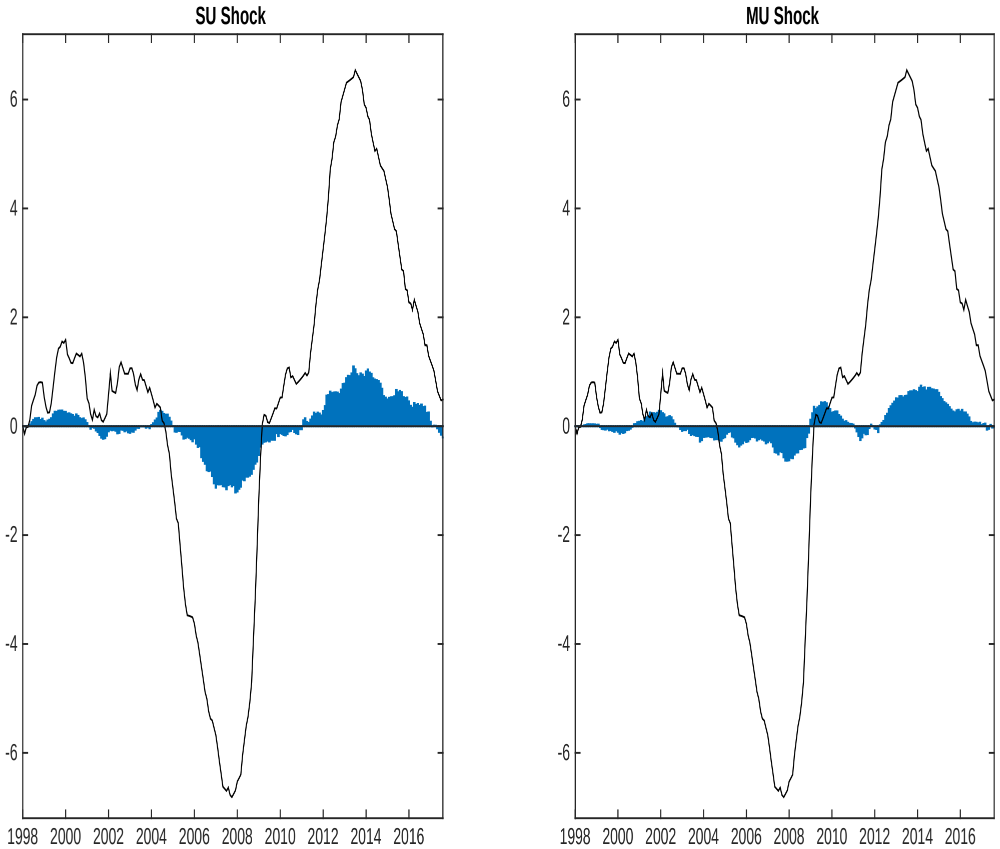

Figure 31: Historical Decomposition of Unemployment Rate

Note: Historical decomposition in selected variables due to SU and MU shocks under the baseline identification with sign, event-based and ratio restrictions. Figures are expressed in percent. The empirical sample is from May 1997 to August 2017.

