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Financial Shocks, Uncertainty Shocks, and Monetary Policy Trade-Offs

Marco Brianti
University of Alberta

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Abstract

This paper separately identifies financial and uncertainty shocks using a novel SVAR procedure and discusses their distinct monetary policy implications. The procedure relies on the qualitatively different responses of corporate cash holdings: after a financial shock, firms draw down their cash reserves as they lose access to external finance, while uncertainty shocks drive up cash holdings for precautionary reasons. Although both financial and uncertainty shocks are contractionary, my results show that the former are inflationary while the latter generate deflation. I rationalize this pattern in a New-Keynesian model: after a financial shock, firms increase prices to raise current liquidity; after an uncertainty shock, firms cut prices in response to falling demand. These distinct channels have stark monetary policy implications: conditional on uncertainty shocks, the monetary authority can potentially stabilize output and inflation at the same time, while in the case of financial shocks, the central bank can stabilize inflation only at the cost of more unstable output fluctuations.

JEL classification: E3, E31, E32, E44
Keywords: financial shocks, uncertainty shocks, SVAR, inflation, monetary policy

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†Department of Economics, University of Alberta, 8-14 Tory Building, Room 9-25 (9th floor), Canada T6G 2H4; mail: brianti@ualberta.ca; website: sites.google.com/site/marcobriantieconomics

1 Introduction

This paper shows how to separately identify two major sources of business-cycle fluctuations — financial shocks and uncertainty shocks — and what different monetary policy intervention they require. Although both financial and uncertainty shocks have contractionary effects on output, consumption, investment, and employment, my results reveal that financial shocks are associated with inflationary forces while uncertainty shocks trigger deflationary patterns. The monetary authority faces very different trade-offs: in case of uncertainty shocks, the monetary policy can potentially stabilize output and inflation at the same time; while, in case of financial shocks, the central bank can stabilize output only at the cost of more unstable inflation.

This paper provides three main contributions. First, I propose a novel structural VAR strategy that relies on the qualitatively different responses of corporate cash holdings to separately identify financial and uncertainty shocks on aggregate data. In support of the identifying assumption on corporate cash, I analyze a partial equilibrium model and provide a set of supportive evidence. Second, I identify the distinct empirical patterns associated with financial and uncertainty shocks on aggregate U.S. data. Empirical results reveal that, although both shocks have contractionary effects on key macroeconomic variables, financial shocks are associated with inflationary forces, while uncertainty shocks are related to deflationary patterns. Third, I integrate the partial equilibrium model presented above in a general equilibrium New Keynesian framework to rationalize the qualitatively different responses of inflation and conclude that the monetary authority deals with different challenges in the face of the two shocks.

To support the identifying assumption that corporate cash displays a qualitatively different response to financial and uncertainty shocks, the first part of the paper analyzes a partial equilibrium model. In this infinite-horizon model, a continuum of firms maximize the expected present value of the dividend flow by choosing cash holdings after observing aggregate shocks but before observing the idiosyncratic productivity level. In the spirit of Riddick and Whited (2009), the model features financial frictions in the form of a dilution cost that firms have to pay if they have to issue negative dividends due to low idiosyncratic productivity. In case of a financial shock, captured by a current increase in the dilution cost of issuing negative dividends, firms prefer to draw down the stock of cash in order to avoid accessing external funds. In case of an uncertainty shock, captured by an increase in the variance of future technology shocks, firms prefer to invest current resources in the stock of cash for a precautionary motive. In other words, cash holdings can be seen as an insurance that firms implicitly purchase as a protection against the risk of future cash flow shortages. After a financial shock, the implicit cost of this insurance rises and firms opt to hold less of it; after an uncertainty shock, firms attribute more value to this insurance and opt to hold more of it.

A set of reduced-form evidence supports the theoretical prediction. First, it turns out that although proxies for financial conditions (credit spread) and uncertainty (expected volatility) are highly and positively correlated with each other, corporate cash is negatively correlated with the former and positively correlated with the latter. This suggests that corporate cash can capture a source of heterogeneous variation between these two endogenous variables that is consistent with the theoretical prediction discussed above. Results hold using both aggregate and firm-level data. Second, the behavior of corporate cash during the latest recessions appears to be consistent with the identifying assumption. For instance, the 2001 Recession — featured by an exceptional financial market disruption — is associated with a pronounced fall of corporate cash. Besides, the recent Covid-19 Recession — characterized by heightened uncertainty without a proportional credit crunch thanks to assorted policy interventions — is experiencing a huge increase in the share of cash held by the non-financial corporate sector.

The second part of the paper proposes a novel econometric strategy in a structural VAR context that uses the qualitatively different responses of corporate cash as an internal instrument to uniquely identify financial and uncertainty shocks without relying on any ordering assumption. The econometric procedure can be summarized in two steps. In the first step, the econometrician identifies financial and uncertainty shocks by maximizing two objective functions simultaneously. The objective function associated with the identification of financial shocks is increasing in the impact response of a proxy for financial conditions (credit spread) and *decreasing* in the impact response of corporate cash. Importantly, the parameter δ governs the relative importance that this function gives to the response of financial conditions and of corporate cash holdings. At the same time, the objective function associated with the identification of uncertainty shocks is increasing in the impact response of a proxy for uncertainty (expected volatility) and *increasing* in the impact response of corporate cash. Importantly, the *same* parameter δ governs the relative importance that this function gives to the response of measured uncertainty and of corporate cash holdings. In the second step, the econometrician selects δ^* such that the two types of shocks identified with the maximization problems described above are orthogonal to each other. Given δ^* — which I show exists and is unique under mild assumptions — financial and uncertainty shocks are uniquely identified.

Although one could use sign restrictions as they provide valid insights about the economic effects of the two shocks (results are amply confirmed when using this approach), in this context, my identification strategy is more convenient for two reasons. First, this procedure emphasizes the idea that financial and uncertainty shocks should have the maximum effect on their endogenous counterpart (credit spread and expected volatility, respectively), using corporate cash as a control to avoid any confounding effect. Second, this procedure does not impose any sign restrictions on the responses of cash, since it actually imposes that the response of this variable should be lower after a financial shock than after an uncertainty shock. This feature allows for an additional degree of flexibility which makes the identifying assumption less restrictive.

In the third part, I employ the econometric strategy presented above on aggregate U.S. data in order to estimate the effect of the two shocks on the real economy. The baseline specification is a ten-variable VAR with the excess bond premium (Gilchrist et al., 2017), measured macroeconomic uncertainty (Jurado et al., 2015), corporate cash holdings over total assets, GDP, consumption, investment, total hours, GDP deflator, the real stock of money (M2 over GDP deflator), and the shadow federal funds rate (Wu and Xia, 2016). The impulse responses implied by the procedure show that financial and uncertainty shocks have contractionary effects on output, consumption, investment, and total hours. Meanwhile, financial shocks have a positive impact effect on GDP deflator, while uncertainty shocks have a negative and persistent effect on inflation. Finally, the federal funds rate displays a pronounced and persistent fall after an uncertainty shock and only a mild and marginally significant decrease after a financial shock.

Quantitatively, uncertainty shocks explain almost 20% of the variations in real GDP over a business-cycle frequency, while financial shocks explain about 40%. Although financial shocks appear to be a more important driver of business-cycle fluctuations, uncertainty shocks trigger a much larger effect on total hours: financial shocks explain roughly 20% of the forecast error variance of total hours, while uncertainty shocks explain almost 40%.

In addition, financial shocks explain a large size of the forecast error variance of corporate cash and little of the one of GDP deflator over a business-cycle frequency. By contrast, uncertainty shocks explain less than a fifth in the case of corporate cash but more than 20% in the case of GDP deflator.

In the last part of the paper, I integrate the partial equilibrium model presented above in a New Keynesian framework with the aim to: (i) confirm that the economic intuition on cash is robust to general equilibrium forces, (ii) rationalize the differential empirical response of inflation to financial and uncertainty shocks, and (iii) discuss monetary policy implications. The model is a standard New Keynesian model (see Gilchrist et al., 2017) augmented with good-specific habits, costly external finance, and a market for cash and liquid assets. In line with Ravn et al. (2006), the household good-specific demand depends also on an external habit stock determined by previous levels of the good-specific consumption. Firms can influence the future value of the good-specific habit stock, which operates as a customer base, by changing prices. Moreover, following the partial equilibrium model described above, all external finance takes the form of equity, and financial frictions are featured by a dilution cost that firms have to pay when issuing negative dividends. Finally, the model features a market for cash and liquid assets where households receive utility from holding cash, while firms hold cash as a device to have more financial flexibility.

The general equilibrium forces magnify the qualitatively different effects that financial and uncertainty shocks have on corporate cash holdings. In the case of financial shocks, the stochastic discount factor decreases because households expect the effects of the contraction to die out in the near future; vice versa, in case of uncertainty shocks, the same object increases because risk-averse households expect larger consumption variance in the future. As a result, after a financial shock, households are more impatient and push firms to cut corporate cash holdings in order to distribute more dividends today. Conversely, after an uncertainty shock, households are more patient and, due to a precautionary motive, put pressure on firms to increase current savings in order to receive more dividends in the future. Moreover, if we consider the effect of inflation, it turns out that inflationary (deflationary) forces create an incentive to draw down (build up) the stock of cash because, for a given nominal interest rate, the benefit of holding cash and liquid assets decreases (increases). Thus, as long as the model is consistent with the empirical results of inflationary financial shocks and deflationary uncertainty shocks, inflation is also pushing corporate cash holdings in the expected direction.

Regarding the effect of financial and uncertainty shocks on inflation, the different response mainly works through the good-specific habit that results in firms having a customer base with the short-run demand elasticity lower than the long-run demand elasticity. This implies that when firms need to generate current internal sources of finance, they have an incentive to raise prices since the benefit of generating additional revenue *today* is larger than the cost of losing customers *in future*. As a result, the response of inflation during a recession depends on two forces that move prices in two different directions: (i) the increase in the need of generating internal sources of finance that is associated with inflationary forces; and (ii) the fall in demand that is related to deflationary patterns. In the case of a financial shock, firms increase prices because they want to generate additional internal resources in order to avoid costlier external finance. Conversely, after an uncertainty shock, the need to generate current internal finance is not largely affected, while the fall in the overall demand (for the households' precautionary motive) encourages firms to cut prices. Using a large set of reasonable calibrations, simulations robustly confirm this intuition.

I conclude by using the model as a laboratory to discuss the monetary policy implications for financial and uncertainty shocks. Conditional to the latter, the positive comovement between output and inflation suggests that the monetary authority can potentially stabilize output and inflation at the same time. Conversely, the negative comovement between output and inflation after a financial shock suggests that the central bank has to deal with a non-trivial trade-off between quantities and prices. I formally analyze this intuition by running a counter-factual experiment where the monetary authority — everything else equal — is relatively more concerned about stabilizing inflation. In the case of uncertainty shocks, the further attempt to stabilize inflation implies an even further stabilization of output; while, in the case of financial shocks, the central bank stabilizes inflation only at the cost of more unstable output fluctuations.

Related literature. This paper contributes to different strands of the literature. The econometric procedure presented here relates to other papers proposing the use of internal instruments to identify structural shocks in a VAR context.[1] First, this paper is related to Faust (1998) and Uhlig (2005) that introduce the penalty function approach. I contribute to this literature by proposing an econometric strategy that uses a specific type of penalty function to disentangle two shocks that have a qualitatively different effect on an observable variable. In addition, this project is also related to a series of papers that introduce and develop sign-restriction set identification procedures such as Faust (1998); Canova and De Nicoló (2002); Peersman (2005); Uhlig (2005); Fry and Pagan (2011); and Rubio-Ramírez et al. (2010). I contribute to this literature by providing an alternative methodology that also uses qualitative assumptions to provide a unique solution to the structural VAR system without relying on any ordering assumptions.

Regarding the empirical identification of either financial or uncertainty shocks or both, this project relates to those papers, such as Bloom (2009), Basu and Bundick (2017), and Leduc and Liu (2016), that use a recursive ordering to identify the effects of uncertainty shocks on real variables. I contribute to this literature by providing empirical evidence that does not rely on recursive ordering assumptions. Moreover, this project is also related to Jurado et al. (2015) who also use the Cholesky identification but provide a more refined proxy for economic uncertainty. I contribute to this paper by disentangling from their proxy the part explained by financial shocks. Moreover, this project is related to Berger et al. (2017), who identify uncertainty shocks as second-moment news shocks on realized volatility and find that uncertainty shocks have negligible effects on real variables. I contribute to this paper by providing an alternative method, which does not rely on any zero impact restrictions, to identify uncertainty shocks. Finally, this project is also related to Ludvigson et al. (2020) who use a novel identification strategy based on a set of assumptions on the features of the estimated shock series to identify financial uncertainty shocks together with economic uncertainty shocks. They find that financial uncertainty shocks have large and adverse effects on the economy, while adverse economic uncertainty shocks have positive and significant effects on the same variables. I differ in terms of the objective since my aim is to identify financial shocks, which can possibly include second-moment financial shocks (see Section 4.2), from macroeconomic uncertainty shocks. In addition,

[1] See Stock and Watson (2018) on a comparison and discussion between external and internal instruments on structural VARs.

I use a different econometric strategy which relies on a single identifying assumption and provides a unique solution.[2]

Moreover, I am also related to those papers that show the empirical effect of financial shocks on the economy. First, Gilchrist and Zakrajšek (2012) provide two novel variables, the GZ credit spread and the excess bond premium, to proxy for time-varying financial conditions. They show that those variables have a large predictive power on real variables and explain a large portion of economic activity. I contribute to this paper by disentangling from the innovations in the excess bond premium the part explained by uncertainty shocks.[3] Moreover, Gilchrist et al. (2017) use US firm-level data to show that credit-constrained firms increased prices relatively more to their unconstrained counterparts during the Great Recession in order to boost their internal sources of finance.[4] Although my analysis uses aggregated data, I obtain similar inflationary patterns in response to financial shocks.[5] Moreover, this project is closely related to the empirical contribution by Furlanetto et al. (2019) who identify different types of financial shocks in the same VAR system. In the second part of the paper, they also disentangle credit shocks from uncertainty shocks and find that the latter ones have negligible effects on real variables. My empirical evidence differs from this last exercise for two main reasons. First, my focus is specifically on macroeconomic uncertainty shocks, while their estimated uncertainty shocks are mostly associated with financial uncertainty because they use the VIX as a proxy for uncertainty.[6] Second, my exercise aims to show the qualitative difference between financial and uncertainty shocks, while their focus is on their quantitative importance. Finally, a closely related paper that also inspired my analysis is Caldara et al. (2016). They show lower and upper bounds of the effects of financial and uncertainty shocks using the penalty function

[2] See also Carriero et al. (2018), Angelini et al. (2019), Caggiano et al. (2020), Colombo and Paccagnini (2020a), Lhuissier et al. (2016), Popp and Zhang (2016), Alessandri and Mumtaz (2019), Benati (2013) for other econometric strategies and evidence regarding the economic effects of financial uncertainty shocks, macroeconomic uncertainty shocks, and/or policy uncertainty shocks. See also Cascaldi-Garcia et al. (2020) for a survey.

[3] Related to Gilchrist and Zakrajšek (2012), see also Gambetti and Musso (2017) and Colombo and Paccagnini (2020b) for other empirical evidence on the effects of financial shocks.

[4] See also Asplund et al. (2005), de Almeida (2015), Kimura (2013), Lundin et al. (2009), and Montero and Urtasun (2014) for additional evidence supporting this result. Kim (2020), instead, provides evidence that firms facing an adverse financial shock reduce prices in the short run to liquidate inventories and generate cash flow.

[5] See also Abbate et al. (2016) for an analogous empirical result on U.S. aggregate data using a structural VAR with sign restrictions.

[6] The VIX, as shown by Ludvigson et al. (2020) and as argued at the end of Section 4.2 later on, is much more related to first- and second-moment financial shocks rather than to macroeconomic uncertainty shocks.

approach together with ordering assumptions. They find that both shocks explain a sizable fraction of output over a business-cycle frequency. My project contributes to this paper in two ways. First, my identification strategy provides point estimates within their bounds to quantify the respective effects of the two shocks on the economy. Second, I empirically find qualitatively different effects of financial and uncertainty shocks on inflation and derive the associated monetary policy implications.

Finally, the model presented here is related to those theoretical contributions that analyze the effects of either financial shocks or uncertainty shocks, or both. Regarding the effects of financial shocks, the model presented here shares many elements with the one by Gilchrist et al. (2017) that also rationalizes the inflationary patterns associated with financial shocks. I contribute to their model by adding a market for cash and liquid assets and by showing that, together with corporate cash holdings, inflation also displays qualitatively different patterns in response to financial and uncertainty shocks.[7] Regarding the theoretical effects of uncertainty shocks, this project is related to the early contribution of Bloom (2009) that proposes a model with partial irreversibility of capital to rationalize the large drop in investment after an uncertainty shock. Moreover, the model presented here is also related to Leduc and Liu (2016) and Basu and Bundick (2017) who show that in New Keynesian general equilibrium models, uncertainty shocks have the same flavor as demand shocks and generate business-cycle comovements among hours, consumption and investment.[8] I contribute to this literature by providing an analysis of the deflationary effects of uncertainty shocks together with the inflationary effects of financial shocks, and by deriving the associated monetary policy implications. Regarding theoretical contributions with both financial and uncertainty shocks, the model presented in this project is closely related to Gilchrist et al. (2014) and Alfaro et al. (2018). Both models feature financial frictions and partial irreversibilities of capital together with financial and uncertainty shocks. I contribute to this literature by emphasizing the qualitatively different effects of the two shocks.

[7] On models that analyze the effects of financial shocks, see Jermann and Quadrini (2012) for an early contribution. Moreover, see also Bacchetta et al. (2019) for a model in which corporate liquidity can be used to distinguish between credit shocks and liquidity shocks. Among other contributions, see also Christiano et al. (2010) and Khan and Thomas (2013).

[8] For theoretical models that analyze the effects of different types of uncertainty shocks see also Justiniano and Primiceri (2008), Fernández-Villaverde et al. (2011), Christiano et al. (2014), Fernández-Villaverde et al. (2015), and Bloom et al. (2018). See Fernández-Villaverde and Guerrón-Quintana (forthcoming) for a survey.

2 Identifying assumption on corporate cash holdings

This section argues that financial and uncertainty shocks have a qualitatively different impact effect on aggregate corporate cash holdings. Intuitively, corporate cash is expected to fall after a financial shock since firms use those reserves as a substitute for the costlier external finance, while the stock of corporate cash is expected to rise after an uncertainty shock for a precautionary motive. Section 2.1 formalizes this argument with a partial equilibrium model, while Section 2.2 shows some reduced-form evidence that confirms the empirical relevance of my identifying assumption.

2.1 Firm model

Firms are indexed by i and seek to maximize the expected present value of a the following dividend flow,

$$\mathbb{E}_t \left[\sum_{s=0}^{\infty} \beta^s d_{i,t+s} \right]$$

where $\beta \in (0,1)$ represents the deterministic discount factor and $d_{i,t}$ represents the dividend flow defined by the following flow-of-funds constraint

$$d_{i,t} = a_{i,t} A_t + R^x x^f_{i,t-1} + g(x^f_{i,t-1}) - x^f_{i,t} + \varphi_t \min\{0, d_{i,t}\}.$$

Variable $a_{i,t}$ is the realized level of idiosyncratic productivity which is i.i.d. across firms and over time, and has cumulative distribution function $F(\cdot)$; and A_t is the realized level of aggregate productivity which is i.i.d. over time. Variable $x^f_{i,t}$ represents end-of-period corporate cash holdings, $R^x < 1/\beta$ is the interest paid on cash saved in the previous period, and $g(\cdot)$ is a positive, increasing, and concave function which captures the benefit of the financial flexibility given by the availability of cash holdings.[9] Moreover, all external finance takes the form of equity and φ_t is a dilution cost which implies that when firms issue negative dividends $d_{i,t} < 0$, the actual flow from the issuance is reduced by

[9] As discussed in the survey by Strebulaev and Whited (2012), corporate cash holdings provide financial flexibility for near-term obligations such as payment of salaries and wages, taxes, bills for goods and services rendered by suppliers, rent, utilities, and debt services.

$\varphi_t d_{i,t}$. As argued by Riddick and Whited (2009), this simplification allows to emphasize the interaction between technology, financial frictions, and cash holdings.[10]

Firm i chooses optimal cash $x_{i,t}$ after observing productivity A_t and the other aggregate shocks, but before knowing the realized idiosyncratic productivity $a_{i,t}$. Following Kiley and Sim (2014) and Gilchrist et al. (2017), this timing assumption implies that firms are identical ex ante and the subscript i can be suppressed. There are two possible aggregate shocks: financial shocks ε_t^F which affect the dilution cost φ_t (Gilchrist et al., 2017) such that $\varphi_t = \varphi_{ss} + \varepsilon_t^F$; and uncertainty shocks ε_t^U which affect the variance σ_t^A of future aggregate technology A_{t+1} (Leduc and Liu, 2016) such that $\sigma_t^A = \sigma_{ss}^A + \varepsilon_t^U$. For simplicity I assume that there is no persistence in the exogenous processes for σ_t^A and φ_t.