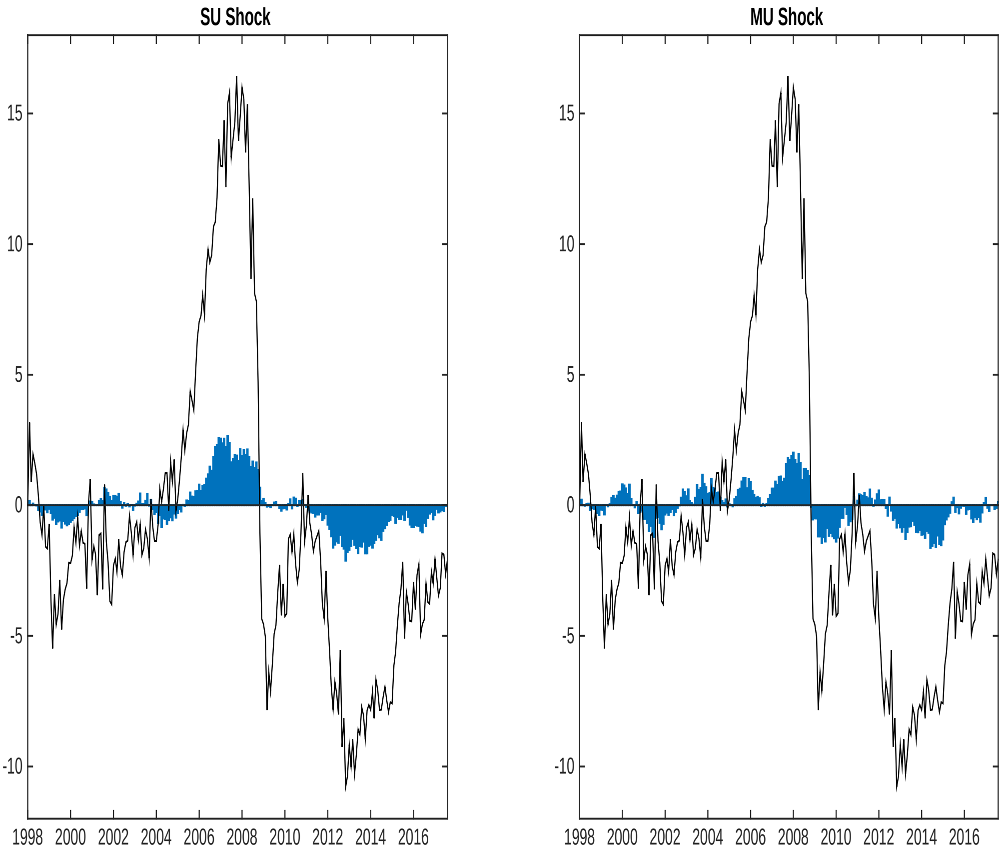

Figure 32: Historical Decomposition of Industrial Production

Note: Historical decomposition in selected variables due to SU and MU shocks under the baseline identification with sign, event-based and ratio restrictions. Figures are expressed in percent. The empirical sample is from May 1997 to August 2017.

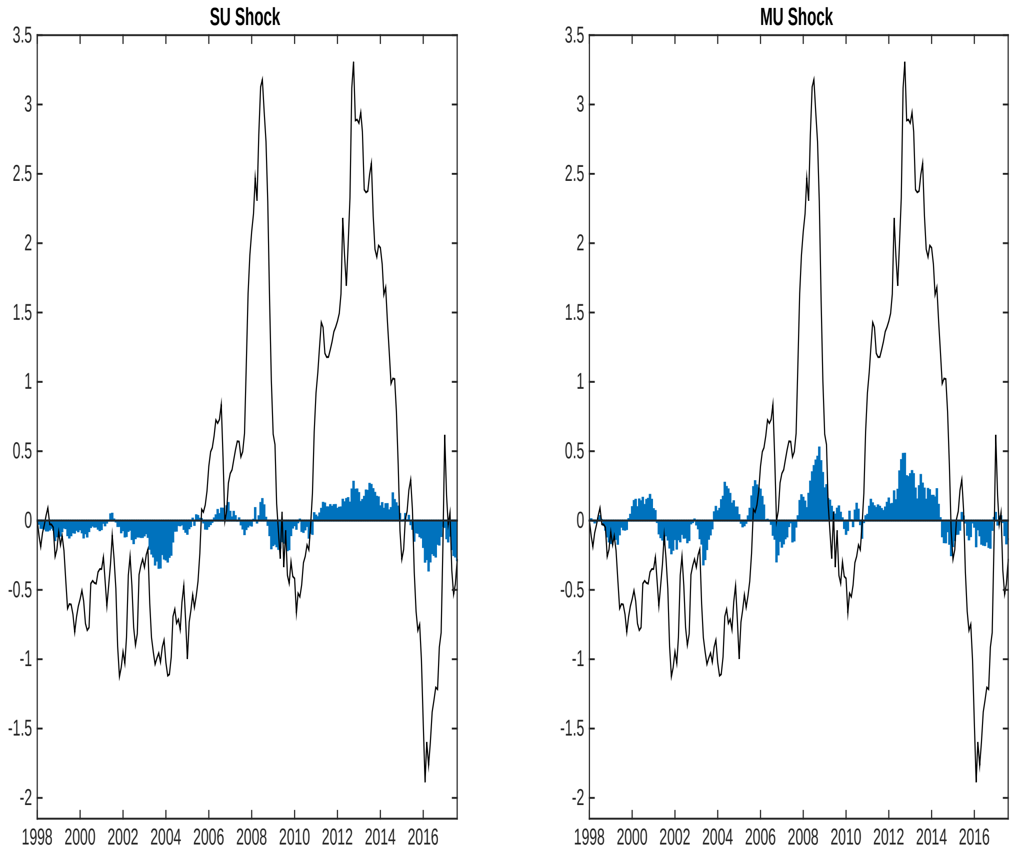

Figure 33: Historical Decomposition of CPI

Note: Historical decomposition in selected variables due to SU and MU shocks under the baseline identification with sign, event-based and ratio restrictions. Figures are expressed in percent. The empirical sample is from May 1997 to August 2017.

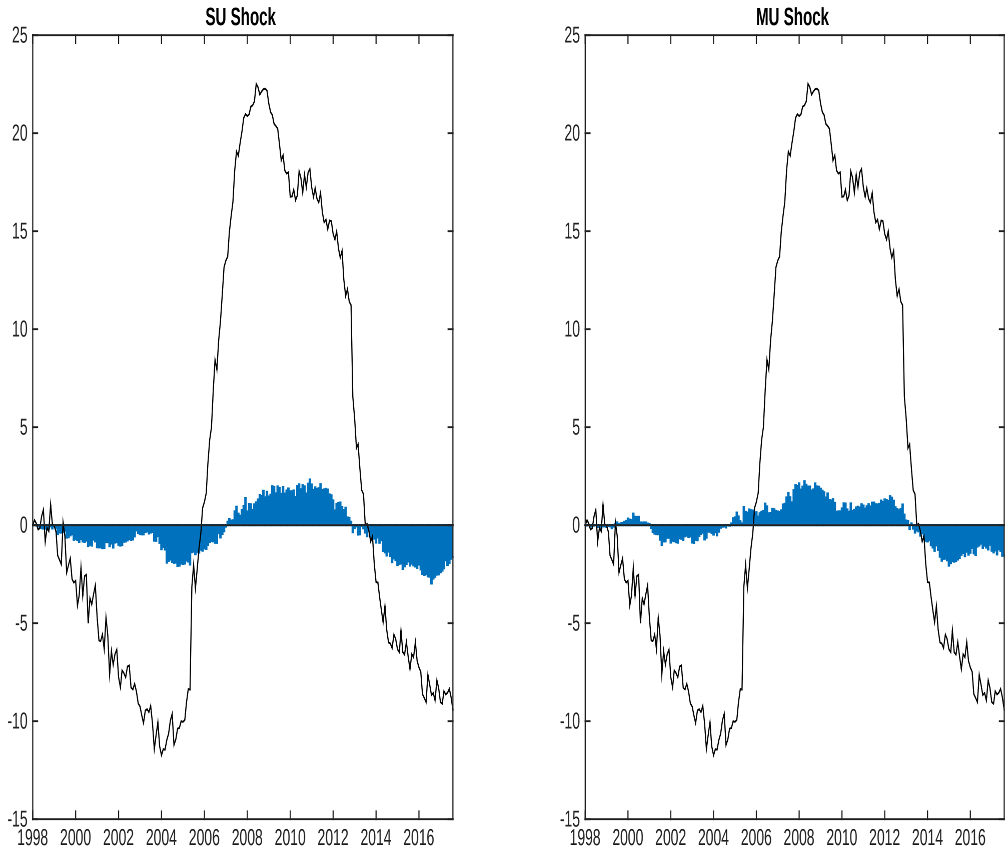

Figure 34: Historical Decomposition of Bank Loans

Note: Historical decomposition in selected variables due to SU and MU shocks under the baseline identification with sign, event-based and ratio restrictions. Figures are expressed in percent. The empirical sample is from May 1997 to August 2017.