The first order condition for corporate cash $x_{i,t}^f$, after invoking symmetry across i, implies

$$1 = E_t\left\{\beta\frac{\xi_{t+1}}{\xi_t}\left[R^x + g'\left(x_t^f\right)\right]\right\} \tag{1}$$

where $\xi_t = 1 + \varphi_t/(1-\varphi_t) \times F(\bar{a}_t)$ is the multiplier of the flow-of-funds constraint and $R_t^x + g'(x_t^f)$ is the future marginal benefit of holding cash. In addition, $\bar{a}_t = 1/A_t \times \left[x_t^f - x_{t-1}^f - g(x_{t-1}^f)\right]$ is the threshold for idiosyncratic productivity such that $d_t = 0$ and $F(\bar{a}_t)$ is the probability of issuing negative dividends.

Proposition 1 provides the main motivation for my empirical approach to separately identify financial and uncertainty shocks on aggregate data.

Proposition 1 *Financial shocks decrease corporate cash* x_t^f *, while uncertainty shocks increase corporate cash* x_t^f *.*

Proof. The right-hand side of Equation 1 is monotonically decreasing in a financial shock ε_t^F. The right-hand side of Equation 1 is monotonically increasing in an uncertainty shock ε_t^U. The latter statement is true because $1/A_{t+1}$ is a convex function and, due to the Jensen's inequality, the expectation of a convex function increases after a mean-preserving spread. Since the right-hand side of Equation 1 is monotonically decreasing in end-of-period cash holdings x_t^f , it must be the case that in order to satisfy the equality of Equation 1, x_t^f decreases after a financial shock ε_t^F and increases after an uncertainty shock ε_t^U. ■

[10] The simplest formulation of this type of financial frictions comes from Gomes (2001). See also Bolton et al. (2011) for a model with analogous financial frictions and corporate cash in continuous time. In addition, see the survey by Strebulaev and Whited (2012) Sections 3.2 and 3.3 for a detailed description.

The intuition of Proposition 1 comes directly from the first order condition for corporate cash (Equation 1). Note that the multiplier ξ_t disciplines the current need of internal resources and, the larger its value, the greater the incentive to generate current internal liquidity. In case of financial shocks, ξ_t rises because of the higher cost of external finance and firms prefer to draw down the stock of cash in order to avoid or limit accessing external funds. In case of uncertainty shocks, the expected value of ξ_{t+1} rises because of the additional risk of a future cash flow shortfall (due to the mean-preserving spread in future aggregate technology), and firms prefer to invest current resources in end-of-period cash for a precautionary motive. In other words, cash holdings x_t^f can be interpreted as an insurance that firms implicitly purchase *today* as a protection against the risk of cash flow shortages *tomorrow*. After a financial shock, the implicit cost of this insurance rises and firms opt to hold less of it; after an uncertainty shock, firms attribute more value to this insurance and opt to hold more of it.

2.2 Supportive Evidence

The objective of this section is to show some supportive evidence to confirm the empirical relevance of the identifying assumption on corporate cash.

Table 1 shows the correlations among aggregate corporate cash, a proxy for financial conditions, and a proxy for uncertainty across different data treatments. Following Bacchetta et al. (2019), aggregate corporate cash holdings (x_t^f) is defined as the sum of private foreign deposits, checkable deposits and currency, total time and saving deposits, and money market mutual fund shares over total assets for the non-financial corporate sector. As a proxy for financial conditions, I opt for the excess bond premium (f_t) by Gilchrist and Zakrajšek (2012) because is an aggregate measure of credit spread that controls for the expected default risk of the borrowers. Among all available proxies of uncertainty, I prefer to use the macroeconomic uncertainty (u_t) by Jurado et al. (2015) for two reasons. First, it is estimated with a stochastic volatility model which provides series orthogonal to current economic innovations. This characteristic is particularly useful to make sure that the analysis is not confounding the effect of other first-moment shocks. Second, since my identifying assumption builds on a theoretical prediction, this variable is particularly convenient because it refers to a type of uncertainty shocks on which there is large consensus on how should be featured in a model.[11]

[11] I will consider different types of uncertainty — using an a-theoretical approach — on Section 4.2.

Table 1: Correlation of corporate cash with key endogenous variables

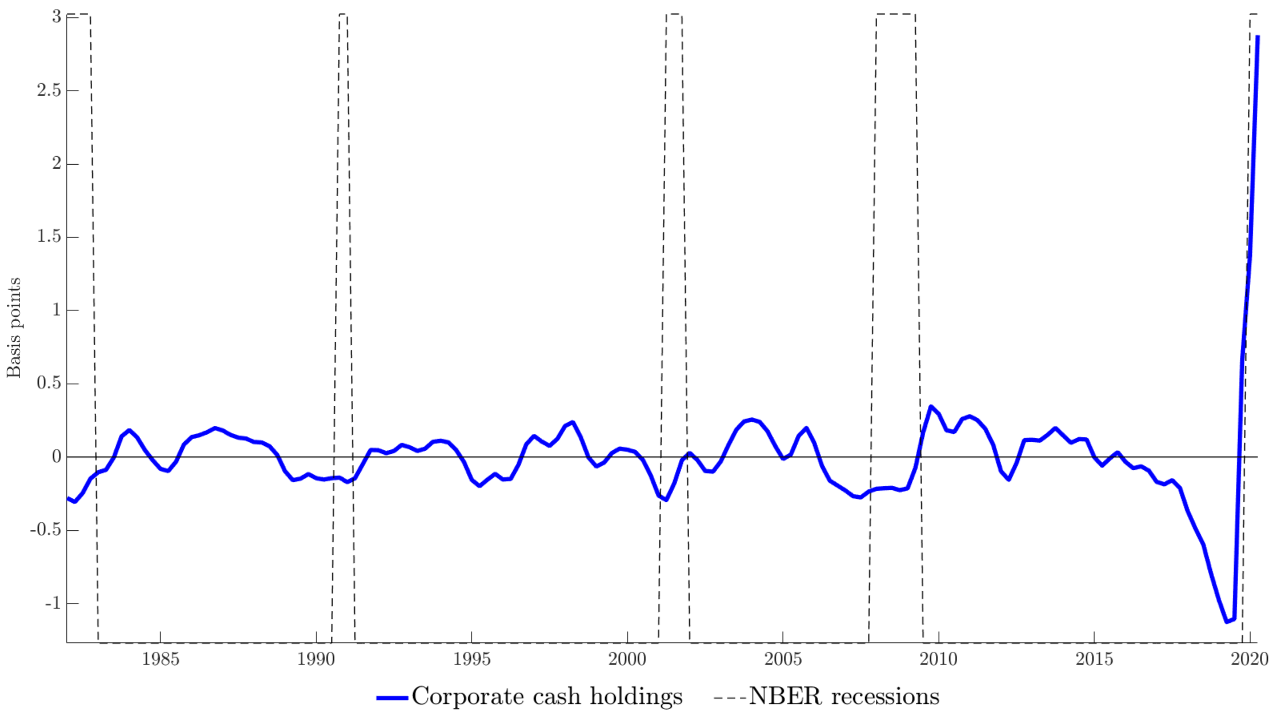
	corr(f_t,u_t)	corr(f_t,x_t^f)	corr(u_t,x_t^f)
1. Series, no trend	0.66773*** (3.7333e-19)	-0.11982 (0.16157)	0.22208*** (0.0088478)
2. Residuals, no trend	0.52594*** (4.1193e-11)	-0.12205 (0.15538)	0.4378*** (8.8008e-08)
3. Series, quadratic trend	0.70225*** (8.2501e-22)	-0.18503** (0.029806)	0.10557 (0.21785)
4. Residuals, quadratic trend	0.51463*** (1.2491e-10)	-0.14637* (0.087883)	0.42118*** (2.9749e-07)
5. Series, BP filter	0.70172*** (9.1098e-22)	-0.37708*** (5.1445e-06)	0.082759 (0.33454)
6. Residuals, BP filter	0.58332*** (7.4378e-14)	-0.25699*** (0.0024334)	0.14891** (0.08244)
7. Series, HP filter	0.73708*** (6.6106e-25)	-0.26109*** (0.0019811)	0.086978 (0.3104)
8. Residuals, HP filter	0.49685*** (6.6044e-10)	-0.16101* (0.060162)	0.42697*** (1.9602e-07)

Notes. f_t is the excess bond premium by Gilchrist and Zakrajsek (2012), u_t is macroeconomic uncertainty by Jurado et al. (2015), and x_t^f is corporate cash holdings over total assets of from the Flow of Funds. Residuals are from a three variables VAR(1) with f_t, u_t, and x_t. P-values in parenthesis and *** p<0.01, ** p<0.05, * p<0.1.

The first column displays the correlation of the excess bond premium f_t with macroeconomic uncertainty u_t. Across different data treatments, the correlation remain positive, large, and highly significant. This result is not surprising as it represents the econometric challenge of separately identifying financial and uncertainty shocks. As the exogenous processes for financial and uncertainty shocks cannot be observed, the econometrician needs to rely on the endogenous counterparts — f_t and u_t, respectively — which simultaneously jump in face of the two shocks. This implies that, without any further assumption, the econometrician cannot separately identify financial shocks and uncertainty shocks when only observing f_t and u_t.

The second and third columns display the correlations of the corporate cash x_t^f respectively with the excess bond premium f_t and the macroeconomic uncertainty u_t across different data treatments. The key result of this table is that although f_t and u_t are highly positively correlated with each other, corporate cash x_t^f captures a source of the heterogeneous variation between the two variables as it is correlated with opposite signs to f_t and u_t. In particular, as predicted by the model presented in Section 2.1, changes in the

Figure 1: Aggregate corporate cash holdings and NBER recessions



Notes. Corporate cash is defined as corporate cash over total assets of non-financial corporate firms from the Flow of Funds. Variable is de-trended with the HP filter.

excess bond premium f_t are always negatively correlated with variations in corporate cash x_t^f, and, in most of the cases, this correlation is significant. At the same time, consistent with the model, changes in macroeconomic uncertainty u_t are always positively correlated with variations in corporate cash x_t^f, and, in most of the cases, this correlation is significant. See Appendix A for cross-sectional evidence on US non-financial firms that confirms the aggregate results presented here. In the same Appendix I also discuss other existing firm-level evidence that supports the identifying assumption on the different response of corporate cash.

Moreover, Figure 1 shows the aggregate corporate cash with the aim of building a narrative on the behavior of this variable during the latest recessions. First, if we focus on the 2001 Recession we observe a pronounced fall of corporate cash. This result is in line with the theoretical prediction presented above because this recession is associated with a huge financial market disruption and should be intimately related to the presence of adverse financial shocks. In addition, focusing on the recent Covid-19 Recession, we observe a huge increase in the share of cash held by the non-financial corporate sector. Also in this case, the empirical pattern supports the identifying assumption because during the crisis there has be a spike in uncertainty without a proportional financial market disruption thanks to the prompt interventions of the Federal Reserve. Thus, the Covid-19 Recession is most likely related also to adverse uncertainty shocks without a large contraction in the credit supply, which implies that firms are actually using their external finance to build a larger stock of cash as a buffer against the uncertain evolution of the crisis. Finally, focusing on the Great Recession, we do not observe a clear pattern for the behavior of corporate cash since it is quite stable during the onset of the crisis with a moderate increase during the second part. As I will describe later on, this result is fully consistent with the empirical results because, during the Great Recession, the US economy experienced the peculiar case in which adverse financial and uncertainty shocks simultaneously hit the economy.

3 Econometric strategy

After motivating the identifying assumption, this section presents the econometric strategy and discuss its performance on simulated data from the model in Section 5. Importantly, although one could simply use sign restrictions (Section 4.2 show that results are amply confirmed when using this approach), I will argue that — at least in this context — this econometric procedure is more convenient.

3.1 Procedure

Consider a dynamic system $Y_t = [\ f_t,\ u_t,\ x_t^f,\ \dots\ ]$ where f_t is a proxy for financial conditions such as the credit spread; u_t is a proxy for macroeconomic uncertainty such as the expected forecast error variance on economic variables; and x_t^f is aggregate corporate cash holdings. Other variables can be embedded in the system without affecting the econometric procedure and the estimation is completely independent to the ordering of the variables.

The reduced-form VAR is,

$$Y_t = B(L)Y_{t-1} + i_t \tag{2}$$

where $i_t i_t' = \Sigma$ is the variance-covariance matrix of the reduced-form innovations $i_t = [\ i_t^f,\ i_t^u,\ i_t^x,\ \cdots\ ]$. The objective is to identify the structural shocks of interest (financial shocks ε_t^F and uncertainty shocks ε_t^U) from the reduced-form innovations i_t with the structural impact matrix A^*, such that $A^*\varepsilon_t = i_t$, $\varepsilon_t\varepsilon_t' = I$ and $\varepsilon_t = [\ \varepsilon_t^F,\ \varepsilon_t^U,\ \cdots\ ]$. Specifically, following the Structural VAR literature, I am assuming that the shocks ε_t are orthogonal to each others with unit variance ($\varepsilon_t\varepsilon_t' = I$).

Assume that econometricians have the following three pieces of information:

1. Adverse financial shocks ε_t^F has a positive impact effect on variable f_t, and a negative impact effect on the corporate cash x_t^f.

2. Adverse uncertainty shocks ε_t^U has a positive impact effect on variable u_t and x_t^f.

3. Other shocks have a negligible impact effect on f_t and u_t.

The first two assumptions are justified by the theoretical model and reduced-form evidence presented in Section 2. The last assumption, instead, is justified by the empirical observation that the residuals of the excess bond premium by Gilchrist and Zakrajšek (2012) and of the macroeconomic uncertainty by Jurado et al. (2015) are orthogonal to a large series of structural shocks previously identified by the literature. With this last empirical observation, financial shocks ε_t^F and uncertainty shocks ε_t^U can be directly identified without controlling for any other structural shocks in the economy. In addition, in Section 4.2 I show that the estimated shock series are orthogonal to other structural shocks previously identified by the literature implying that any ex ante control would be unnecessary. As a result, other shocks affecting the economy can be treated as residuals which can have a contemporaneous effect only on cash. Note that although is reasonable to assume that an uncertainty shock has a positive impact effect on f_t and a financial shock has a positive effect on u_t, I do not need to explicitly make this assumption but I will leave the two responses unconstrained.

With these elements in hand, I am ready to define the econometric procedure.

Definition 1 *Decompose $A^* = CD^*$ where C is the Cholesky decomposition of Σ and $D^* = [\ d_f^*,\ d_u^*,\ \cdots\ ]$ is an orthogonal matrix where:*

1. *Column vector d_f^* is the solution of the following problem,*

$$d_f^* = \textit{argmax}_{d_f}\big\{(1-\delta^*)e_1Cd_f - \delta^*e_3Cd_f \quad \textit{subject to} \quad d_f^{'}d_f = 1\big\}; \tag{3}$$

2. *Column vector d_u^* is the solution of the following problem,*

$$d_u^* = \textit{argmax}_{d_u}\left\{(1-\delta^*)e_2 C d_u + \delta^* e_3 C d_u \quad \textit{subject to} \quad d_u^{'} d_u = 1\right\}; \tag{4}$$

3. *$\delta^* \in (0,1)$ is such that $d_f^{*'} d_u^* = 0$.*

Note that e_j is a raw vector that equals the inverse of the standard deviation of reduced-form innovations i_t^j in the j-th position and zero otherwise; Cd_f and Cd_u represent the impact of a standard deviation financial shock ε_t^F and a standard deviation uncertainty shock ε_t^U, respectively; and δ^* is a scalar that takes a real value strictly between zero and one.[12]

Intuitively, in Problem 3, the impact effect of a financial shock is identified by maximizing a function that is increasing in the impact response of financial conditions f_t ($e_1 C d_f$) and *decreasing* in the impact response of cash x_t^f ($e_3 C d_f$); where the parameter δ^* governs the relative importance that this function gives to the two impact responses. Similarly, in Problem 4, the impact effect of an uncertainty shock is identified by maximizing a function that is increasing in the impact response of measured uncertainty u_t ($e_2 C d_u$) and *increasing* in the impact response of cash x_t^f ($e_3 C d_u$); where the *same* parameter δ^* governs the relative importance that this function gives to the two impact responses. In addition, note that the two conditions above are subject to the normalization $d_i^{'} d_i = 1$ since both column vectors are part of the orthogonal matrix D^*. Thus, for a given δ^*, Condition 3 imposes that ε_t^F must have a relatively large impact effect on f_t and a relatively low impact effect on x_t^f. Alternatively, for a given δ^*, the second item imposes that ε_t^U must have a relatively large effect on its endogenous counterpart u_t and on corporate cash x_t^f. Condition 3 selects a δ^* such that the two vectors d_f^* and d_u^* are orthogonal to each other as they are part of the orthogonal matrix D^*.

Together with Definition 1, I can now state the main technical result of the econometric strategy. Its formal proof is in Appendix B.

Proposition 2 *If corr$(i_t^f, i_t^u) > 0$, solution δ^*, d_f^*, and d_u^* exists.*

The proof can be explained intuitively. Consider Problems 3 and 4 as a function of a value of δ^* — say δ — that does not necessarily satisfy Condition 3. When δ is equal to

[12] Note that, in line with Uhlig (2005), given the definition of e_j, each impact response $e_j C d_k$ is already normalized for the standard deviation of reduced-form innovations i_t^j.

zero then $d_f^*(\delta = 0)$ and $d_u^*(\delta = 0)$ maximize the impact effect on f_t and u_t, respectively. In other words, $d_f^*(\delta = 0)$ and $d_u^*(\delta = 0)$ solve a Cholesky identification problem where f_t and u_t are placed on top, respectively. Since $corr(i_t^f, i_t^u) > 0$, then $d_f^*(\delta = 0)' d_u^*(\delta = 0) > 0$. Alternatively, when δ is equal to one, then $d_f^*(\delta = 1)$ and $d_u^*(\delta = 1)$ maximize the impact effect on $-x_t^f$ and x_t^f, respectively. In other words, $d_f^*(\delta = 1)$ and $d_u^*(\delta = 1)$ solve a Cholesky identification problem where $-x_t^f$ and x_t^f are placed on top, respectively. This implies, by construction, that $d_f^*(\delta = 1)' d_u^*(\delta = 1) = -1$. Invoking the continuity of solutions $d_f^*(\delta)$ and $d_u^*(\delta)$ in function of δ, it follows that also $d_f^*(\delta)' d_u^*(\delta)$ is a continuous function of δ. As a result, it must be the case that, moving from $\delta = 0$ to $\delta = 1$, function $d_f^*(\delta)' d_u^*(\delta)$ crosses the zero line at least once confirming that δ^* such that $d_f^*(\delta^*)' d_u^*(\delta^*) = 0$ does exist.

Proving uniqueness is more challenging. In Appendix C I show that under the assumption that financial conditions f_t and measure uncertainty u_t are perfectly correlated then a solution always exists and is unique. In addition, both on actual data and simulated data I have never met a single case where two δ^* exist in the same system.

Finally, in order to test the reliability of the econometric procedure, I simulate data from the model described in Section 5 and use this econometric strategy to identify financial and uncertainty shocks only using variables of which empirical counterpart can be observed in the data. Using small samples generated by a realistic calibrated version of the model, it appears that the procedure is able to recover more than 96% of the two unobservable shocks on average. See Appendix D for details and results.

3.2 Comparison with other methodologies

Since Sims (1980) the Cholesky identification has been used to identify a plethora of shocks in the literature. For example, Christiano et al. (2005) estimate monetary policy shocks as innovations to the federal funds rate which do not have a contemporaneous effect on macroeconomic variables but they have an impact effect on fast-moving variables such as the growth rate of money. Although appealing for its simplicity, no plausible recursive assumptions can be used when aiming to identify financial and uncertainty shocks. As already argued by Caldara et al. (2016), this is the case because both proxies for financial conditions and uncertainty are fast-moving variables and simultaneously respond to financial and uncertainty shocks.

A similar problem appears with the penalty function approach (Faust, 1998; Uhlig, 2005). For example Caldara et al. (2016) identify financial and uncertainty shocks maximizing a penalty function with measured uncertainty and credit spreads. Although more general than a Cholesky identification, their identification scheme still needs an ordering assumption. As a result, Caldara et al. (2016) provides upper and lower bounds of the quantitative effects of financial and uncertainty shocks conditionally on the ordering assumption.

Moreover, my identification strategy is conceptually close to sign restrictions (Faust, 1998; Canova and De Nicoló, 2002; Peersman, 2005; Uhlig, 2005; Rubio-Ramírez et al., 2010; Fry and Pagan, 2011). Although sign restrictions provide valid insights about the effects of financial and uncertainty shocks in the economy, in this context my identification strategy is more convenient mainly for two reasons. First, this novel approach identifies financial shocks (uncertainty shocks) as the ones that maximize the response of financial conditions (measured uncertainty) conditional on controlling for uncertainty shocks (financial shocks). In other words, this procedure emphasizes the idea that the two shocks should have the maximum effect on their endogenous counterpart using corporate cash as a control to avoid any confounding effect. Second, this procedure does not impose any sign restrictions on the responses of corporate cash, but it imposes that the response of this variable should be lower after a financial shock than after an uncertainty shock. For example, with this strategy the econometrician can identify the two shocks even if the response of corporate cash would be negative in face of the two shocks but relatively more negative in case of financial shocks. This feature allows for an additional degree of flexibility which makes the identifying assumption less restrictive. Besides, I also compare the effectiveness of my econometric procedure to recover the actual impulse responses with the effectiveness of sign restrictions using simulated data from the model presented in Section 5. Results suggest that — at least in this case — my identification strategy performs better than sign restrictions in recovering the true responses implied by the model. See Appendix E for details and results.

In addition, following Stock et al. (2012), a potential avenue to identify financial and uncertainty shocks is by using external instruments. As discussed by Stock and Watson (2018), with a valid instrument in hand, it is possible to obtain a consistent analysis of the shock of interest. However, as emphasized by Stock et al. (2012) and Caldara et al.

(2016), finding an instrument correlated only with financial or uncertainty shocks is not an easy task and no valid candidates have been proposed so far.[13]

Finally, Ludvigson et al. (2020) propose a strategy, known as "shock-based restrictions", that imposes quantitative and qualitative restrictions directly on the series of the estimated shocks rather than on the impulse response functions. This procedure can be an alternative tool to disentangle financial shocks and uncertainty shocks given the correct assumptions on the sign and timing of the shocks. In addition, Caggiano et al. (2020) use a similar approach where they impose (among other conditions) that around specific dates financial shocks (uncertainty shocks) explain the most of their endogenous counterpart. Although both approaches can be suitable and can be seen as complements to my procedure, the main benefit of my strategy is of being free from a set of narrative-based restrictions.

4 Financial and uncertainty shocks on U.S. aggregate data

In this section, I simultaneously identify financial and uncertainty shocks on U.S. aggregate data using the identifying assumption on aggregate cash holdings presented in Section 2 together with the econometric strategy presented in Section 3.

4.1 Baseline specification and main results

In the baseline specification I estimate a reduced-form VAR with (i) credit spread as the level of the excess bond premium (EBP) by Gilchrist and Zakrajšek (2012); (ii) measured uncertainty as macroeconomic uncertainty at a three-month horizon by Jurado et al. (2015); (iii) corporate cash holdings as the level of corporate cash over total assets from the Flow of Funds; (iv) the log-transformation of real GDP; (v) the log-transformation of real consumption defined as consumption of non-durables plus consumption of services; (vi) the log-transformation of real investment defined as consumption of durables plus domestic investment; (vii) the log-transformation of total hours as hours of all persons in the non-farm business sector; (viii) the log-transformation of the GDP deflator; (ix) the log-transformation of the stock of money M2 over the GDP deflator; and (x) the shadow federal funds rate (FFR) by Wu and Xia (2016). In order to focus on the post-Volcker era,

[13] Note that Forni et al. (2017), using the intuition that news on future outcomes have both first and second moment effects, use the square of identified news shocks as a proxy for uncertainty shocks in a VARX context. Their measure for uncertainty shocks can be interpreted as an instrument (or a proxy) which is possibly uncorrelated with financial shocks. In addition, Piffer and Podstawski (2018) identify uncertainty shocks using as an instrument the variations of gold around specific dates.

data range from the first quarter of 1982 to the second quarter of 2019 and, following the Bayesian Information Criterion (BIC), reduced-form innovations are obtained controlling for one lag of all the variables in the system.[14]

Figure 2a shows responses to a standard deviation financial shock. First, both the excess bond premium and the macroeconomic uncertainty display a positive and significant impact response. Following the identifying assumption, corporate cash falls on impact and, in about two years, returns to its steady state value. Output, consumption, investment, and hours fall in the short run returning to their steady state values in two/three years. Besides, the GDP deflator significantly jumps suggesting that financial shocks are associated with inflationary forces. Finally, in line with the response of prices, financial shocks trigger only a mild decrease in the federal fund rate that falls for only a few quarters after one year and half.

Figure 2b shows impulse responses to a standard deviation uncertainty shock. Also in this case, both the excess bond premium and measured macroeconomic uncertainty display a positive and significant impact response to an uncertainty shock, confirming the simultaneous response of those two variables to financial and uncertainty shocks. Corporate cash responds significantly on impact and displays a delayed build-up response which lasts almost five years. Analogously to financial shocks, uncertainty shocks trigger a contraction in output, consumption, investment, and hours; in case of output, consumption, and investment the effect lasts for about three years and a half, while in the case of total hours, the effect remains significant for almost five years. In addition, uncertainty shocks are robustly associated with deflationary forces — as shown by the fall in the GDP deflator — together with an increase in the real stock of money and a significant response of the monetary authority. The deflationary effect of uncertainty shocks is in line with the empir-

[14] The excess bond premium by Gilchrist and Zakrajšek (2012) is a measure of credit spread after controlling for firm-level characteristics. With this procedure they aim to provide a proxy for financial conditions orthogonal to economic fundamentals. In addition, Jurado et al. (2015) define macroeconomic uncertainty as the expected forecast error variance of more than 100 economic variables. To estimate these expected forecast error variances they use a stochastic volatility model which provides series orthogonal to current economic fundamentals. With these series they then build an index for uncertainty at different horizons. Finally, following Bacchetta et al. (2019), corporate cash holdings is defined as the sum of the level of: (i) private foreign deposits, (ii) checkable deposits and currency, (iii) total time and saving deposits and (iv) money market mutual fund shares. These variables refer to the nonfinancial corporate business sector and are divided by the total assets of the same sector. Note that the normalization over total assets is helpful to control for the potential criticism by Abel and Panageas (2020) who provide a model where the level of corporate cash may fall in response to an uncertainty shock. See Appendix F for more details on data sources.

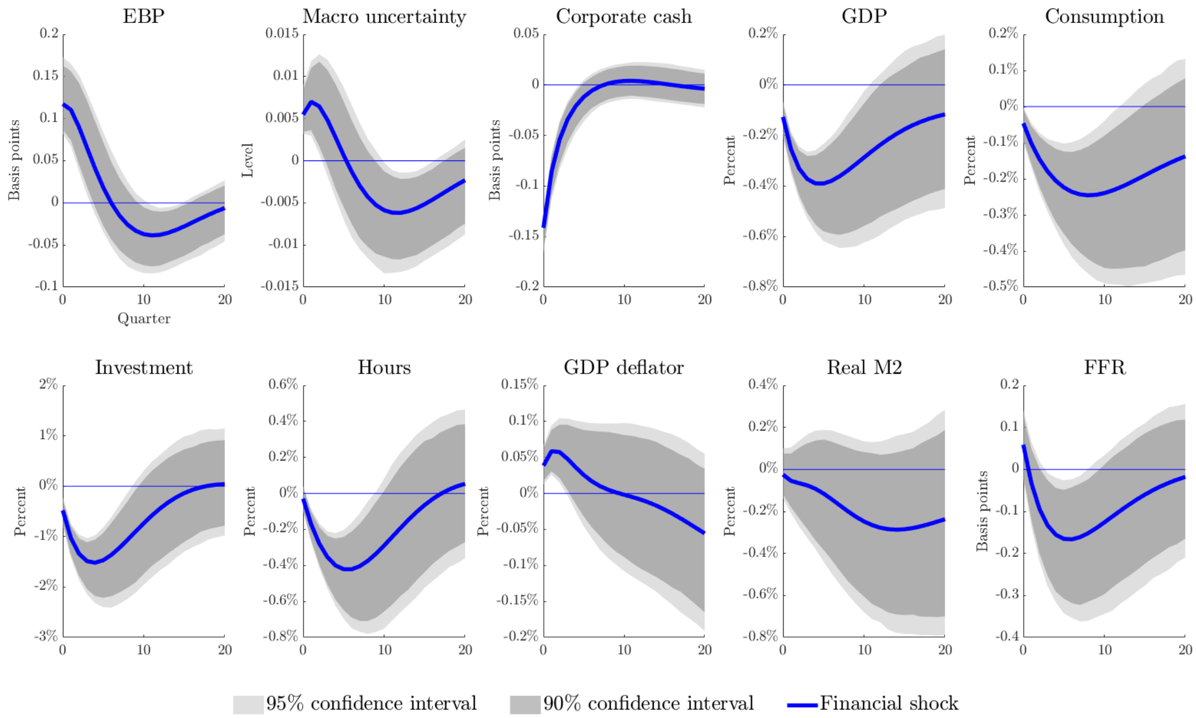
ical evidence and theoretical arguments of Leduc and Liu (2016) and Basu and Bundick (2017).

Importantly, the different response of nominal variables provides important insights on the nature of business cycle fluctuations. First, the fact that those two identified shocks display an ex post different effect on other variables confirms the hypothesis that there are two distinct forces associated with innovations in measured uncertainty and credit spreads. Second, this different response of inflation suggests that disentangling financial and uncertainty shocks may have important monetary policy implications. In Section 5 I will rationalize the different response of prices to the two shocks and discuss potential trade-offs faced by the monetary authority.

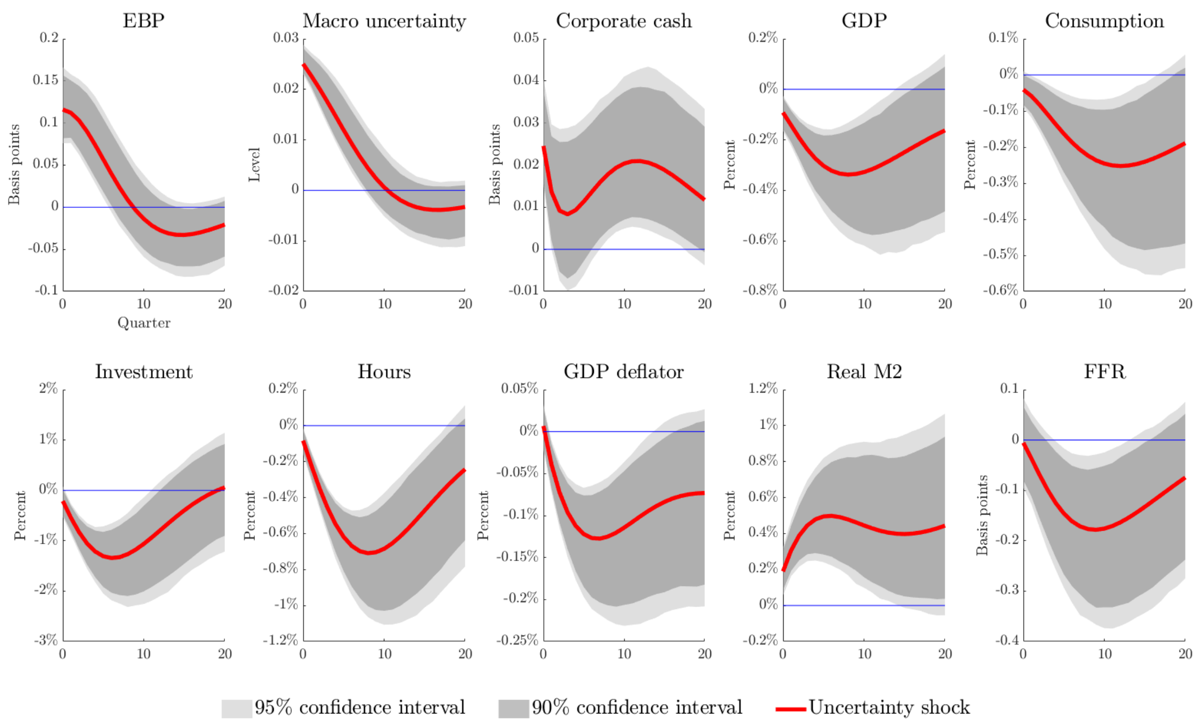
Figure 3 shows the forecast error variance of the endogenous variables in the system explained by financial shocks (blue solid lines), uncertainty shocks (red solid lines), and the two shocks together (dashed black lines). Financial shocks trigger about 25% of the unexpected fluctuations in the excess bond premium over business-cycle frequencies, and explain little of macroeconomic uncertainty. In line with the argument of the financial flexibility (see Strebulaev and Whited, 2012), corporate cash holdings seem to be mostly affected by financial shocks (about 90%) in the short run, and this effect slowly dies out over time. Financial shocks explain about 40% of real GDP over the six-quarter horizon and roughly 20%, 40%, and 20% of consumption, investment, and total hours over the same period. Finally, these shocks explain little of the GDP deflator, the real stock of money, and the shadow federal funds rate rate. In contrast, uncertainty shocks (red solid lines) trigger about 20% of the unexpected fluctuations in the excess bond premium over short-run horizons, and this effect dies out in the medium run. Macro uncertainty seems to be mostly affected by uncertainty shocks on impact (about 90%) and this large effect dies out over time. In the short run, uncertainty shocks do not have a remarkable quantitative effect on corporate cash, but this effect builds up over time reaching up to 20% in the five-year horizon. In addition, these shocks explain almost 20% of real GDP between the first and fourth year and roughly 15% of consumption and investment over the medium run. Interestingly, uncertainty shocks have a large quantitative effect (more than 40%) on total hours at business cycle frequencies. Finally, these shocks explain more than 20% of the GDP deflator and the real stock of money over business-cycle frequency, and about 15% of the shadow policy rate over a five-year horizon.

Figure 2: Estimated impulse responses on U.S. aggregate data

(a) Financial shocks

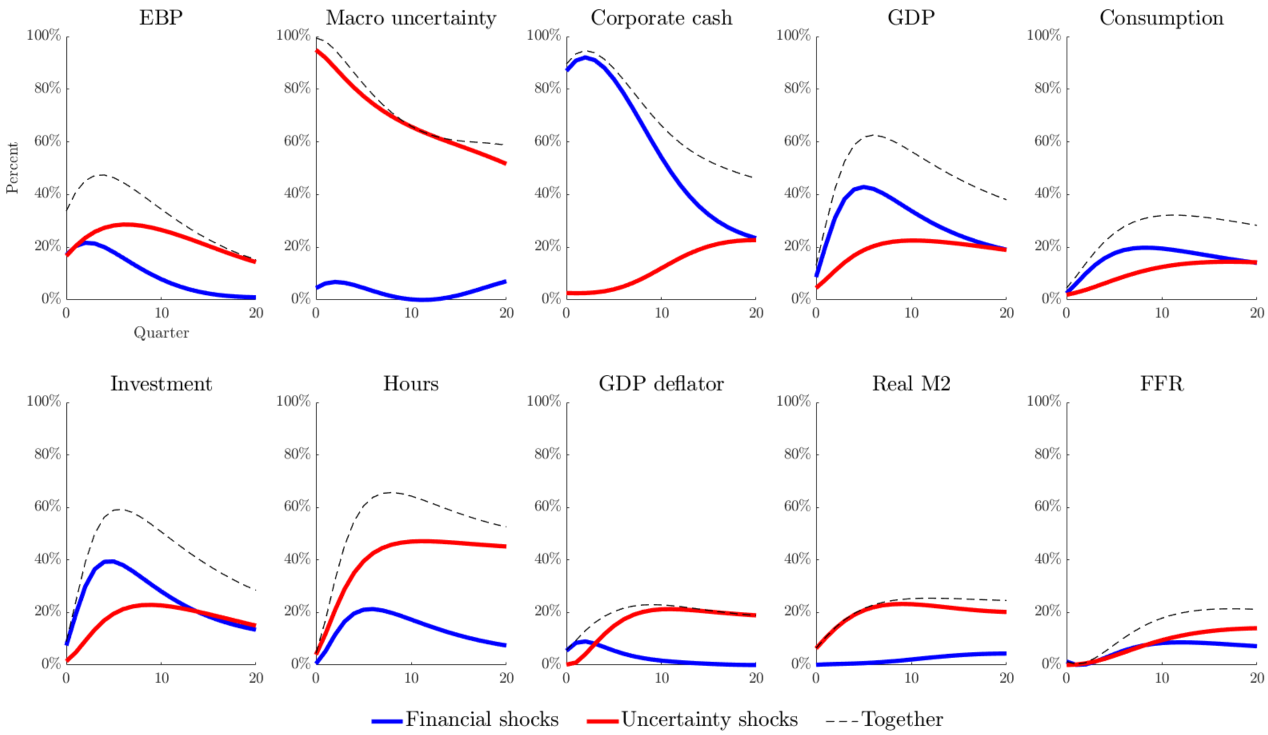


(b) Uncertainty shocks



Notes. Data range: 1982:q2-2019:q2. VAR has one lag (BIC). Confidence intervals are obtained using standard Bayesian techniques (Sims and Zha, 1999). See Appendix F for variable descriptions.

Figure 3: Estimated forecast error variance on U.S. aggregate data



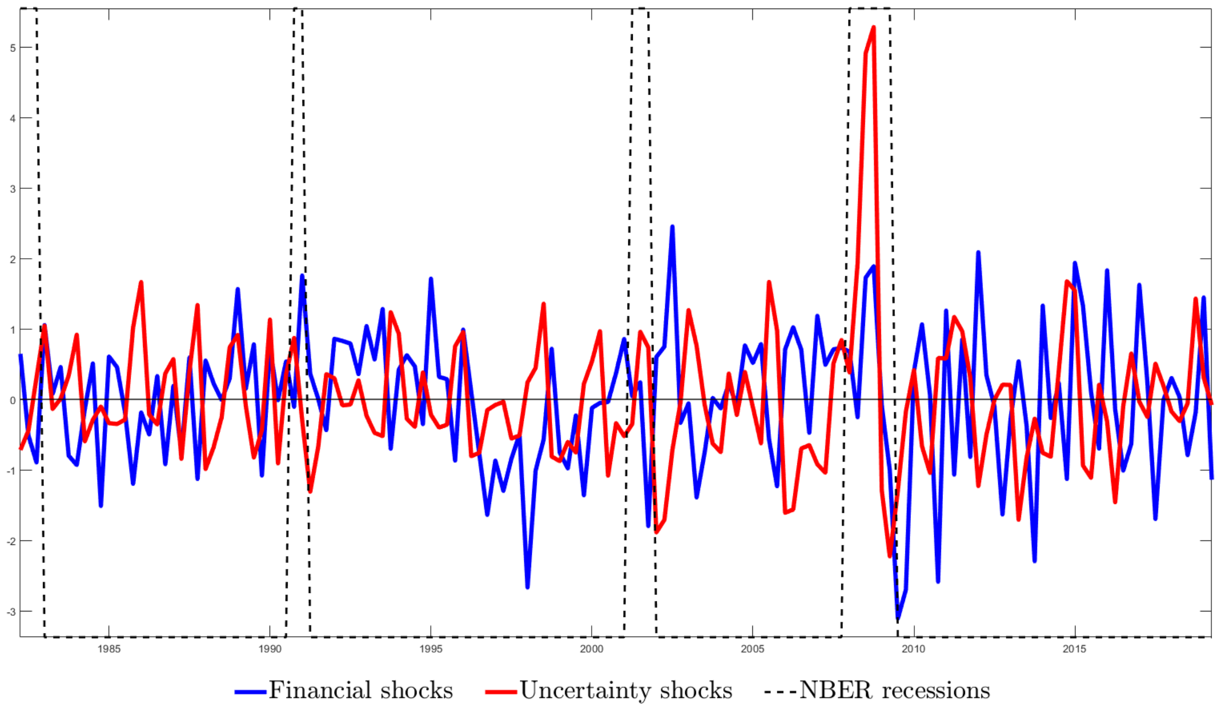
Notes. Forecast error variance estimated from baseline estimation. See Appendix F for variable descriptions.

In summary, the analysis suggests three main conclusions. First, both shocks have sizable contractionary effects on macroeconomic variables and, although financial shocks seem to be a stronger driver of business cycle fluctuations, uncertainty shocks trigger a much larger effect on total hours. Second, prices (together with the real stock of money) display qualitatively different responses to financial and uncertainty shocks making the case relevant for monetary policy implications. Third, macroeconomic uncertainty measured by Jurado et al. (2015) seems to be more exogenous than the excess bond premium by Gilchrist and Zakrajšek (2012) as shown by the forecast error variance decomposition.

4.2 Shocks series, robustness, and financial uncertainty shocks

This section has three main objectives: (i) it shows the estimated shocks series to discuss their respective roles played during major U.S. economic contractions; (ii) it presents evidence that the two identified shocks are exogenous to a set of structural shocks previously identified by the literature; (iii) it provides a set of extensions to the baseline specifica-

Figure 4: Financial and uncertainty shocks series



tion useful to inform on the robustness of the results and on the role played by financial uncertainty shocks in the U.S. economy.