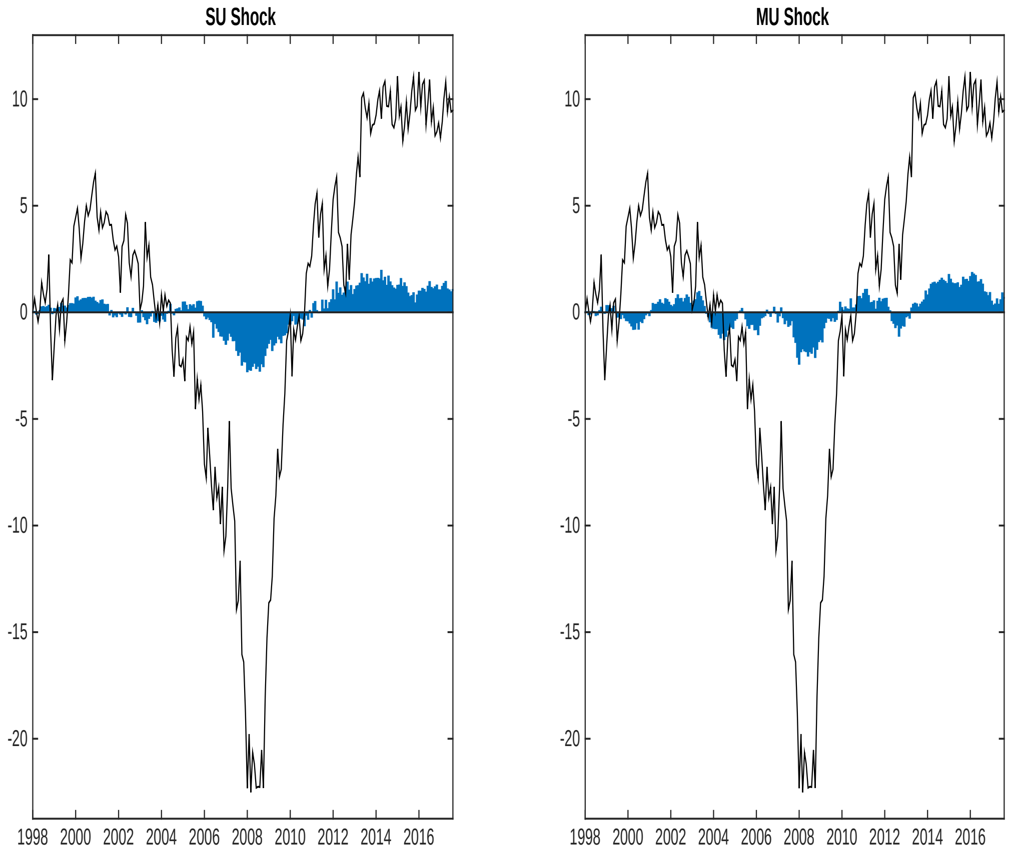

Figure 35: Historical Decomposition of Government Debt

Note: Historical decomposition in selected variables due to SU and MU shocks under the baseline identification with sign, event-based and ratio restrictions. Figures are expressed in percent. The empirical sample is from May 1997 to August 2017.

A.6 The (Non-linear) Transmission of SU Shocks

The Threshold VAR is defined as follows:

$$y_t = \left(c_1 + \sum_{k=1}^{p} \beta_{1,k} y_{t-k} + \epsilon_{1,t}\right) \times S_t + \left(c_2 + \sum_{k=1}^{p} \beta_{2,k} y_{t-k} + \epsilon_{2,t}\right) \times (1 - S_t), \tag{51}$$

with

$$S_t = \begin{cases} 1 & if \;\; r_{t-d} \leq \bar{r} \\ 0 & otherwise \end{cases} \tag{52}$$

and

$$\epsilon_{1,t} \sim \mathbb{N}(0, \, Q_1) \;\; \text{and} \;\; \epsilon_{2,t} \sim \mathbb{N}(0, \, Q_2),$$

where y_t stands for the vector of endogenous variables, c_i are constants in the respective regimes, and $\epsilon_{i,t}$ are Gaussian white noise shocks with covariance matrices Q_i, $\forall j = 1, 2$. Different from the linear VAR, coefficients c_i and β_i are regimen-dependent. The state prevailing in each period depends on whether the level of the threshold variable, which in my case is represented by a 12-months moving average of the growth rate of industrial production, is above or below a latent threshold level. This choice is in line with the previous empirical studies analyzing the non-linear effects of uncertainty shocks.[39]

In this extended version, the conjugate Normal-inverse Wishart prior (for the VAR parameter vector in both regimes) is implemented via dummy observations (Bańbura et al., 2010). The prior means of the coefficients on the first lag are set to one for non-stationary variables, and set to zero otherwise. The overall prior tightness is set to 0.10 and the prior on the intercept to 100. For the latent threshold level, $\bar{r}$, it is assumed a normal prior, and for the delay, d, a uniform prior with a maximum delay of nine months. While the posterior distribution of the VAR parameter vector is known (conditional now on the values of $\bar{r}$ and d), the posterior distributions of $\bar{r}$ and d conditional on the VAR coefficients are unknown. Therefore, I employ the Gibbs (MCMC) sampler introduced by Chen and Lee (1995) to simulate the posterior distribution of the model's parameters with 20,000 replications. I discard the first 15,000 iterations as burn-in and use the last 5,000 for inference.

The observables are sovereign uncertainty, bank lending, industrial production and unemployment rate.[40] Again, I use Spanish monthly data in log-levels for all variables except those expressed in rates (see Appendix A.1.3 for data description). The sample is from May 1997 to August 2017 and the model features nine lags. The reason for this reduced system is as follows. First, a non-linear VAR model is particularly rich in terms of coefficients to be estimated and thus requires the inclusion of a smaller set of indicators, especially if I have already selected nine lags. Moreover, as I have previously shown in the main text, the dynamics for the main indicators of interest — bank lending, industrial production and unemployment rate — were highly robust after a large battery of checks.

[39] Given that the Gross Value Added of the service sector is relatively high in the Spanish economy, I have also employed the unemployment rate as a threshold variable. The baseline results are confirmed under this alternative specification (see Figure 38).

[40] I have also controlled for macro-financial uncertainty by adding it last in the vector of observables. The main results are again unchanged (see Figure 38).

In other words, the inclusion or exclusion of other economic aggregates in the vector of observables did not change their particular conclusions.