Figure 4 shows the estimated shocks series on US aggregate data. There are two relevant adverse financial shocks in 1994 and 2003 as showed by the blue solid line. In addition, there are two large expansionary financial shocks before the early 2000s recession which are possibly associated with the formation of the dot-com bubble. Interestingly, in 1998 the level of inflation was slightly below the 2% confirming that a non-inflationary financial expansion was playing a relevant role during that period. Finally, at the end of 2009 and 2010, there are two large contractionary financial shocks associated with the credit crunch of the Great Recession. On the other hand, uncertainty shocks (red solid line) do not display remarkable peaks over time except for two huge spikes during the Great Recession. Thus, in line with Stock et al. (2012), both financial and uncertainty shocks played an important role during the Great Recession, and my estimation suggests that financial shocks and uncertainty shocks contributed approximately to 40% and 50% of the contraction in output experienced during this crisis, respectively.

Table 2: Correlation with other structural shocks

	Financial shocks	Uncertainty shocks	Original source
Military News	-0.096 (0.272)	-0.106 (0.225)	Ramey (2016)
Expected Tax	-0.089 (0.397)	0.030 (0.773)	Leeper et al. (2013)
Unanticipated Tax	0.170* (0.086)	-0.060 (0.548)	Mertens and Ravn (2011)
Anticipated Tax	-0.153 (0.122)	0.081 (0.415)	Mertens and Ravn (2011)
Monetary Policy	0.137 (0.174)	-0.011 (0.917)	Romer and Romer (1989)
Technology Surprise	-0.114 (0.185)	0.007 (0.933)	Basu et al. (2006)

Notes. All the shocks, with the exception of technology surprises, are available on Valerie Ramey's website. Technology surprises are estimated as residuals from an AR(1) process using utilization-adjusted total factor productivity (Basu et al., 2006) available on the San Francisco Fed website. P-values in parenthesis and *, **, *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

Table 2 displays the correlation between financial and uncertainty shocks identified from the baseline specification presented in Section 4.1 with other structural shocks. The main takeaway is that no correlations are significant at a 5% level. Nevertheless, unanticipated tax shocks (Mertens and Ravn, 2011) are correlated with financial shocks at a 10% significance level. To make sure that these shocks are not playing any role in the identification of financial shocks, as a robustness check I re-estimate the VAR system controlling for those shocks. All the results presented so far are robust to this additional control (see Table 3). These results suggest that any additional control would be unnecessary.

In Table 3 I show the correlation between the shocks identified from the baseline specification with financial and uncertainty shocks identified from a set of robustness checks and extensions. Baseline results appear to be quite robust to a series of perturbations. Specification (1) allows the number of lags to vary accordingly to the Hannan-Quinn information criterion.[15] Specifications (3) and (4) estimate a three-dimensional and a seven-dimensional VAR, respectively. Specifications (4), (5), (6), and (7) use different proxies for financial conditions. Specifications (8), (9), (10), (11) and (12) use different proxies for measured uncertainty. Moreover, Specification (13) uses an alternative definition of cash holdings, Specification (14) uses variables per capita, and Specification (15) starts in

[15] I exclude the Akaike Informartion Criterion (AIC) since it requires 8 lags: too large for the number of observations and of endogenous variables.

Table 3: Correlation with robustness checks and extensions

Specification	Robustness	Financial Shocks	Uncertainty Shocks
(1)	HQ: 2 lags	0.90	0.83
(2)	Dimension: 3 variables	0.90	0.92
(3)	Dimension: 7 variables	0.98	0.99
(4)	Credit spread: GZ	0.97	0.99
(5)	Credit spread: BAA10Y	0.93	0.98
(6)	Credit spread: FU3	0.83	0.96
(7)	Credit spread: VIX	0.85	0.95
(8)	Uncertainty: MU1	1	0.99
(9)	Uncertainty: MU12	0.99	0.96
(10)	Uncertainty: RU3	1	0.84
(11)	Uncertainty: FU3	0.94	0.53
(12)	Uncertainty: VIX	0.86	0.35
(13)	Cash: plus Treasury	0.84	0.97
(14)	Per Capita	1	1
(15)	Start: 1990Q1	0.93	0.97
(16)	Control: Tax shocks	0.98	1

Notes. Specifications (1) uses two lags to estimate reduced-form innovations following the HQ criterion. Specification (2) is a three-dimensional system with measured uncertainty, excess bond premium and corporate cash. Specification (3) is a seven-dimensional system with all the variables of the baseline except the GDP deflator, Real M2, and FFR. Specification (4), (5), (6), and (7) use the GZ spread (Gilchrist and Zakrajšek, 2012), the Moody's Baa spread at 10 years, financial uncertainty at three months (Ludvigson et al., 2020), and the VIX as a proxy for financial conditions, respectively. Specifications (8), (9), (10), (11) and (12) use one-month macroeconomic uncertainty (Jurado et al., 2015), 12-months macroeconomic uncertainty (Jurado et al., 2015), three-month real uncertainty (Jurado et al., 2015), three-month financial uncertainty (Ludvigson et al., 2020), and the VIX as a proxy for measured uncertainty, respectively. Specification (13) adds to the definition of corporate cash holdings also the level of treasury securities for the nonfinancial corporate sector. Specification (14) uses the log of GDP, consumption, investment and hours per capita. Specification (15) starts in the first quarter of 1990 and Specification (16) controls for the unanticipated tax shocks (Mertens and Ravn, 2011).

the first quarter of 1990. See notes in Table 3 for additional details. Finally, Specification (16) controls for the unanticipated tax shocks by Mertens and Ravn (2011).[16]

In most cases there is little to learn except the fact that results are not particularly affected by the perturbations listed above. Nevertheless, it is important to highlight results in Specification (7) and Specification (12). Following Bloom (2009), Specification (12) uses the VIX as a proxy for macroeconomic uncertainty. In this case, uncertainty shocks remain correlated with their baseline counterpart only at 35% while financial shocks barely change. Even if not shown, those estimated uncertainty shocks trigger no significant effects on real variables and, consequently, do not explain any of the variations in output, consumption, investment and hours. On the other hand, in Specification (7) I use the VIX

[16] Empirical impulse response functions are available upon request.

as a proxy for financial conditions instead of the credit spread. In this case, both estimated shocks remain highly correlated with their baseline counterpart. In particular, in the case of financial shocks the correlation with its baseline counterpart is 85%.

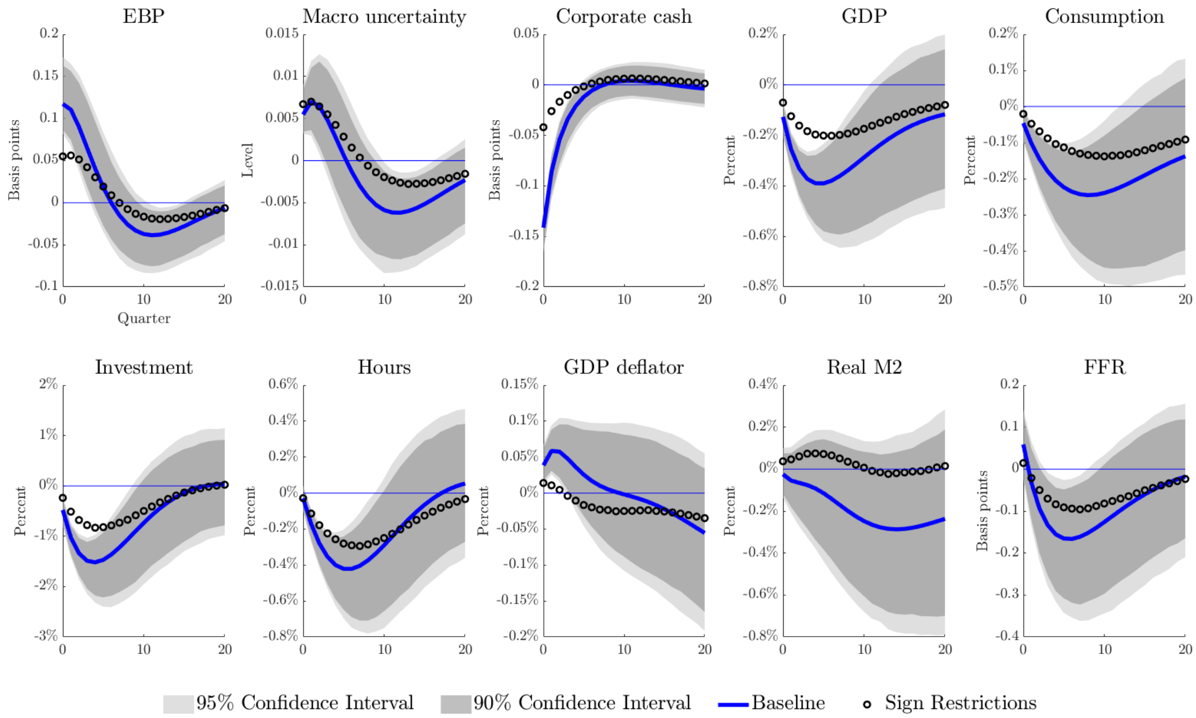
This result suggests two conclusions. First, the VIX is not a proper substitute for measured macroeconomic uncertainty because its innovations (see also Ludvigson et al., 2020) are mostly related to uncertainty concerning financial conditions. Second, the VIX is a legitimate substitute for the credit spread because also second-moment financial shocks have a negative effect on corporate cash holdings. As a result financial shocks as estimated by my identification strategy are broadly defined financial shocks which potentially capture a mix between first- and second-moment shocks within the financial sector. This conclusion is also supported by Specifications (6) and (11) where I use financial uncertainty by Ludvigson et al. (2020) as a proxy for financial conditions and economic uncertainty, respectively. Financial uncertainty works much better as a proxy for financial conditions — financial shocks remain correlated up to 83% — rather than as a proxy for macroeconomic uncertainty — uncertainty shocks remain correlated only at 53%.

This result can be rationalized with a risk-averse financial intermediary that, observing a larger level of financial uncertainty, decreases the supply of loans and increases the cost of borrowing. Although the model presented in Section 5 is way too simple to capture this idea, micro-founding financial frictions with the presence of a risk-averse financial intermediary can rationalize the fact that financial shocks and financial uncertainty shocks affect the economy through an analogous mechanism. Although possibly interesting, the objective of analyzing and separately identifying financial first-moment shocks and financial second-moment shocks is beyond the aim of this project.

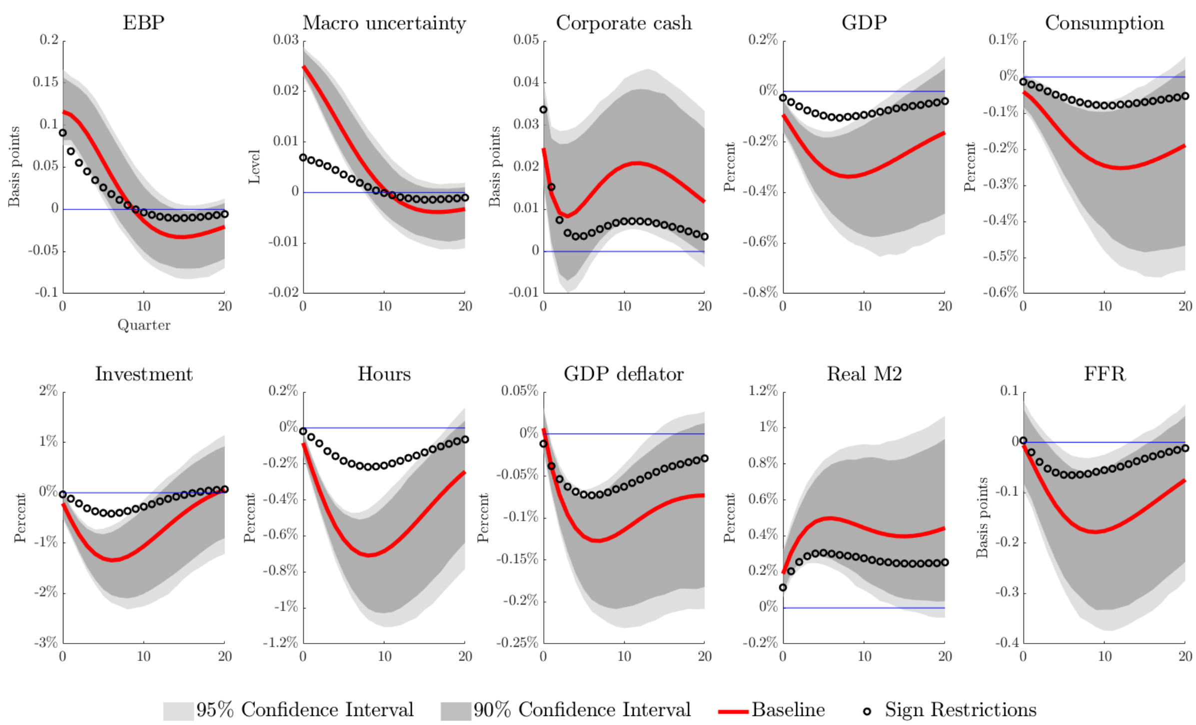
Finally, Figures 5a and 5b show the impulse responses respectively to a financial and an uncertainty shock estimated using sign restrictions together with the baseline specification. The black circles represent the median responses from the set of solutions that satisfies the same identifying assumptions used in the baseline specification. Also in this case, results are not particularly affected by the estimation procedure and the sign-restricted responses almost always lie within the confidence intervals of the baseline specification. In particular, it is important to highlight that the qualitatively different response of prices does not depend on the estimation procedure since the GDP deflator displays a positive (negative) response to a financial (uncertainty) shock also with sign restrictions.

Figure 5: Estimated impulse responses on U.S. aggregate data

(a) Financial shocks



(b) Uncertainty shocks



Notes. Data range: 1982:q2-2019:q2. VAR has one lag (BIC). Robustness check using sign restrictions as an identification procedure.

Besides, there is one difference that it is worth highlighting to better understand the specific features of the two identification procedures. The response of the endogenous counterpart to the respective shock is undoubtedly smaller when the shocks are estimated with sign restrictions: in response to a financial (uncertainty) shock, the response of the excess bond premium (macroeconomic uncertainty) is significantly lower compared to the baseline counterparts. This difference reflects the fact that sign restrictions are not meant to maximize any impact response, while my identification procedure identifies financial and uncertainty shocks as the ones that respectively maximize the response on their endogenous counterparts with the response of cash to be different enough such that the two shocks are going to be orthogonal to each other. Although it is reassuring that a more conventional approach as sign restrictions delivers qualitatively analogous results, I believe that my econometric procedure remains more appropriate for this empirical exercise since financial and uncertainty shocks are naturally expected to have a large effect on credit spread and measured uncertainty, respectively.

5 Theory

In this section I integrate the partial equilibrium model presented into Section 2.1 in a general equilibrium framework with nominal frictions (Rotemberg, 1982) and households with good-specific habits (Ravn et al., 2006; Gilchrist et al., 2017). The model presented in this section has three main objectives: (i) confirming that the economic intuition presented in Section 2.1 is robust to allowing for general equilibrium forces; (ii) rationalizing the different empirical response of inflation to financial and uncertainty shocks shown in Section 4; and (iii) deriving monetary policy implications.

5.1 Model description

The economy is populated by (i) a continuum of utility-maximizing households that choose the habit-adjusted consumption bundle q_t, leisure $1 - n_t$, cash holdings (and/or liquid assets) X_t^h, and risk-free bonds B_t^h; (ii) a continuum of value-maximizing firms $i \in [0, 1]$ that make pricing and production decisions in order to maximize the present discount value of dividends; (iii) and a monetary authority that sets the nominal risk-free rate R_t and affects the nominal stock of cash in the economy $\bar{X}_t$.

5.1.1 Households

The model contains a continuum of identical households that consumes a variety of consumption goods indexed by $i \in [0, 1]$. The preferences of households are defined over a habit-adjusted consumption bundle q_t, leisure $1 - n_t$, and beginning-of-period real cash holdings $x^h_{t-1} = X^h_{t-1}/P_{t-1}$ as follows

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left[\frac{(q_{t+s})^{1-\gamma_q}}{1-\gamma_q} + \chi_n \log(1 - n_{t+s}) + \chi_x \log(x^h_{t-1}) \right]; \quad 0 < \beta < 1.$$

where X^h_{t-1} is the nominal stock of cash held at the beginning of the period and P_t is the aggregate price index. Following Gilchrist et al. (2017), the habit consumption aggregator is defined as

$$q_t \equiv \left[\int_0^1 \left(\frac{c_{i,t}}{s^{\theta}_{i,t-1}} \right)^{1-\frac{1}{\eta}} di \right]^{\frac{1}{1-\frac{1}{\eta}}}; \quad \theta < 0 \quad \text{and} \quad \eta > 0$$

where $c_{i,t}$ denotes the amount of a good of variety i consumed by the representative household at time t and $s_{i,t}$ is the external habit stock associated with good i. The law of motion of external habit is $s_{i,t} = \rho_s s_{i,t-1} + (1-\rho)c_{i,t}$ with $0 < \rho < 1$. Parameters θ and η govern the intensity of the good-specific habit and the elasticity of substitution across differentiated goods, respectively. The cost-minimization problem solved by the household gives rise to a good-specific demand (see Appendix G.1 for derivations) which is going to be relevant in the firms' maximization problem presented in the following section.

In addition, the household maximizes the present value of utility subject to the following budget constraint

$$\tilde{p}_t q_t + \frac{B_t}{P_t} + \frac{X^h_t}{P_t} = w_t n_t + R_{t-1}\frac{B_{t-1}}{P_t} + R^x_{t-1}\frac{X^h_{t-1}}{P_t} + \tau_t.$$

Note that the budget constraint is expressed in real terms since $\tilde{p}_t q_t$ is the cost of the consumption bundle over the aggregate price index P_t. In addition, $w_t = W_t/P_t$ is the real wage, R_{t-1} is the nominal interest rate, set by the monetary authority, on previous period risk-free bonds B_{t-1}, R^x_{t-1} is the nominal interest rate on previous period cash and liquid assets X^h_{t-1}, and τ_t represents a series of real transfers that in every period the central authority and the firms make to the households. Optimality conditions, formally derived in Appendix G.2, give rise to the inter-temporal Euler equation for risk-free bonds, the labor supply, and the demand of real cash and liquid assets x_t^h. The two former optimality conditions are standard, while the latter takes the following form,

$$x_t^h = \beta \chi_x \frac{R_t}{R_t - R_t^x} \lambda_t^{-1}.$$

Intuitively, the demand for cash is increasing in χ_x and R_t^x which represent the taste for and the interest rate on cash and liquid assets, respectively. In addition, x_t^h is decreasing in R_t, interest on risk-free bonds, due to a substitution effect, and decreasing in λ_t, the multiplier of the budget constraint, due to a wealth effect.

5.1.2 Firms

Firms' problem coincides with the partial equilibrium model presented in Section 2.1 properly augmented with pricing and production decisions. Firms' side is characterized by a continuum of monopolistically competitive firms $i \in [0, 1]$ producing a differentiated variety of goods with the following production function:

$$y_{i,t} = \left(\frac{A_t}{a_{i,t}} n_{i,t} \right)^{\alpha} - \phi; \quad 0 < \alpha \leq 1 \text{ and } \phi > 0. \tag{5}$$

As before, A_t is aggregate productivity and $a_{i,t}$ is the idiosyncratic productivity level, which follows the log-normal distribution $\log a_{i,t} \sim N(-0.5\sigma_a^2, \sigma_a^2)$. In addition, parameter α governs the degree of decreasing returns of labor input $n_{i,t}$ and ϕ is a common fixed cost of production.

Following Kiley and Sim (2014) and Gilchrist et al. (2017), firms make pricing $p_{i,t} = P_{i,t}/P_t$, production $y_{i,t}$, and saving (corporate cash and liquid assets) $x_{i,t}^f = X_{i,t}^f / P_t$ decisions after observing aggregate shocks but before observing idiosyncratic productivity $a_{i,t}$. After committing to those decisions, idiosyncratic productivity $a_{i,t}$ is revealed and firms hire labor $n_{i,t}$ to meet demand $c_{i,t}$ such that $y_{i,t} = c_{i,t}$. Analogously to the model presented in Section 2.1, the value of $a_{i,t}$ can be such that (real) dividends $d_{i,t}$ are strictly less than zero and, in this case, firm i faces the dilution cost φ_t which implies that the actual flow from the issuance is reduced by $\varphi_t d_{i,t}$. This timing convention — together with the assumption of $a_{i,t}$ to be i.i.d. across firms and over time — implies that firms are always identical at the beginning of the period and that dividends $d_{i,t}$ and labor input $n_{i,t}$ are functions of the idiosyncratic level $a_{i,t}$.

Analogously to the definition of dividends in Section 2.1, the flow-of-funds constraint is

$$\begin{aligned} d_{i,t} = p_{i,t}c_{i,t} - w_t n_{i,t} - \frac{\gamma_p}{2}\left(\pi_t \frac{p_{i,t}}{p_{i,t-1}} - \pi_{ss}\right)^2 c_t \\ + \frac{R^x_{t-1}}{\pi_t} x^f_{i,t-1} + g(x^f_{i,t-1}/\pi_t) - x^f_{i,t} + \varphi_t \min\{0, d_{i,t}\}. \end{aligned} \tag{6}$$

Relatively to its partial equilibrium counterpart, Equation 6 is augmented with pricing $p_{i,t}$, production $c_{i,t} = y_{i,t}$, and input $n_{i,t}$ decisions, together with nominal rigidities à la Rotemberg (1982). In addition, $\pi_t = P_t/P_{t-1}$ is current inflation, R^x_{t-1} is the nominal interest rate on previous period cash and liquid assets, and $g(\cdot)$ is a positive, increasing, and concave function which captures the benefits of the financial flexibility associated with the stock of cash.

The firm's objective is to maximize the expected present value of dividends,

$$\max_{d_{i,t}, n_{i,t}, c_{i,t}, s_{i,t}, p_{i,t}} \mathbb{E}_0 \left[\sum_{t=0}^{\infty} m_t d_{i,t}\right],$$

where m_{t+1} represents the stochastic discount factor set by the households, subject to: (i) the production function presented in Equation 5; (ii) the flow-of-funds constraint presented in Equation 6; (iii) habit-augmented good-specific demand:

$$c_{i,t} = \left(\frac{p_{i,t}}{\tilde{p}_t}\right)^{-\eta} s_{i,t-1}^{\theta(1-\eta)} q_t;$$

and (iv) the law of motion of the habit stock $s_{i,t} = \rho s_{i,t-1} + (1-\rho)c_{i,t}$. See Appendix G.3 for derivations and optimality conditions.

5.1.3 Closing the model

I assume that the supply of nominal cash and liquid assets $\bar{X}_t$ is defined as follows

$$\bar{X}_t = (\bar{X}_{t-1})^{\omega_x} \left[\bar{x}_{ss} P_t \left(\frac{R^x_{ss}}{R^x_t}\right)^{\omega_r}\right]^{1-\omega_x}$$

where $\bar{x}_{ss}$ and R^x_{ss} represents the amount of and the interest rate on cash and liquid assets in steady state, respectively. In addition, parameters $\omega_x \in [0,1]$ and $\omega_r > 0$ govern the degree of persistence of cash and liquid assets, and the elasticity of $\bar{X}_t$ to its interest rate R^x_t, respectively. As a result, the real supply of cash and liquid assets $\bar{x}_t = \bar{X}_t/P_t$ can be expressed as follows,

$$\bar{x}_t = \left(\frac{\bar{x}_{t-1}}{\pi_t}\right)^{\omega_x} \left[\bar{x}_{ss}\left(\frac{R^x_{ss}}{R^x_t}\right)^{\omega_r}\right]^{1-\omega_x}. \tag{7}$$

Note that the real stock of cash has the consistent features to be a decreasing function of inflation π_t and of the nominal interest rate R^x_t. Moreover, if $\omega_x = \omega_r = 0$, then the real stock of liquid assets is perfectly inelastic and always equal to $\bar{x}_{ss}$; while if $\omega_x = 0$ and ω_r approaches infinity, then the real stock of money is perfectly inelastic and $R^x_t = R^x_{ss}$. In Section 5.4 I show that all the results are robust to any combinations of parameters ω_x and ω_r. Given the supply of cash, the market clearing that pins down R^x_t is,

$$\bar{x}_t = x^f_t + x^h_t,$$

where the left-hand side and the right-hand side represent the economy-wide supply and demand of cash and liquid assets, respectively.

The monetary authority set the nominal interest rate R_t following a standard Taylor rule,

$$R_t = R^{\rho_r}_{t-1}\left[R_{ss}\left(\frac{\pi_t}{\pi_{ss}}\right)^{\psi_\pi}\left(\frac{y_t}{y_{ss}}\right)^{\psi_y}\right]^{1-\rho_r}.$$

where R_{ss}, π_{ss}, and y_{ss} represent the steady state values of nominal interest rate R_t, inflation π_t, and output y_t, respectively. In addition, parameters ρ_r, ψ_π, and ψ_y govern the degrees of the policy inertia, inflation response, and output response, respectively.

In addition, I assume that the frictional costs of negative equity issuance and price adjustments, and all the benefits and costs associated with cash holdings are paid back to the households together with dividends d_t such that the resource constraint boils down to

$$c_t = y_t.$$

Finally, analogously to the partial equilibrium model presented in Section 2.1, an adverse financial shock is an unexpected increase in the dilution cost φ_t, and an uncertainty shock is a second-moment shock to future aggregate productivity A_{t+1}. The respective laws of motions of the exogenous processes are,

$$\log(\varphi_t/\varphi_{ss}) = \rho_F \log(\varphi_{t-1}/\varphi_{ss}) + \sigma^F \varepsilon_t^F,$$

$$\log(A_t) = \rho_A \log(A_{t-1}) + \sigma_{t-1}^A \varepsilon_t^A,$$

$$\log(\sigma_t^A/\sigma^A) = \rho_U \log(\sigma_{t-1}^A/\sigma^A) + \sigma^U \varepsilon_t^U,$$

where ε_t^F, ε_t^A, and ε_t^U are a financial shock, a technology shock, and an uncertainty shock, respectively. In addition, ρ_F, ρ_A, and ρ_U govern the persistence of the three processes, and σ^F, σ^A, and σ^U represent the variance of the three shocks.

5.2 Dynamics of corporate cash and inflation

Analogously to the partial equilibrium model presented in Section 2.1, the first order condition for corporate cash holdings is

$$1 = \mathbb{E}_t \left\{ \frac{m_{t+1}}{\pi_{t+1}} \frac{\xi_{t+1}}{\xi_t} \left[R_t^x + g'(x_t^f) \right] \right\}, \tag{8}$$

where ξ_t is the multiplier associated with the flow-of-funds constraint, and $R_t^x + g'(x_t^f)$ is the marginal benefit of holding cash at time $t+1$. Equation 8 mirrors Equation 1 with the only difference that the deterministic discount factor β is now substituted by m_{t+1}/π_{t+1} which is the stochastic discount factor divided by future inflation. This implies that the partial equilibrium intuition of cash holdings x_t^f as an insurance against the future risk of cash flow shortages is still in place. In particular, after a financial shock, the implicit cost of purchasing this insurance rises ($\uparrow \xi_t$) and firms opt for holding less of it, while, after an uncertainty shock, firms appreciate this insurance more ($\uparrow \xi_{t+1}$) and opt for holding more of it.

At this stage, it is more interesting to evaluate how general equilibrium forces affect firms' saving decisions after the two shocks. By replacing β with the stochastic discount factor m_{t+1} at the numerator and π_{t+1} at the denominator, I need to address how those two variables separately affect the right-hand side of Equation 8. In case of financial shocks, the stochastic discount factor decreases because households expect the effects of the contraction to die out in the near future; viceversa, in case of uncertainty shocks, the same variable increases due to the Jensen's inequality because households expect larger consumption variance in future. Thus, after a financial shock, households are more impatient and push firms to decrease savings, i.e. cutting corporate cash holdings, and distribute more dividends today. Conversely, after an uncertainty shock, households are more patient and push firms to increase savings in order to receive larger dividends in future for a precautionary motive.

Moreover, consistent with the empirical results, let's consider the case where financial shocks are inflationary and uncertainty shocks are deflationary (I will explain why it is the case later on in this section). In the case of a financial shock, inflation is above its steady state level and the benefit of holding cash is now lower because, for a given interest rate R_t^x, the future purchasing power of cash is falling. As a result, firms have an additional incentive to draw down the stock of cash holdings in case of financial shocks. On the other hand, in the case of an uncertainty shock, inflation is below its steady state level and the benefit of holding cash is now higher because, given R_t^x, the purchasing power of cash is raising. Thus, uncertainty shocks push firms to invest on cash over this additional channel.[17] In addition, since the real supply of cash $\bar{x}_t$ is decreasing (increasing) after a financial (uncertainty) shock (see Equation 7), the fact that also households want to decrease (increase) cash holdings for an analogous reason does not particularly affect the analysis described here.[18]

To understand why inflation has a qualitatively different response to financial and uncertainty shocks, let's focus on the optimality condition (after aggregation) for prices $p_{i,t}$:

$$\gamma_p\big(\pi_t - \pi_{ss}\big)\pi_t = \mathbb{E}_t\left[m_{t+1}\frac{\xi_{t+1}}{\xi_t}\gamma_p\big(\pi_{t+1} - \pi_{ss}\big)\pi_{t+1}\frac{c_{t+1}}{c_t}\right] - \eta\frac{\nu_t}{\xi_t} = 0,$$

that, as a first order approximation, leads to

$$\hat{\pi}_t = \beta\,\mathbb{E}_t\left[\hat{\pi}_{t+1}\right] + \tilde{\eta}(\hat{\xi}_t - \hat{\nu}_t) \tag{9}$$

where $\tilde{\eta} > 0$, ξ_t is the multiplier associated with the flow-of-funds constraint, and ν_t is the multiplier associated with the good-specific demand (see Appendices G.3 and G.4 for de-

[17] Note that this theoretical argument is in line with the empirical evidence by Curtis et al. (2017).

[18] From the optimality condition presented in Appendix G.2, households have analogous incentives on cash holdings when inflation is deviating from its steady state level. If the real stock of cash $\bar{x}_t$ would be constant, then the argument described in this paragraph would survive only if those incentives were stronger for the firms than for the household. Nevertheless, since the real stock of cash $\bar{x}_t$ is moving in the desired direction (see Equation 7), this issue is not in place. In addition, as shown in Section 5.4, even if the real stock of cash is constant and equal to $\bar{x}_{ss}$ — which implies that this channel is potentially neutralized — the direction of corporate cash holdings after financial and uncertainty shocks is robustly preserved.

tails). As already explained by Gilchrist et al. (2017), $\hat{\xi}_t$ has an inflationary effect because, given a larger need of internal resources ($\uparrow \xi_t$), firms' best response is to increase prices to generate additional liquidity from the customer base associated with the good-specific habit. In addition, $\hat{\nu}_t$ is an inverse function of the output gap and the larger is a contraction ($\downarrow y_t$), the lower is the good-specific demand ($\downarrow c_{i,t}$), and the larger the incentive to decrease prices ($\uparrow \nu_t$).

As a result, given future inflation expectations $\mathbb{E}_t[\pi_{t+1}]$, the response of inflation π_t to financial and uncertainty shocks depends on the response of $\hat{\xi}_t$ relative to $\hat{\nu}_t$. Intuitively, after a financial shock, the higher cost of external finance increases the need to generate current internal liquidity ($\uparrow \xi_t$) relatively more than the fall in demand ($\uparrow \nu_t$), and firms would rather increase prices to avoid costly external finance. On the other hand, after an uncertainty shock, the need to generate current internal liquidity is not largely affected (since φ_t is unchanged, ξ_t is relatively stable), while the fall in demand ($\uparrow \nu_t$) for a precautionary motive encourages firms to cut prices. In addition, the fall in prices in response to an uncertainty shock has an inter-temporal effect which is more concealed and related to a precautionary motive. If firms decrease prices today, the good-specific demand and the stock of good-specific habit are increasing more (or decreasing less), which implies a larger increase (or smaller decrease) of the future customer base. Thus, after an uncertainty shock, firms are encouraged to cut prices also to increase the future customer base (which guarantees more future profits) for a precautionary motive against the heightened uncertainty.

5.3 Calibration and model simulations

In this section, I numerically solve the model in order to see if the economic intuitions described above hold for a set of reasonable parameterizations. Following Fernández-Villaverde et al. (2011) I solve the model to a third-order approximation of the policy functions in order to estimate the independent effect of a second-moment shock.[19] Moreover, following Basu and Bundick (2017) I analyze traditional impulse response functions in percent deviation from the stochastic steady state of the model. To obtain these responses, I set the exogenous shocks to zero and iterate the third-order solution forward

[19] I use the Dynare software package developed by Adjemian et al. (2011) to solve and simulate the baseline model.

until the model converges to a fixed point, i.e., the stochastic steady state.[20] Then, I hit the economy with a one standard deviation financial shock ε_t^F or uncertainty shock ε_t^U under the assumption that the economy is hit by no other shocks. I compute the impulse response functions as the percent deviation between the obtained responses and the stochastic steady state.

I calibrate the model to a quarterly frequency using steady-state relation on U.S. data or results from previous studies. In the baseline parameterization, I set β in order to match a 3% annual interest yield on bonds. The inverse of households' inter-temporal elasticity of substitution γ_q is equal to one, which implies log-utility in consumption. The multiplicative parameter in leisure χ_n is such that percentage of hours worked in steady state is equal to 0.3 while the multiplicative parameter in household cash holdings χ_x is such that the interest rate on cash and liquid assets R_t^s in steady state is equal to one. The good-specific habit parameter θ, the elasticity of substitution across differentiated goods η, and the persistence of the habit stock ρ_s are -0.8 (Ravn et al., 2006; Gilchrist et al., 2017), 0.95 (Gilchrist et al., 2017), and 2 (Broda and Weinstein, 2006; Gilchrist et al., 2017), respectively. Following Gilchrist et al. (2017), the decreasing return to scale parameter α, the fixed cost of production ϕ, and the variance of the distribution of idiosyncratic productivity σ_a^2 are equal to 0.8, 0.3, and 0.05, respectively. The parameter that governs the cost of price adjustment γ_p is equal to 10, which is in the range suggested by Ravn et al. (2006). The parameters ζ_x of the financial flexibility function of cash $g(x) = \zeta_x x^{1-\iota_x}/(1-\iota_x)$ is calibrated to match the empirical average of corporate cash holdings over total cash in the whole economy, while the parameter $\iota_x \in (0,1)$ is set equal to 0.5. The total amount of cash in steady state $\bar{x}_{ss}$ is calibrated to match the average empirical value of total cash over output. In the baseline calibration, persistence of total cash $\omega_x \in [0,1]$ and its elasticity to the related interest rate $\omega_r \geq 0$ are set equal to 0.5 and 1. In line with the standard New Keynesian literature, the monetary policy inertia ρ_r, the Taylor rule parameter on the inflation gap ψ_π, and the Taylor rule parameter on the output gap ψ_y are respectively 0.75, 2, and zero. Following Leduc and Liu (2016), persistence of technology shocks ρ_A is equal to 0.95; and, for a comparison, the persistence of financial shocks ρ_F and uncertainty

[20] Other contributions refer to the stochastic steady state as the mean of the endogenous variables when simulating an infinity number of observations. The definition of stochastic steady state used here is in line with the one provided in the Online Appendix by Basu and Bundick (2017). In addition, the results presented here are robust to using the Generalized impulse responses around the ergodic steady state as described by Koop et al. (1996).

shocks is ρ_U is equal to 0.9 in both cases. In addition, following Leduc and Liu (2016) variance of aggregate technology shocks σ^A and of uncertainty shocks σ^U is equal to 0.01 and 0.392, respectively; following Gilchrist et al. (2017), variance of financial shocks σ^F is equal to 0.075. Table 4 summarizes the baseline calibration.[21]

Figure 6 shows model-implied impulse responses to a financial shock and an uncertainty shock. In particular, Figure 6a displays responses to a financial shock that triggers a one percent decrease in output y_t. A financial shock has a contractionary effect on output y_t, consumption c_t, and hours n_t. Real wages w_t also fall due to a large decrease in the labor demand which is associated with a jump in markup μ_t, defined as the inverse of the real marginal cost (see Figure 8 for the response of the markup μ_t). As suggested by the qualitative analysis in Section 5.2, inflation π_t jumps on impact because the shadow value of boosting internal resources ξ_t increases more than the shadow value of attracting new demand $\nu_{i,t}$. As suggested by the quantitative analysis in Section 2.1 and the qualitative analysis in Section 5.2, corporate cash holdings x_t^f falls by a large amount in order to substitute the costly external finance. Both the rise in inflation and the fall in consumption encourage the households to cut investment in cash and liquid assets and, as a general equilibrium effect, the interest rate on cash and liquid assets R_t^x increases. Along those lines, the real supply of cash and liquid assets $\bar{x}_t$ increases consistently with the empirical results presented in Figure 2. Finally, the policy rate set by the monetary authority R_t rises, rather than decreasing, because the output gap parameter ψ_y is currently equal to zero and the central bank prefers to decrease inflation. This result is fairly in line with the empirical results where the federal funds rate is mildly decreasing in face of a financial shock.

Figure 6b displays responses to an uncertainty shock that triggers a one percent decrease in output y_t. Analogously to a financial shock, also uncertainty shocks have a contractionary effect on output y_t, consumption c_t, hours n_t, and real wage w_t due to the decrease in labor demand associated with an increase in markup μ_t (see, also in this case, Figure 8 for the response of markup μ_t). Contrary to a financial shock, uncertainty shocks are associated with deflationary forces since in this case the shadow value of generating internal resources ξ_t increases less than the shadow value of attracting new demand $\nu_{i,t}$. Moreover, in line with the arguments and results provided in previous sections, corporate cash hold-

[21] All the parameters target values of the *deterministic* steady state since those values from the stochastic steady state are quantitatively analogous. In addition, values for ι_x, ω_x, and ω_r are given on an arbitrarily basis because results are robust to *all* the possible values that those parameters can take. See Section 5.4.

Table 4: Model's parameter values

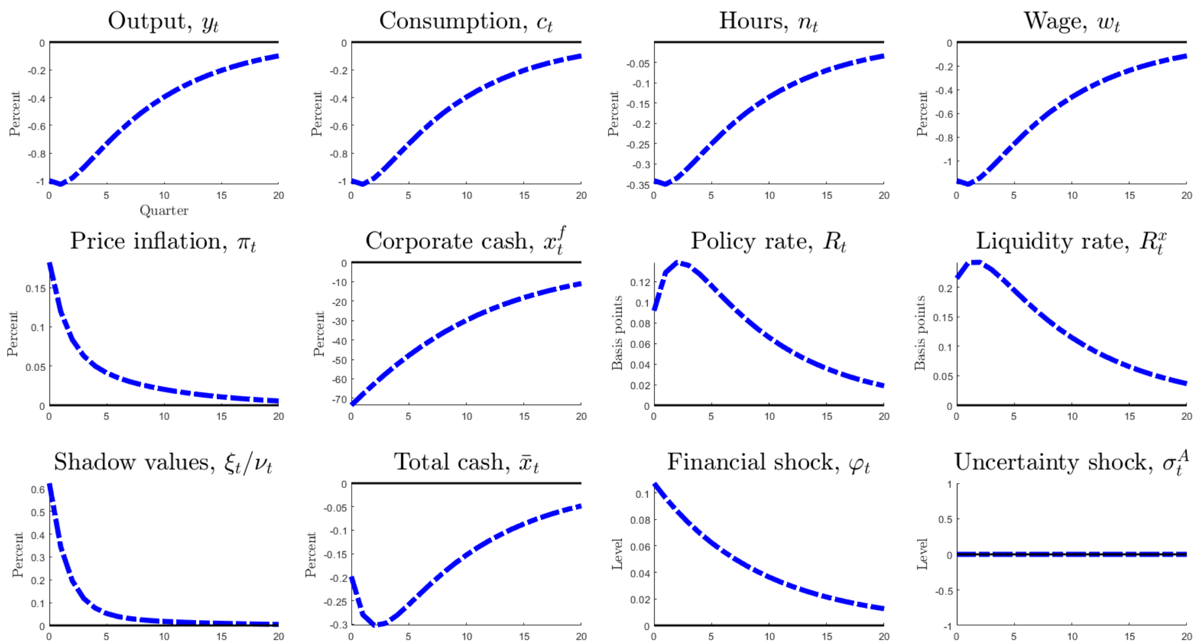
Param.	Interpretation	Value	Objective
β	Discount factor	0.9926	$R_{ss} = 3\%$
γ_q	CRRA in q_t	1	Log-utility
χ_n	Utility from leisure	5.036	$n_{ss} = 0.33$
χ_x	Utility from liquidity	0.0143	$R^x_{ss} = 1$
θ	Habit parameter	-0.8	Ravn et al. (2006)
ρ_s	Habit stock persistence	0.95	Gilchrist et al. (2017)
η	Elasticity of substitution	2	Broda and Weinstein (2006)
α	DRS parameter	0.8	Gilchrist et al. (2017)
ϕ	Fixed cost	0.3	Gilchrist et al. (2017)
σ^2_a	Variance of $a_{i,t}$	0.05	Gilchrist et al. (2017)
γ_p	Price adj. cost	10	Ravn et al. (2006)
ζ_x	Financial flexibility (1)	0.0013	$x^f_{ss}/\bar{x}_{ss} = 0.116$
ι_x	Financial flexibility (2)	0.5	See robustness checks
$\bar{x}_{ss}$	Total cash in s.s.	0.2451	$\bar{x}_{ss}/y_{ss} = 2.176$
ω_x	Persistence of $\bar{x}_t$	0.5	See robustness checks
ω_r	Elasticity of $\bar{x}_t$ to R^x_t	1	See robustness checks
ρ_r	Monetary policy inertia	0.75	Standard NK literature
ψ_π	Taylor Rule on π gap	2	Standard NK literature
ψ_y	Taylor Rule on y gap	0	Standard NK literature
ρ_F	Persistence of ε^F_t	0.9	Comparison with ρ_U
ρ_A	Persistence of ε^A_t	0.95	Leduc and Liu (2016)
ρ_U	Persistence of ε^U_t	0.9	Comparison with ρ_F
σ^F	Standard deviation of ε^F_t	0.075	Gilchrist et al. (2017)
σ^A	Standard deviation of ε^A_t	0.01	Leduc and Liu (2016)
σ^U	Standard deviation of ε^U_t	0.392	Leduc and Liu (2016)

Notes. β is the deterministic discount factor; γ_q is the constant relative risk aversion parameter in the consumption bundle γ_q; χ_n is the multiplicative parameter in household leisure; χ_x is the multiplicative parameter in household cash and liquid assets; θ governs the intensity of the external good-specific habit; ρ_s governs the persistence of the good-specific habit stock; η is the elasticity of substitution across differentiated goods i; α governs the decreasing return of labor input to total output; ϕ is the fixed cost of production; ς_a is the variance of the distribution of idiosyncratic productivity $a_{i,t}$; γ_p governs the price adjustment-cost; ζ_x is the multiplicative parameter of the financial flexibility function $g(\cdot)$; ι_x is the elasticity of the financial flexibility function $d(\cdot)$ to the argument; $\bar{x}_s s$ is the nominal and real stock of total cash and liquid assets in steady state; ω_x is the persistence of the nominal stock of assets $\bar{X}_t$; ω_r is the elasticity of the nominal stock of assets to its interest rate R^x_t; ρ_r governs the degree of inertia in the monetary policy response to the output gap and inflation gap; ψ_π governs the degree of response of the monetary policy to the inflation gap; ψ_y governs the degree of response of the monetary policy to the output gap; ρ_F and σ^2_F are the persistence and the variance of financial shocks ε^F_t; ρ_A and σ^2_A are the persistence and the variance of technology shocks ε^A_t; ρ_U and σ^2_U are the persistence and the variance of uncertainty shocks ε^U_t.