Following Koop et al. (1996), I compute the generalized impulse response functions (GIRFs) as the difference between two conditional expectations since the TVAR is non-linear:

$$GIRF_t = \mathbb{E}[y_{t+h}|\xi, \Theta_{t-1}] - \mathbb{E}[y_{t+h}|\Theta_{t-1}], \tag{53}$$

where h is the considered horizon, ξ is the size of the shock and Θ_{t-1} is a set of initial conditions which is formed by the parameters of the model. For each history, I compute 500 time paths of length h. Then, I average the GIRFs over all histories in each regime.[41]

Figure 36 shows the two different regimes that the model endogenously identifies by using industrial production as a threshold. Dashed-grey areas indicate the estimated bust regimes. Hence, by definition, recessions (expansions) occur when the level of the threshold variable is below (above) the latent threshold level. It is worth noting that estimated recessions are almost identical to the ones considered by the Spanish Business Cycle Dating Committee and the Economic Cycle Research Institute (ECRI) during the twin global financial crisis and eurozone debt crisis. Moreover, the threshold variable also determines the span 2001–2002 as a short episode of economic slowdown. While this limited period is not dated by the previous institutions, it is reflected in the Spanish macro-financial uncertainty index as a high uncertainty event.

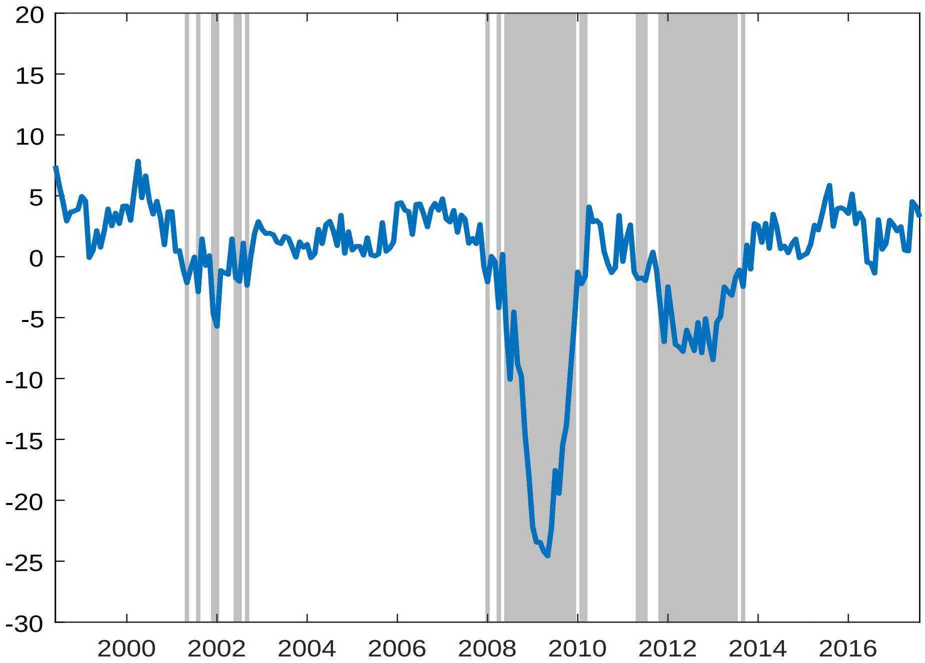

Figure 36: Threshold Dynamics

Note: Dashed-grey areas indicate the estimated bust regimes.

Next, Figure 37 plots the generalized impulse response functions (GIRFs) to a one stan-

[41]The model can switch across the endogenous states conditional on the sign and the size of the shock.

dard deviation shock to sovereign uncertainty in the Threshold VAR model.[42] On the one hand, we can observe that following a shock to SU during recessions, industrial production decreases on impact by around -0.2% and reaches a value of -0.5% after two years. On the other hand, when the economy is in normal times, industrial production goes down only as time passes and hits the bottom with a value of -0.3%. The same analysis applies to bank lending and unemployment rate, i.e., the impact is larger in bad times but still substantial in good times.