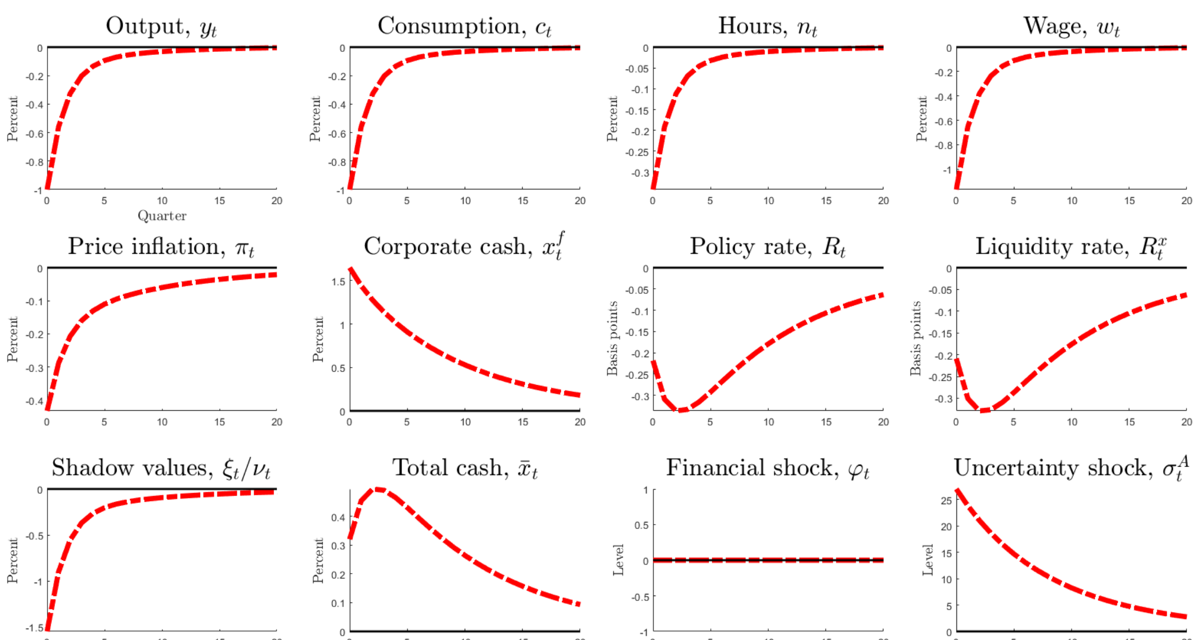
ings x^f_t increases in order to cushion the larger future risk associated with the heighten uncertainty. The fall in inflation and a precautionary motive encourage the households to investment more in cash and liquid assets with the result that the interest rate R^x_t decreases. As a result, the real supply of cash and liquid assets $\bar{x}_t$ increases consistently with

Figure 6: Model-implied impulse responses

(a) Financial shocks



(b) Uncertainty shocks



Notes. Model-implied responses to a financial shock and an uncertainty shock whose size trigger a one-percent contraction in output. Model's parameter values are presented in Table 4.

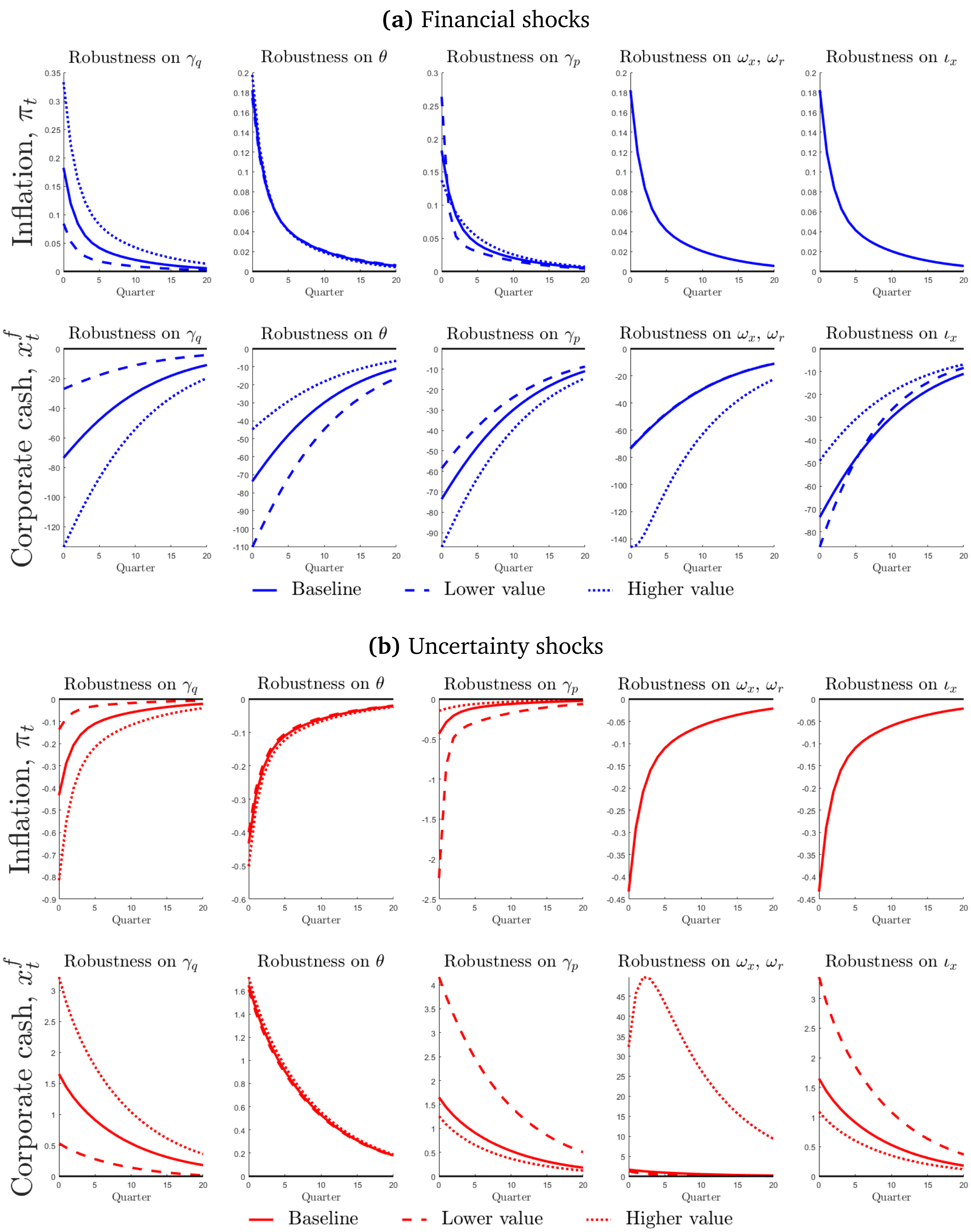
the empirical results presented in Figure 2b. In addition, in line with the empirical results presented in the Section 4, the policy rate R_t falls in response to an uncertainty shock.

5.4 Robustness

In this section, I show a series of robustness checks to confirm that the qualitative implications presented in Figure 6 are robust to different parameterizations. Figure 7 presents various responses to inflation π_t and corporate cash holdings x_t^f to a financial and an uncertainty shock that trigger a one percent contraction in output y_t. Each subplot displays the response for the baseline calibration (solid line), for a calibration that decreases the value of one (or two) parameter(s) (dashed line), and for a calibration that increases the value of the same parameter(s) (dotted line) relatively to the baseline calibration. I show five robustness checks. The subplots presented in the first column show responses to different values of the inverse of households' inter-temporal elasticity of substitution γ_q. The values are one third, one, and two for the lower value, the baseline, and the higher value, respectively. The second column is associated to changes in the good-specific habit parameter θ; values are -0.5, -0.8, and -1.5 for the lower absolute value, the baseline, and the higher absolute value. The third column is related to changes in the parameters that govern the price adjustment costs; values are one, 10, and 50 for the three cases. The fourth column show responses associated with calibrations that affect the supply of cash and liquid assets $\bar{x}_t$ as presented in Equation 7. The lower value means $\omega_x = \omega_r = 0$ which implies a perfectly inelastic real cash supply, such that $\bar{x}_t = \bar{x}_{ss}$ in every period; while, the higher value means $\omega_x = 0$ and ω_r approaching infinity which implies a perfectly elastic cash supply, such that $R_t^x = R_{ss}^x$ in every period. Finally, the last column is associated with different values of the parameters $\iota_x \in (0, 1)$, that governs the elasticity of financial flexibility $g(\cdot)$ to changes in corporate cash x_t^f. Values are 0.01, 0.5, and 0.99 for the lower case, the baseline, and the higher case, respectively.

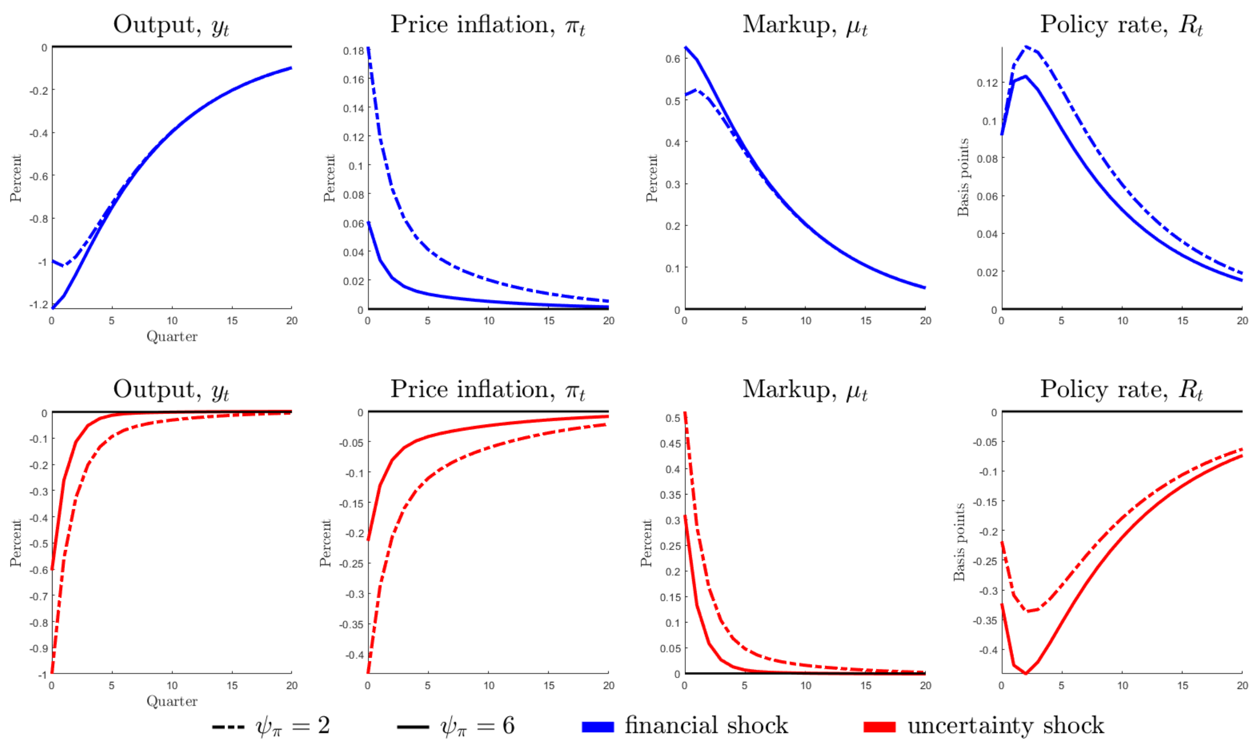
In all cases, the qualitatively different responses of both inflation π_t and corporate cash x_t^f to financial and uncertainty shocks are preserved across all the robustness checks. This suggests that the results presented in the baseline are not implied by a specific combination of parameter values but are mostly implied by the structure of the model as discussed in Section 5.2. Although not shown here, the qualitative results on output y_t, consumption c_t, hours worked n_t, and real wage w_t are always confirmed.

Figure 7: Robustness checks on model-implied impulse responses



Notes. Model-implied responses to a financial shock and an uncertainty shock whose size trigger a one-percent contraction in output in the baseline calibration. Responses are obtained from different calibrations.

Figure 8: Monetary policy experiment on Taylor rule parameter ψ_y



Notes. Model-implied responses to a financial shock and an uncertainty shock whose size trigger a one-percent contraction in output in the baseline calibration. Responses are obtained using different values of the inflation gap coefficient ψ_π.

5.5 Monetary policy implications

According to the empirical and model-implied responses, financial shocks move inflation π_t and output y_t in two different directions, while uncertainty shocks move these two variables in the same direction. This difference is the key reason why being able to disentangle financial shocks from uncertainty shocks is of primary importance for monetary policy. In case of uncertainty shocks, the positive comovement between output and inflation suggests monetary policy can potentially close the output gap and the inflation gap at the same time. Conversely, the negative comovement between output and inflation after a financial shock suggests the existence of a non-trivial trade-off between output and inflation for the monetary policy.

In order to formally explore those implications, I examine the two contractions presented in Figure 6 by allowing monetary policy to respond differently to the inflation gap, ψ_π. Figure 8 shows responses of output y_t, inflation π_t, markup μ_t, and policy rate R_t to a financial shock (top row) and uncertainty shock (bottom row). Each subplot presents two responses: the dashed line refers to the baseline presented in Figure 6 ($\psi_\pi = 2$) and the solid line is obtained from a new calibration where, everything else equal, the monetary authority is relatively more concerned about the inflation gap ($\psi_\pi = 6$).

As shown by the differences in the responses, increasing the coefficient associated with the inflation gap ψ_π successfully stabilize inflation π_t both in the case of financial shocks and uncertainty shocks. Besides, in the case of uncertainty shocks, the stabilization of inflation is followed by an even further stabilization of output y_t; while, in the case of financial shocks, the monetary authority can stabilize inflation only at the cost of a relatively more unstable output. Thus, after a financial shock, the monetary authority has to balance its intervention between output and inflation.

6 Conclusions

This paper shows that there exist two distinct sources of business cycle fluctuations that are both associated with higher uncertainty and wider credit spreads. Beyond the labeling of financial and uncertainty shocks, corporate cash holdings can be useful to understand how much an economic contraction is inherent to the financial sector or to the uncertainty associated with the real economy. With the help of a new econometric strategy, empirical results suggest that (i) financial shocks explain almost 40% of output fluctuations over a business cycle frequency, while uncertainty shocks explain roughly 20%; (ii) the Great Recession can be almost evenly attributed to both financial and uncertainty shocks; and (iii) financial shocks are associated with inflationary forces, while uncertainty shocks are related to deflationary patterns.

I rationalize previous results in a tractable New Keynesian model with financial frictions, good-specific habits, and a market for cash and liquid assets. Counter-factual experiments show that the monetary authority deals with different challenges in face of the two shocks making the case undoubtedly interesting for policy implications. I find that in case of uncertainty shocks, the monetary authority can potentially stabilize output and inflation without facing any trade-off. Conversely, in case of adverse financial shocks, the central bank can stabilize inflation only at the cost of an even deeper contraction.

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A Additional supportive evidence

A.1 Firm-level evidence

I now provide reduced-form cross-sectional evidence that supports the empirical relevance of Proposition 1. Using Compustat data, I document how firms' cash management is differently affected by changes in firm-specific credit conditions and changes in firm-specific uncertainty. Firm-specific credit conditions are proxied by the Interest Rate$_{i,t}$ measured as the total interest and related expenses over total liabilities. This ratio is an average interest rate paid by firm i at time t and is aimed to capture possible changes in the cost of external finance. Firm-specific Uncertainty$_{i,t}$ is defined as the standard deviation of income before extraordinary items over the past 16 quarters. As suggested by Han and Qiu (2007), this measure is aimed to capture future expected cash flow risk at a firm level.

With those two measures in hand, the objective is to estimate their relation with firm-level corporate Cash$_{i,t}$ holdings measured as cash and short-term investments over total assets. I estimate the following regression,

$$\text{Cash}_{i,t} = \alpha + \beta_f \text{Interest Rate}_{i,t} + \beta_u \text{Uncertainty}_{i,t} + \gamma_W W_{i,t} + \lambda_i + \lambda_t + \epsilon_{i,t}$$

where $W_{i,t}$ is a vector of controls that contains the lagged values of Cash$_{i,t-1}$ and the log of total Assets$_{i,t-1}$. $W_{i,t}$ also contains the log of Long-Term Debt$_{i,t}$ and the Long-Term Debt Ratio$_{i,t}$ (Long-Term Debt$_{i,t}$ over Assets$_{i,t}$) to control for changes in the duration of firm i's liabilities, and Income$_{i,t}$ before extraordinary items to control for idiosyncratic first-moment real shocks. Finally, I also control for λ_i and λ_t which represent firm fixed effects and time fixed effects, respectively. Residual $\epsilon_{i,t}$ is a firm-level time-varying innovation assumed to be uncorrelated with Interest Rate$_{i,t}$ and Uncertainty$_{i,t}$. See Appendix A for details on data sources and construction.

The hypothesis to be tested is whether the sign of β_f is significantly negative and the sign of β_u is significantly positive. Baseline results are presented in Table 5. The table shows strong evidence favoring the mechanism that a worsening in credit conditions — a rise in Interest Rate$_{i,t}$ — is associated with a fall in corporate Cash$_{i,t}$ holdings, while an increase in risk — a rise in Uncertainty$_{i,t}$ — is related to an increase in corporate Cash$_{i,t}$.

Table 5: Firm-level evidence

VARIABLES	(1) $\text{Cash}_{i,t}$	(2) $\text{Cash}_{i,t}$	(3) $\text{Cash}_{i,t}$	(4) $\text{Cash}_{i,t}$	(5) $\text{Cash}_{i,t}$	(6) $\text{Cash}_{i,t}$
Interest $\text{Rate}_{i,t}$	-0.452***	-0.182***	-0.208***	-0.187***	-0.179***	-0.167***
	(0.0440)	(0.0517)	(0.0605)	(0.0611)	(0.0556)	(0.0539)
$\text{Uncertainty}_{i,t}$	0.0152***	0.0150***	0.0156***	0.0131***	0.0164***	0.0206***
	(0.00388)	(0.00388)	(0.00388)	(0.00381)	(0.00354)	(0.00336)
$\text{Cash}_{i,t-1}$	0.847***	0.844***	0.844***	0.844***	0.845***	0.848***
	(0.00422)	(0.00431)	(0.00432)	(0.00432)	(0.00396)	(0.00383)
$\text{Assets}_{i,t-1}$	-0.0763***	0.148***	0.162***	0.150***	0.0725**	0.0770**
	(0.0152)	(0.0343)	(0.0428)	(0.0435)	(0.0370)	(0.0363)
Long-Term $\text{Debt}_{i,t}$		-0.189***	-0.206***	-0.212***	-0.155***	-0.189***
		(0.0242)	(0.0354)	(0.0353)	(0.0304)	(0.0300)
Long-term debt $\text{ratio}_{i,t}$			0.156	0.206	-0.195	0.0465
			(0.185)	(0.184)	(0.132)	(0.128)
$\text{Income}_{i,t}$				0.0123***	0.0117***	0.0119***
				(0.00324)	(0.00294)	(0.00269)
Firm fixed effects λ_i	✓	✓	✓	✓	✓	✓
Quarter fixed effects λ_t	✓	✓	✓	✓	✓	✓
Utility firms	✗	✗	✗	✗	✓	✓
Financial firms	✗	✗	✗	✗	✗	✓
Observations	62,014	62,014	62,014	62,014	75,213	82,725
Adj. R-squared	0.801	0.802	0.802	0.802	0.803	0.810

Notes. OLS estimates with robust standard errors.

Results are robust using different sets of controls and including utility and financial firms in the sample.

A.2 Data sources and other details

- Software: `Stata 15.1 SE`
- Data from Compustat (Wharton Reseach Data Service via Boston College affiliation) at a quarterly frequency. Data range 2004:Q1-2018Q4.
- Keep final reports, remove double observations and observations where total assets (atq), cash (chq), cash and short-term investment (cheq), interest rate expenses (xintq), long-term debt (dlttq), or total liabilities (ltq) are non-positive or missing.
- Define corporate cash holdings over total assets $\text{Cash}_{i,t}$ as cash and short-term investments (cheq) over total assets (atq) of firm i at time t. Definition is from the literature.

- Define Interest rate$_{i,t}$ as total interest and related expense (xintq) over total liabilities (ltq) of firm i at time t.
- Define Uncertainty$_{i,t}$ as the standard deviation of income before extraordinary items (ibq) over the past four years (16 quarters) of firm i at time t over 1000 (Han and Qiu, 2007).
- Define Assets$_{i,t}$ as the log of total assets (atq) over 100; Long-Term Debt$_{i,t}$ as the log of long-term debt (dlttq) over 100; Long-Term Debt Ratio$_{i,t}$ as long-term debt (dlttq) over total liabilities (ltq) over 100; Income$_{i,t}$ as income before extraordinary items (ibq) over 1000.
- Run a series of distinct panel regressions with firm and time fixed effects to detect outliers from the residuals of Cash$_{i,t}$, Interest rate$_{i,t}$, Uncertainty$_{i,t}$, Assets$_{i,t}$, Long-Term Debt$_{i,t}$, Long-Term Debt Ratio$_{i,t}$, and Income$_{i,t}$, cash and short-term investment (cheq), and total liabilities (ltq). Remove observations if the related residuals on at least one regression is below the 5th percentile or above the 95th percentile.
- At this point, 62,014 observations are left.
- Run the regressions presented in Section A.1 using the package `reghdfe` with robust standard errors.

A.3 Comparison with existing firm-level evidence

Results presented above are consistent with a large set of existing firm-level evidence that studies the relation between corporate cash with financial conditions or uncertainty.

In the case of financial conditions, Keynes (1973) argued that the relevance of holding cash is influenced by the extent to which firms have access to external capital markets: if firms are financially constrained, a more liquid balance sheet allows firms to undertake valuable projects when they arise. For example, Campello et al. (2010) gather firm-level information using a survey of 1050 CFOs in the forth quarter of 2008. Their approach provides the opportunity to directly ask managers whether their decisions have been affected by the cost or availability of credit. They find that firms that report themselves as being financially constrained systematically planned to store less cash in order to use it as an internally generated source of finance. Specifically, corporate cash in those firms significantly decrease by 3% while cash holdings in unconstrained firms remain unchanged. In addition, Lins et al. (2010) use a 2005 survey of CFOs and ask whether firms opt for storing additional non-operational cash. Among a different set of answers, CFOs state that cash reserves act as a buffer against future cash flow shortfalls and how much should be stored depends on the interest rates and time needed to rise funds. Finally, Lins et al. (2010) also show that non-operational aggregate cash holdings are positively related to private credit-to-GDP, suggesting that when aggregate credit constraints are tight firms tend to draw down relatively more cash as a substitute for the lack of external finance.

In the case of uncertainty, existing firm-level evidence suggests that firms hold more cash in response to higher cash flow risks due to a precautionary motive. For example, the empirical evidence by Opler et al. (1999) suggests that firms tend to hold more liquid assets if their industry average cash flow volatility is higher. Analogously to the results presented in Table 5, Han and Qiu (2007), among others, show that higher cash flow volatility is associated with an increase in the stock of corporate cash holdings. Moreover, the empirical evidence presented by Bates et al. (2009) suggests that the medium-run increase in cash ratios can largely be explained by the change in firms' characteristics. In particular, the evidence is consistent with the view that the precautionary motive is a key determinant of the demand for cash. Finally, Alfaro et al. (2018) use U.S. firm-level data to show that firms accumulate cash reserves and short-term liquid instruments following an uncertainty hike.

I interpret those results, together with the partial equilibrium model presented in Section 2.1, as as robust support for my identifying assumption. In addition, in Section 5, I will embed the partial equilibrium model in a New Keynesian framework and show that the intuition and results are robust after controlling for general equilibrium forces.

B Proof of Proposition 2

Proof. Consider C as the Cholesky decomposition of Σ,

$$CC' = \begin{pmatrix} c_{1,1} & 0 & 0 \\ c_{2,1} & c_{2,2} & 0 \\ c_{3,1} & c_{3,2} & c_{3,3} \end{pmatrix} \begin{pmatrix} c_{1,1} & c_{2,1} & c_{3,1} \\ 0 & c_{2,2} & c_{3,2} \\ 0 & 0 & c_{3,3} \end{pmatrix} = \begin{pmatrix} \sigma_f^2 & \sigma_{f,u} & \sigma_{f,x} \\ \sigma_{f,u} & \sigma_u^2 & \sigma_{u,x} \\ \sigma_{f,x} & \sigma_{u,x} & \sigma_x^2 \end{pmatrix} = \Sigma,$$

where $\sigma_{i,j}^2$ represents the covariance between variable i and variable j. After eliminating the superfluous equations, solution of the system is

$$\begin{cases} c_{1,1}^2 = \sigma_f^2 \\ c_{1,1}c_{2,1} = \sigma_{f,u} \\ c_{1,1}c_{3,1} = \sigma_{f,x} \\ c_{2,1}^2 + c_{2,2}^2 = \sigma_u^2 \\ c_{2,1}c_{3,1} + c_{2,2}c_{3,2} = \sigma_{u,x} \\ c_{3,1}^2 + c_{3,2}^2 + c_{3,3}^2 = \sigma_x^2 \end{cases} \Rightarrow \begin{cases} c_{1,1} = \sigma_f \\ c_{2,1} = \frac{\sigma_{f,u}}{\sigma_f} \\ c_{3,1} = \frac{\sigma_{f,x}}{\sigma_f} \\ c_{2,2} = \sqrt{\sigma_u^2 - (\frac{\sigma_{f,u}}{\sigma_f})^2} \\ c_{3,2} = \frac{\sigma_{u,x} - \frac{\sigma_{f,u}\sigma_{f,x}}{\sigma_f^2}}{\sqrt{\sigma_u^2 - (\frac{\sigma_{f,u}}{\sigma_f})^2}} \\ c_{3,3} = \sqrt{\sigma_x^2 - (\frac{\sigma_{f,x}}{\sigma_f})^2 - \frac{(\sigma_{u,x} - \frac{\sigma_{f,u}\sigma_{f,x}}{\sigma_f^2})^2}{\sigma_u^2 - (\frac{\sigma_{f,u}}{\sigma_f})^2}}. \end{cases}$$

Define orthogonal matrix D as follows

$$D = \begin{pmatrix} d_1, & d_2, & d_3 \end{pmatrix} = \begin{pmatrix} \gamma_{1,1} & \gamma_{1,2} & \gamma_{1,3} \\ \gamma_{2,1} & \gamma_{2,2} & \gamma_{2,3} \\ \gamma_{3,1} & \gamma_{3,2} & \gamma_{3,3} \end{pmatrix}$$

then $A = CD$ can be rewritten as,

$$A = \begin{pmatrix} c_{1,1}\gamma_{1,1} & c_{1,1}\gamma_{1,2} & \cdots \\ c_{2,1}\gamma_{1,1} + c_{2,2}\gamma_{2,1} & c_{2,1}\gamma_{1,2} + c_{2,2}\gamma_{2,2} & \cdots \\ c_{3,1}\gamma_{1,1} + c_{3,2}\gamma_{2,1} + c_{3,3}\gamma_{3,1} & c_{3,1}\gamma_{1,2} + c_{3,2}\gamma_{2,2} + c_{3,3}\gamma_{3,2} & \cdots \end{pmatrix} \tag{10}$$

where the first column represents the impact effect of the first and second shock on financial conditions f_t, measured uncertainty u_t, and the cash holdings x_t^f, respectively. The third column, which represents the impact responses of the endogenous variables to other shocks, is omitted because, as discussed above, independent to the identification of financial and uncertainty shocks.

Then, Problems 3 and 4 can be rewritten as follows

$$\max_{\gamma_{1,1},\gamma_{2,1},\gamma_{3,1}} \quad (1-\delta)c_{1,1}\gamma_{1,1} - \delta[c_{3,1}\gamma_{1,1} + c_{3,2}\gamma_{2,1} + c_{3,3}\gamma_{3,1}]$$
$$\text{subject to} \quad (\gamma_{1,1})^2 + (\gamma_{2,1})^2 + (\gamma_{3,1})^2 = 1$$

and

$$\max_{\gamma_{1,2},\gamma_{2,2},\gamma_{3,2}} \quad (1-\delta)[c_{2,1}\gamma_{1,2} + c_{2,2}\gamma_{2,2}] + \delta[c_{3,1}\gamma_{1,2} + c_{3,2}\gamma_{2,2} + c_{3,3}\gamma_{3,2}]$$
$$\text{subject to} \quad (\gamma_{1,2})^2 + (\gamma_{2,2})^2 + (\gamma_{3,2})^2 = 1.$$

where $d_1^*(\delta)$ and $d_2^*(\delta)$ are the respective solutions for financial and uncertainty shocks that, for a given δ, are uniquely identified.

The first order conditions of Problem 3 are:

i. $\gamma_{1,1} : \ (1-\delta)c_{1,1} - \delta c_{3,1} = 2\lambda\gamma_{1,1}^*$

ii. $\gamma_{2,1} : \ -\delta c_{3,2} = 2\lambda\gamma_{2,1}^*$

iii. $\gamma_{3,1} : \ -\delta c_{3,3} = 2\lambda\gamma_{3,1}^*$

iv. $\lambda_1 : \ (\gamma_{1,1}^*)^2 + (\gamma_{2,1}^*)^2 + (\gamma_{3,1}^*)^2 = 1$

where λ_1 is the Lagrangian multiplier of the constraint.

If $\delta = 0$, solution is $\gamma_{1,1}^* = 1$ and $\gamma_{2,1}^* = \gamma_{3,1}^* = 0$ where the impact effect on financial conditions f_t is σ_f which is the result of a Cholesky identification where f_t is placed on top. As a result, if $\delta = 0$ then $\varepsilon_t^f = i_t^f$. Conversely, if $\delta = 1$, solution is

$$\begin{cases} \gamma_{1,1}^* = -\sqrt{\frac{c_{3,1}^2}{c_{3,1}^2+c_{3,2}^2+c_{3,2}^2}} \\ \gamma_{2,1}^* = -\sqrt{\frac{c_{3,2}^2}{c_{3,1}^2+c_{3,2}^2+c_{3,2}^2}} \\ \gamma_{3,1}^* = -\sqrt{\frac{c_{3,3}^2}{c_{3,1}^2+c_{3,2}^2+c_{3,2}^2}} \end{cases}$$

which delivers an impact effect on corporate cash x_t^f of $-\sigma_x$. As a result, if $\delta = 1$ then $\varepsilon_t^u = -i_t^x$ which is the result of a Cholesky identification where x_t^f is placed on top with opposite sign.

The first order conditions of Problem 4 are:

i. $\gamma_{1,2}: \ (1-\delta)c_{2,1} + \delta c_{3,1} = 2\lambda\gamma^*_{1,2}$

ii. $\gamma_{2,2}: \ (1-\delta)c_{2,2} + \delta c_{3,2} = 2\lambda\gamma^*_{2,2}$

iii. $\gamma_{3,2}: \ \delta c_{3,3} = 2\lambda\gamma^*_{3,2}$

iv. $\lambda_2: \ (\gamma^*_{1,2})^2 + (\gamma^*_{2,2})^2 + (\gamma^*_{3,2})^2 = 1$

where λ_2 is the Lagrangian multiplier of the constraint.

If $\delta = 0$, solution is

$$\begin{cases} \gamma^*_{1,2} = \sqrt{\frac{c^2_{3,1}}{c^2_{2,1}+c^2_{2,2}}} \\ \gamma^*_{2,2} = \sqrt{\frac{c^2_{2,2}}{c^2_{2,1}+c^2_{2,2}}} \\ \gamma^*_{3,2} = 0 \end{cases}$$

where the impact effect on measured uncertainty u_t is σ_u which is the result of a Cholesky identification where u_t is placed on top. As a result, if $\delta = 0$ then $\varepsilon^u_t = i^u_t$. Conversely, if $\delta = 1$, solution is

$$\begin{cases} \gamma^*_{1,1} = \sqrt{\frac{c^2_{3,1}}{c^2_{3,1}+c^2_{3,2}+c^2_{3,2}}} \\ \gamma^*_{2,1} = \sqrt{\frac{c^2_{3,2}}{c^2_{3,1}+c^2_{3,2}+c^2_{3,2}}} \\ \gamma^*_{3,1} = \sqrt{\frac{c^2_{3,3}}{c^2_{3,1}+c^2_{3,2}+c^2_{3,2}}} \end{cases}$$

which delivers an impact effect on the liquidity ration x^f_t of σ_x. As a result, if $\delta = 1$ then $\varepsilon^u_t = i^x_t$ which is the result of a Cholesky identification where x^f_t is placed on top.

Now if $\delta = 0$, then $d^*_1(\delta = 0)' d^*_2(\delta = 0) = \text{Corr}(\varepsilon^f_t, \varepsilon^u_t) = \text{Corr}(i^f_t, i^u_t) > 0$. While, if $\delta = 1$, then $d^*_1(\delta = 1)' d^*_2(\delta = 1) = \text{Corr}(\varepsilon^u_t, \varepsilon^f_t) = \text{Corr}(i^x_t, -i^x_t) = -1$. Since both $d^*_1(\delta)$ and $d^*_2(\delta)$ are continuous functional vectors in δ, it follows that also their product $d^*_1(\delta)' d^*_2(\delta)$ is continuous in δ. This implies that $d^*_1(\delta)' d^*_2(\delta)$ must cross the zero line at least once in the δ support $[0, 1]$.

■

C Proposition 3

Proposition 3 *If Cov*$(i^u_t, i^f_t) = \sigma_u\sigma_f$ *then solution* δ^**,* d^*_1*, and* d^*_2 *exists and is unique.*

Proof. Notice that $\text{Cov}(i^u_t, i^f_t) = \sigma_u\sigma_f$ directly implies that $\text{Corr}(i^u_t, i^f_t)$ is equal to one. This entails that the system is collapsing because the information to identify impact matrix A provided by u_t already includes all the information provided by f_t and viceversa. As a result, I will shrink the system to be bidimensional where the first series of innovations i^1_t is equal to the innovations in both measured uncertainty i^u_t and financial conditions i^f_t with standard deviation σ_1; while the second series of innovations i^2_t is equal to the innovations in corporate cash i^x_t with standard deviation σ_x. As before, I am interested in identifying the first two structural disturbances: financial shocks ε^F_t and uncertainty shocks ε^U_t. Identifying assumptions are the same: financial shocks ε^F_t have a positive impact effect on i^1_t (first variable) and a negative impact effect on i^2_t (second variable), while uncertainty shocks ε^U_t have a positive impact effect on both reduced-form innovations i^1_t and i^2_t.

Consider the solution to the Cholesky identification where $c_{1,2} = 0$,

$$C = \begin{pmatrix} \sigma_{1,1} & 0 \\ \frac{\sigma^2_{1,2}}{\sigma_{1,1}} & \sqrt{\sigma^2_{2,2} - \left(\frac{\sigma^2_{1,2}}{\sigma_{1,1}}\right)^2} \end{pmatrix} = \begin{pmatrix} c_{1,1} & c_{1,2} \\ c_{2,1} & c_{2,2} \end{pmatrix}$$

where, as before, $CC' = \Sigma$. Given orthogonal matrix D, impact matrix A is

$$A = \begin{pmatrix} c_{1,1}\gamma_{1,1} & c_{1,1}\gamma_{1,2} \\ c_{2,1}\gamma_{1,1} + c_{2,2}\gamma_{2,1} & c_{2,1}\gamma_{1,2} + c_{2,2}\gamma_{2,2} \end{pmatrix}$$

which is

$$A = \begin{pmatrix} \sigma_{1,1}\gamma_{1,1} & \sigma_{1,1}\gamma_{1,2} \\ \frac{\sigma^2_{1,2}}{\sigma_{1,1}}\gamma_{1,1} + \sqrt{\sigma^2_{2,2} - \left(\frac{\sigma^2_{1,2}}{\sigma_{1,1}}\right)^2}\gamma_{2,1} & \frac{\sigma^2_{1,2}}{\sigma_{1,1}}\gamma_{1,2} + \sqrt{\sigma^2_{2,2} - \left(\frac{\sigma^2_{1,2}}{\sigma_{1,1}}\right)^2}\gamma_{2,2} \end{pmatrix}.$$

Although results remain perfectly symmetric, consider the case where the impact responses to an uncertainty shock are represented by the first column of Matrix A, and the impact responses to a financial shock are represented by the second column of Matrix A. Problem

4 – to identify uncertainty shocks – can be rewritten as,

$$\max_{\gamma_{1,1},\gamma_{2,1}} \quad \sigma_{1,1}\gamma_{1,1} + \delta\left[\frac{\sigma_{1,2}^2}{\sigma_{1,1}}\gamma_{1,1} + \sqrt{\sigma_{2,2}^2 - \left(\frac{\sigma_{1,2}^2}{\sigma_{1,1}}\right)^2}\gamma_{2,1}\right]$$
$$\text{s.t.} \quad 1 \geq \gamma_{1,1}^2 + \gamma_{2,1}^2$$

and optimality conditions are

$$\gamma_{1,1}: \; \sigma_{1,1} + \delta\frac{\sigma_{1,2}^2}{\sigma_{1,1}} - 2\lambda\left(\gamma_{1,1}^*\right) = 0 \quad \Rightarrow \quad \gamma_{1,1}^* = \frac{1}{2\lambda}\left[\sigma_{1,1} + \delta\frac{\sigma_{1,2}^2}{\sigma_{1,1}}\right] \tag{11}$$

$$\gamma_{2,1}: \; \delta\sqrt{\sigma_{2,2}^2 - \left(\frac{\sigma_{1,2}^2}{\sigma_{1,1}}\right)^2} - 2\lambda\left(\gamma_{2,1}^*\right) = 0 \quad \Rightarrow \quad \gamma_{2,1}^* = \frac{1}{2\lambda}\delta\sqrt{\sigma_{2,2}^2 - \left(\frac{\sigma_{1,2}^2}{\sigma_{1,1}}\right)^2} \tag{12}$$

$$\lambda : (\gamma_{1,1}^*)^2 - (\gamma_{2,1}^*)^2 = 1 \tag{13}$$

where λ is the Lagrangian multiplier of the constraint. The following results will be useful to complete the proof:

- Equation 11 implies that
  1. $\gamma_{1,1}^* \geq 0$ for all $\delta \geq 0$ if $\sigma_{1,2}^2 \geq 0$.
  2. It exists $\bar{\delta}$ such that $\gamma_{1,1}^* \geq 0$ for all $0 \leq \delta \leq \bar{\delta}$ if $\sigma_{1,2}^2 \leq 0$.
- Equation 12 implies $\gamma_{2,1}^* \geq 0$ for all $\delta \geq 0$.
- Dividing 11 over 12 yields

$$\frac{\gamma_{1,1}^*}{\gamma_{2,1}^*} = \frac{\sigma_{1,1} + \delta\frac{\sigma_{1,2}^2}{\sigma_{1,1}}}{\delta\sqrt{\sigma_{2,2} - \left(\frac{\sigma_{1,1}^2}{\sigma_{1,1}}\right)^2}}$$