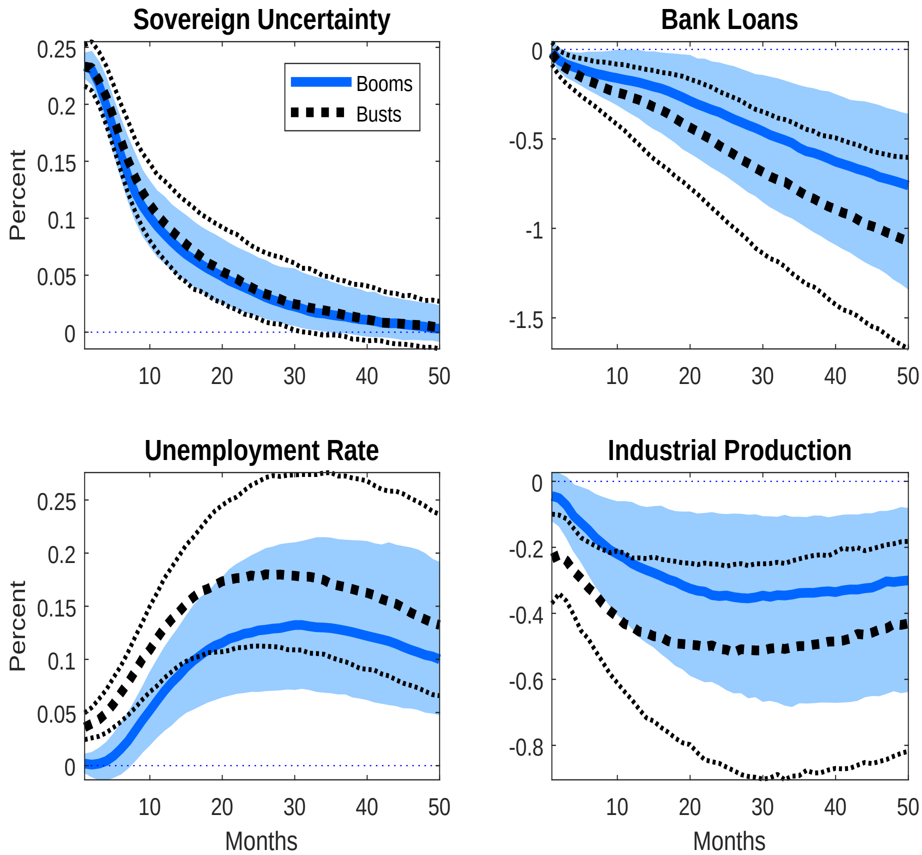

Figure 37: GIRFs to One Standard Deviation Shock to Sovereign Uncertainty

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate, which is expressed in monthly percentage points.

[42]The GIRFs are built on draws from the joint distribution of the structural shocks as in Kilian and Vigfusson (2011). In this case, I only claim that I identify one structural shock based on a Cholesky recursion: a sovereign uncertainty shock. The innovations associated with the remaining endogenous variables of the model are left without interpretation.

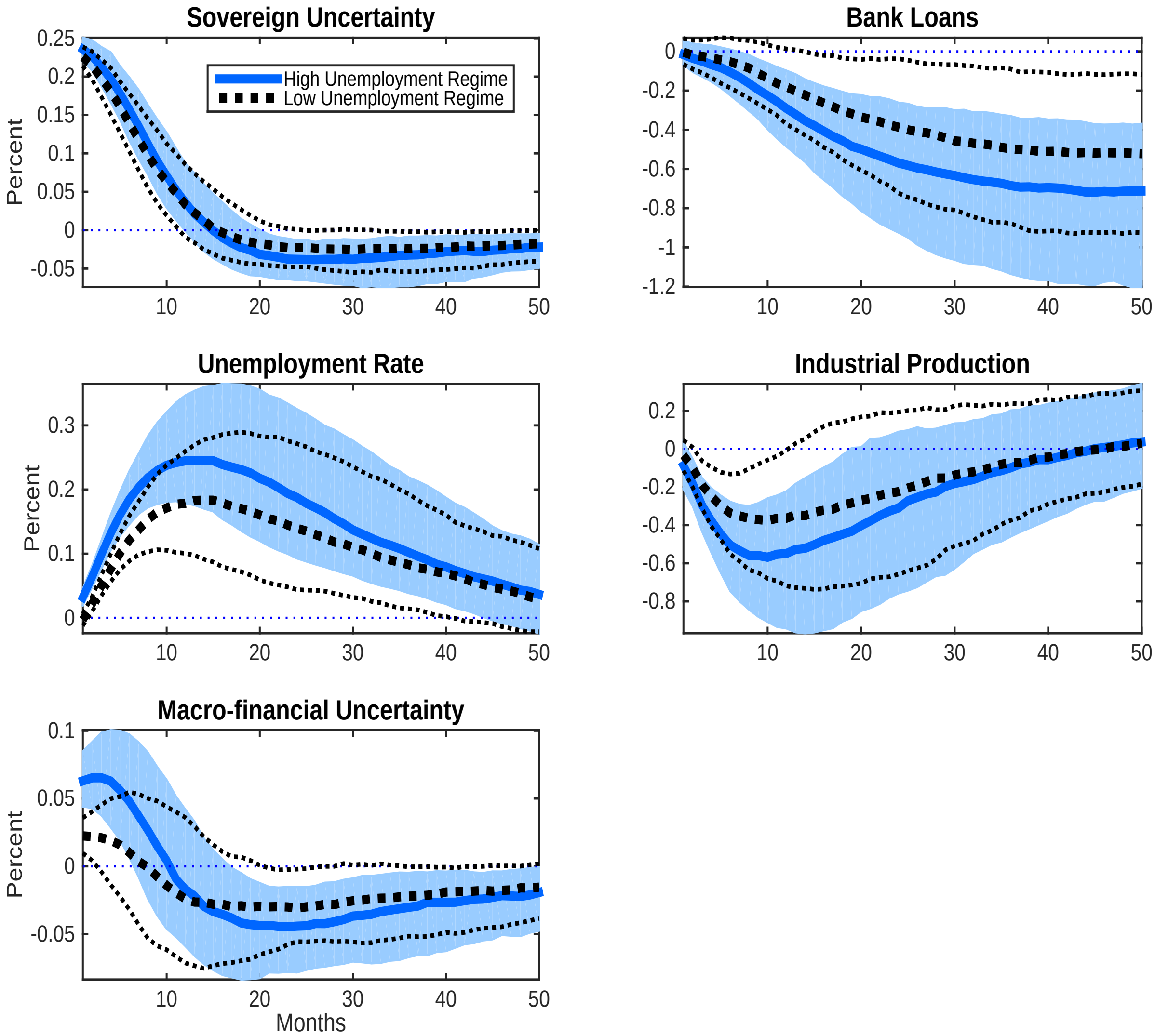

Figure 38: GIRFs to One Standard Deviation Shock to Sovereign Uncertainty: Including MU and Unemployment Rate as a Threshold

Note: Each entry shows the median and the 68% confidence bands. All responses are in monthly percent deviations from trend, except for the unemployment rate, which is expressed in monthly percentage points.

B Theoretical Section

B.1 Quarterly IRFs for Moment Matching

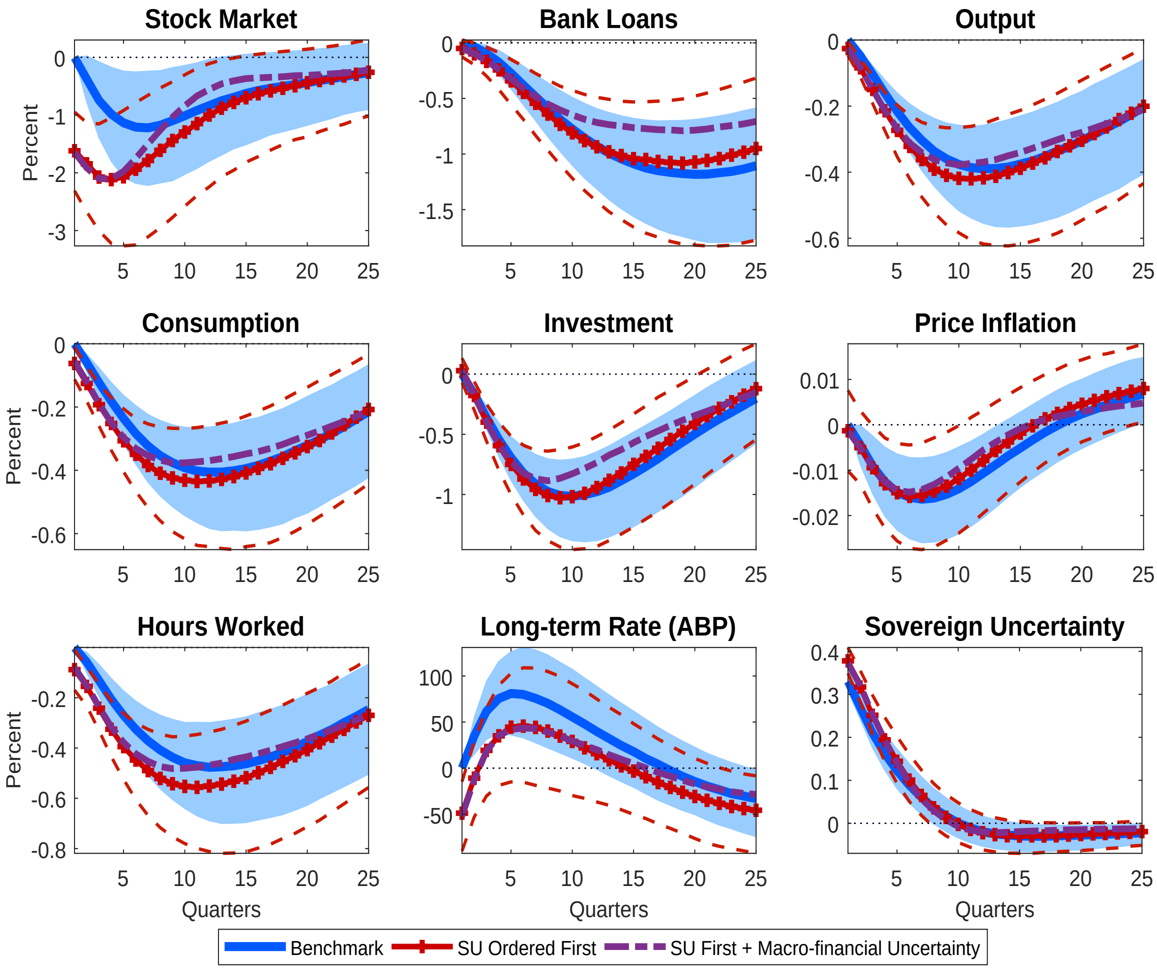

Figure 39: Quarterly IRFs to One Standard Deviation Shock to Sovereign Uncertainty

Note: Each entry shows the median and the 68% confidence bands. All responses are in quarterly percent deviations from trend, except for inflation and the long-term rate, which are expressed in quarterly percentage points and annualized basis points (ABP), respectively.

B.2 Alternative Moment Matching

Table 7: Model Parameters under a Simple Taylor Rule

	Firms		
ϑ	Investment adjustment cost	21.03	Target
δ	Gross depreciation rate	0.02	Standard
α	Capital share in production	0.33	Gertler and Karadi (2013)
ϵ	Elasticity of demand	9	Burriel et al. (2010)
ϕ_P	Price adjustment cost	100	Price stickiness of 0.75
	Banks		
λ	Fraction of divertible capital	0.253	Target
ω	Transfer to new bankers	0.001	Small value
θ	Survival rate of bankers	0.961	Target
Δ	Seizure rate of gov. bonds	0.50	Gertler and Karadi (2013)
	Households		
β	Discount rate	0.992	Standard
γ	Risk aversion	60	van Binsbergen et al. (2012)
ψ	Inter. elasticity of substitution	0.50	Caldara et al. (2012)
$\bar{B}^h/\bar{B}$	Bond holdings by households	0.70 (0.60*)	Data
$\bar{S}^h/\bar{S}$	Capital holdings of households	0.50	Gertler and Karadi (2013)
κ	Portfolio adjustment cost	1	Gertler and Karadi (2013)
	Monetary Policy and Government		
κ_π	Inflation coefficient TR	1.50	Standard
κ_y	Output coefficient TR	0.05	Low value
$\kappa_{\sigma_{RB}}$	Sov. uncertainty coefficient TR	0	Simple TR
$\bar{B}$	Government bond supply	1.36	Data ($B/Y = 0.60$)
	Shocks		
$\rho_{\sigma_{RB}}$	Autocorrelation parameter of σ_{Rb}	0.80 (0.86*)	VAR evidence
η	Stochastic volatility parameter	0.33	VAR evidence
ρ_{RB}	Autocorrelation parameter of Rb	0.961	Target
σ_{RB}	Degree of mean volatility	-7.54	Target
ρ_A	TFP autocorrelation	0.980	Target
σ_A	Standard deviation of TFP	0.090	Target
ρ_ξ	Capital quality autocorrelation	0.914	Target
σ_ξ	S.D. of capital quality shock	0.045	Target
ρ_i	Taylor rule autocorrelation	0.747	Target
σ_i	Taylor rule standard deviation	0.261	Target

Note: These are the parameters employed under the alternative simple Taylor rule. The calibrated parameters from previous literature are as in the baseline economy. The only difference comes from the set of estimated (Target) parameters in the matching estimation. In the paper, three experiments are done with the simplified Taylor rule: (*i*) just setting to zero the monetary policy reaction parameter after a sovereign uncertainty shock (Figure 9 – dashed-black lines); (*ii*) simple Taylor rule + higher persistence in the sovereign uncertainty shock (Figure 9 – dotted-red lines); and (*iii*) simple Taylor rule + higher banks' exposure to government bonds (Figure 9 – dash-dot-green lines). These three experiments share the same set of calibrated and estimated parameters except for $\rho_{\sigma_{RB}}$, which is 0.86 in the second experiment; and for $\bar{B}^h/\bar{B}$, which is equal to 0.60 in the third exercise.

Table 8: Business Cycle Statistics: Model versus Data under a Simple Taylor Rule

Unconditional Volatility	Percent		Relative to Output	
	Model	Data	Model	Data
Targeted Variables				
Output	1.41	1.34	1	1
Consumption	1.52	1.50	1.08	1.12
Investment	4.64	3.87	3.29	2.88
Hours Worked	1.95	1.65	1.38	1.23
Bank Lending	2.78	3.42	1.97	2.55
Non-Targeted Variables				
Inflation	0.43	0.52	0.31	0.39
Nominal Rate	0.50	0.44	0.35	0.33
Credit Spread	3.54	0.96	2.51	0.72
Bond Spread	2.07	1.15	1.47	0.86

Note: The empirical sample period is 1997–2017. *Non-Targeted Variables* are the ones that are not included in the matching estimation. See Appendix A.1.3 and A.1.4 for data description and sources.

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