  Taking first derivative with respect to δ implies

$$\frac{\partial\frac{\gamma_{1,1}^*}{\gamma_{2,1}^*}}{\partial\delta} = \frac{\frac{\sigma_{1,2}^2}{\sigma_{1,1}}\delta\sqrt{\sigma_{2,2} - \left(\frac{\sigma_{1,1}^2}{\sigma_{1,1}}\right)^2} - \left(\sigma_{1,1} + \delta\frac{\sigma_{1,2}^2}{\sigma_{1,1}}\right)\sqrt{\sigma_{2,2} - \left(\frac{\sigma_{1,1}^2}{\sigma_{1,1}}\right)^2}}{\delta^2\left(\sigma_{2,2} - \left(\frac{\sigma_{1,1}^2}{\sigma_{1,1}}\right)^2\right)}$$

which is

$$\frac{\partial \frac{\gamma^*_{1,1}}{\gamma^*_{2,1}}}{\partial \delta} = -\frac{\sigma_{1,1}\sqrt{\sigma_{2,2} - \left(\frac{\sigma^2_{1,1}}{\sigma_{1,1}}\right)^2}}{\delta^2\left(\sigma_{2,2} - \left(\frac{\sigma^2_{1,1}}{\sigma_{1,1}}\right)^2\right)} < 0.$$

Problem 3 – to identify financial shocks– can be rewritten as,

$$\begin{aligned} \max_{\gamma_{1,2},\gamma_{2,2}} \quad & \sigma_{1,1}\gamma_{1,2} - \delta\left[\frac{\sigma^2_{1,2}}{\sigma_{1,1}}\gamma_{1,2} + \sqrt{\sigma^2_{2,2} - \left(\frac{\sigma^2_{1,2}}{\sigma_{1,1}}\right)^2}\gamma_{2,2}\right] \\ \text{s.t.} \quad & 1 \geq \gamma^2_{1,2} + \gamma^2_{2,2} \end{aligned} \tag{14}$$

and optimality conditions are

$$\gamma_{1,2}: \ \sigma_{1,1} - \delta\frac{\sigma^2_{1,2}}{\sigma_{1,1}} - 2\lambda\left(\gamma^*_{1,2}\right) = 0 \quad \Rightarrow \quad \gamma^*_{1,2} = \frac{1}{2\lambda}\left[\sigma_{1,1} - \delta\frac{\sigma^2_{1,2}}{\sigma_{1,1}}\right] \tag{15}$$

$$\gamma_{2,2}: \ -\delta\sqrt{\sigma^2_{2,2} - \left(\frac{\sigma^2_{1,2}}{\sigma_{1,1}}\right)^2} - 2\lambda\left(\gamma^*_{2,2}\right) = 0 \quad \Rightarrow \quad \gamma^*_{2,2} = -\frac{1}{2\lambda}\delta\sqrt{\sigma^2_{2,2} - \left(\frac{\sigma^2_{1,2}}{\sigma_{1,1}}\right)^2} \tag{16}$$

$$\lambda := \lambda\left[1 - \left(\gamma^*_{1,2}\right)^2 - \left(\gamma^*_{2,2}\right)^2\right] = 0 \tag{17}$$

where λ is the Lagrangian multiplier of the constraint. The following results will be useful to complete the proof:

- Equation 15 implies that
  1. $\gamma^*_{1,2} \geq 0$ for all $\delta \geq 0$ if $\sigma^2_{1,2} \leq 0$.
  2. It exists $\bar{\delta}$ such that $\gamma^*_{1,2} \geq 0$ for all $0 \leq \delta \leq \bar{\delta}$ if $\sigma^2_{1,2} \geq 0$.
- Equation 16 implies $\gamma^*_{2,2} \leq 0$ for all $\delta \geq 0$.
- Dividing 15 over 16 yields

$$\frac{\gamma^*_{1,2}}{\gamma^*_{2,2}} = -\frac{\sigma_{1,1} - \delta\frac{\sigma^2_{1,2}}{\sigma_{1,1}}}{\delta\sqrt{\sigma_{2,2} - \left(\frac{\sigma^2_{1,1}}{\sigma_{1,1}}\right)^2}}$$

Taking first derivative with respect to δ implies

$$\frac{\partial \frac{\gamma_{1,2}^*}{\gamma_{2,2}^*}}{\partial \delta} = -\frac{-\frac{\sigma_{1,2}^2}{\sigma_{1,1}}\delta\sqrt{\sigma_{2,2}-\left(\frac{\sigma_{1,1}^2}{\sigma_{1,1}}\right)^2} - \left(\sigma_{1,1}-\delta\frac{\sigma_{1,2}^2}{\sigma_{1,1}}\right)\sqrt{\sigma_{2,2}-\left(\frac{\sigma_{1,1}^2}{\sigma_{1,1}}\right)^2}}{\delta^2\left(\sigma_{2,2}-\left(\frac{\sigma_{1,1}^2}{\sigma_{1,1}}\right)^2\right)}$$

which is

$$\frac{\partial \frac{\gamma_{1,2}^*}{\gamma_{2,2}^*}}{\partial \delta} = \frac{\sigma_{1,1}\sqrt{\sigma_{2,2}-\left(\frac{\sigma_{1,1}^2}{\sigma_{1,1}}\right)^2}}{\delta^2\left(\sigma_{2,2}-\left(\frac{\sigma_{1,1}^2}{\sigma_{1,1}}\right)^2\right)} > 0$$

Notice that there exist two possible cases to focus on: 1. $\delta \leq \bar{\delta}$ and 2. $\delta > \bar{\delta}$. Proof proceeds as follows: I show that case 1. has a unique solution and case 2. has no solutions. In addition, since the problem is symmetric over d_1 and d_2 is irrelevant whether I focus on $\sigma_{1,2} \geq 0$ or $\sigma_{1,2} \leq 0$. Proof holds symmetrically in either cases. For simplicity I assume $\sigma_{1,2} \geq 0$.

1. When $\delta \leq \bar{\delta}$, at least a solution always exists since for $\delta = 0$,

$$\gamma_{1,1}^*\gamma_{1,2}^* + \gamma_{2,1}^*\gamma_{2,2}^* > 0$$

since $\gamma_{1,1}^* = \gamma_{1,2}^* = 1$, and $\gamma_{2,1}^* = \gamma_{2,2}^* = 0$. Moreover, for $\delta = \bar{\delta}$,

$$\gamma_{1,1}^*\gamma_{1,2}^* + \gamma_{2,1}^*\gamma_{2,2}^* < 0$$

since $\gamma_{1,2} = 0$, $\gamma_{2,1}^* > 0$, and $\gamma_{2,2}^* > 0$.[22]

Thus, in order to show that the solution is unique, I need to prove that $\gamma_{1,1}^*\gamma_{1,2}^*+\gamma_{2,1}^*\gamma_{2,2}^*$ is monotonically decreasing in δ. Since both $\gamma_{1,1}^*$ and $\gamma_{2,1}^*$ are positive, and since $\frac{\gamma_{1,1}^*}{\gamma_{2,1}^*}$ is decreasing in δ then it must be the case that $\gamma_{1,1}^*$ is decreasing in δ and $\gamma_{2,1}^*$ is increasing in δ. Since $\gamma_{1,2}^*$ is positive and $\gamma_{2,2}^*$ is negative, and since $\frac{\gamma_{1,2}^*}{\gamma_{2,2}^*}$ is increasing in δ then it must be the case that $\gamma_{1,2}^*$ is decreasing in δ and $|\gamma_{2,2}^*|$ is increasing in δ. As a result, we have $(\downarrow \gamma_{1,1}^*)(\downarrow \gamma_{1,2}^*) - (\uparrow \gamma_{2,1}^*)(\uparrow |\gamma_{2,2}^*|)$ which implies that when $\delta \leq \bar{\delta}$, then $\gamma_{1,1}^*\gamma_{1,2}^*+\gamma_{2,1}^*\gamma_{2,2}^*$ is monotonically decreasing in δ which implies that the solution in this area is unique.

[22] I am implicitly using the result that $\gamma_{1,1}^*\gamma_{1,2}^* + \gamma_{2,1}^*\gamma_{2,2}^*$ is a continuous function of δ.

2. When $\delta > \bar{\delta}$, $\gamma^*_{1,1}\gamma^*_{1,2} + \gamma^*_{2,1}\gamma^*_{2,2}$ is never equal to zero. This happens because when $\delta > \bar{\delta}$, $\gamma_{1,1} > 0$, $\gamma_{2,1} > 0$, $\gamma_{1,2} < 0$, and $\gamma_{2,2} < 0$. As a result,

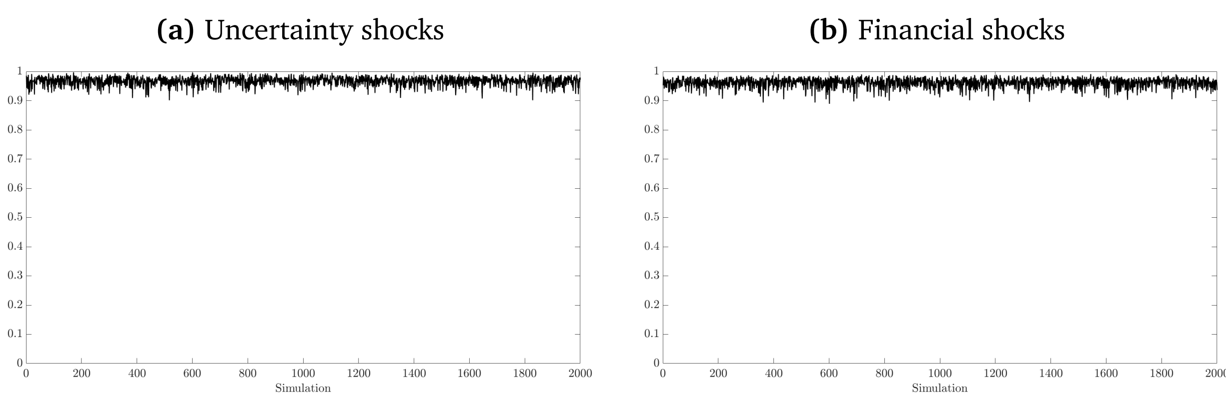
$$\gamma^*_{1,1}\gamma^*_{1,2} + \gamma^*_{2,1}\gamma^*_{2,2} < 0 \ \ \forall \, \delta > \bar{\delta}.$$

■

D Estimation on simulated data

In order to test the reliability of the econometric procedure presented in Section 3, I simulate data from the model presented in Section 5 and employ my econometric strategy in order to recover unobservable financial and uncertainty shocks from the observable endogenous variables. To be in line with the empirical application presented in Section 4, I simulate 2000 series with 137 observations where financial and uncertainty shocks are i.i.d. observations across shocks and over time from a standard normal distribution.[23] I assume the econometrician can only observe endogenous variables such as measured uncertainty u_t, the credit spread as a proxy for financial conditions f_t and the liquidity ratio x_t, and cannot observe exogenous processes such as financial intermediaries' fixed cost χ_t and variance of technology shocks σ_t together with their underlying shocks. Following Jurado et al. (2015), I define measured uncertainty as $u_t = \mathbb{E}_t\{[y_t - \mathbb{E}_t(y_t)]^2\}$. In addition, in order to capture an endogenous variable for financial conditions, I define $f_t = 0.5\bar{a}_t + 0.5\bar{a}_{t+1} + \varphi_t$. Note that both variables display a positive impact effect to financial and uncertainty shocks reproducing the simultaneity observed in the data.

Figure 9: Correlation between actual shocks ε_t and estimated shocks $\hat{\varepsilon}_t$

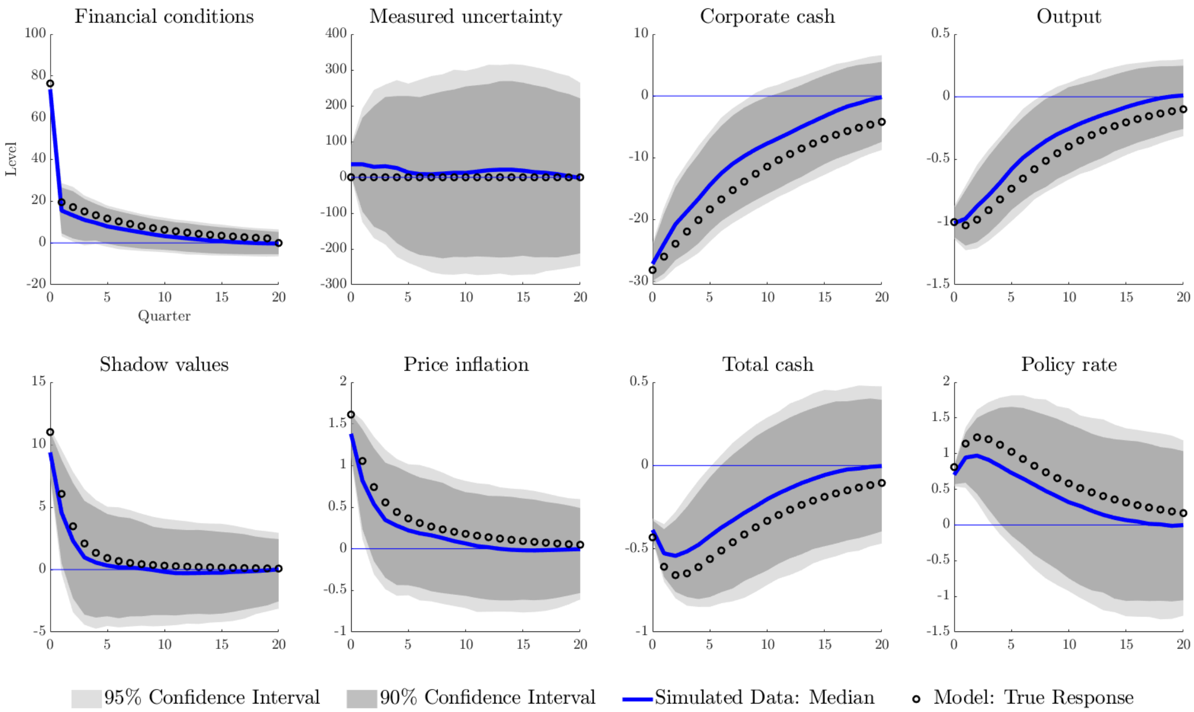


For each simulation, I build a reduced-form VAR composed by measured uncertainty u_t, credit spread f_t, corporate cash x_t^f, output y_t, shadow values ξ_t/ν_t, inflation π_t, total cash $\bar{x}_t$, and policy rate R_t. As suggested by the AIC, BIC and HQ criteria I use one lag to obtain a (8×8) variance-covariance matrix Σ of reduced-form innovations i_t. Finally,

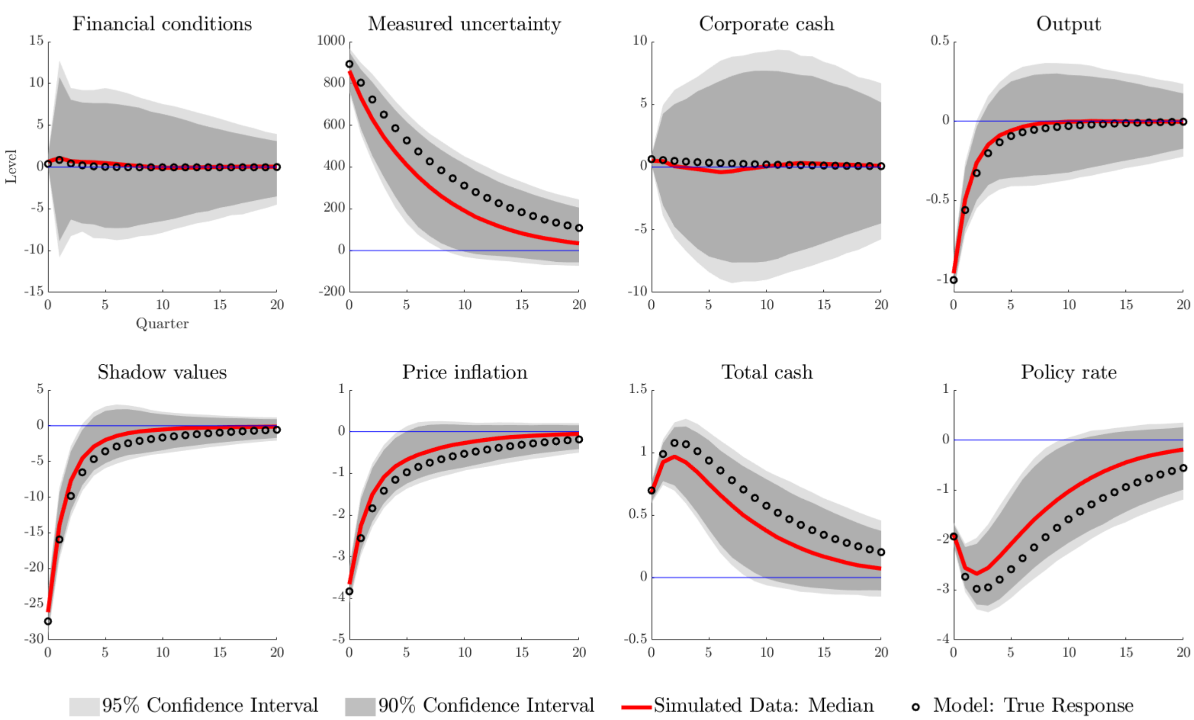
[23] For simplicity, I do not simulate technology shocks because of the empirical observation that the residuals of the excess bond premium by Gilchrist and Zakrajšek (2012) and of measured uncertainty by Jurado et al. (2015) are already orthogonal to unanticipated technology shocks. In any case, if technology shocks are simulated together with financial and uncertainty shocks, it will be sufficient to control for the residuals in measured productivity before employing the econometric strategy presented in Section 3.

Figure 10: Model-implied responses and estimated responses on simulated data

(a) Financial shocks



(b) Uncertainty shocks



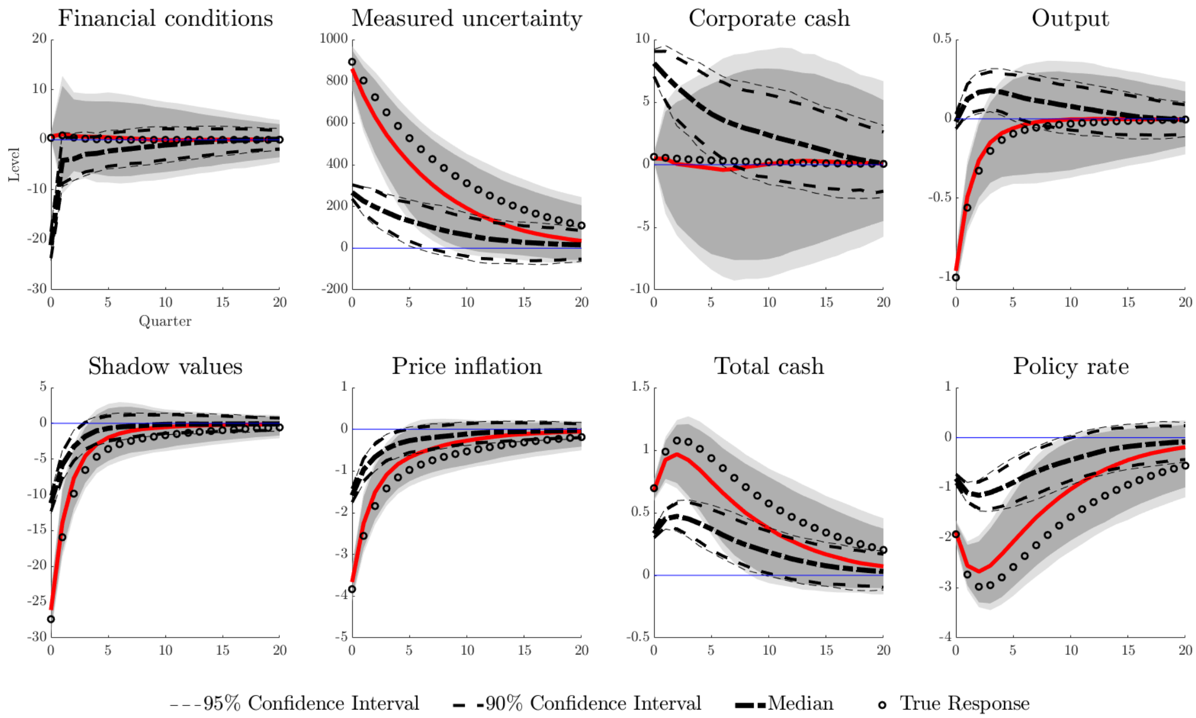
making the same assumptions on the impact response of corporate cash, I employ the same econometric strategy presented in Definition 1. Figure 9b shows the correlation between actual financial shocks ε_t^F and estimated ones $\hat{\varepsilon}_t^F$ and in most of the cases the correlation is above 90% with an average of 96%. Similarly, Figure 9a shows the correlation between actual uncertainty shocks ε_t^U and estimated ones $\hat{\varepsilon}_t^U$ and in most of the cases the correlation is above 90% with an average of 96% as well. At the same time, Figure 10 shows the model-implied true responses together with the estimated ones on simulated data for both financial and uncertainty shocks. The econometric strategy does a good job in estimating the actual responses to the two shocks since, in almost all the cases, the actual responses lie within the confidence interval of the estimated ones.

E Comparison with sign restrictions

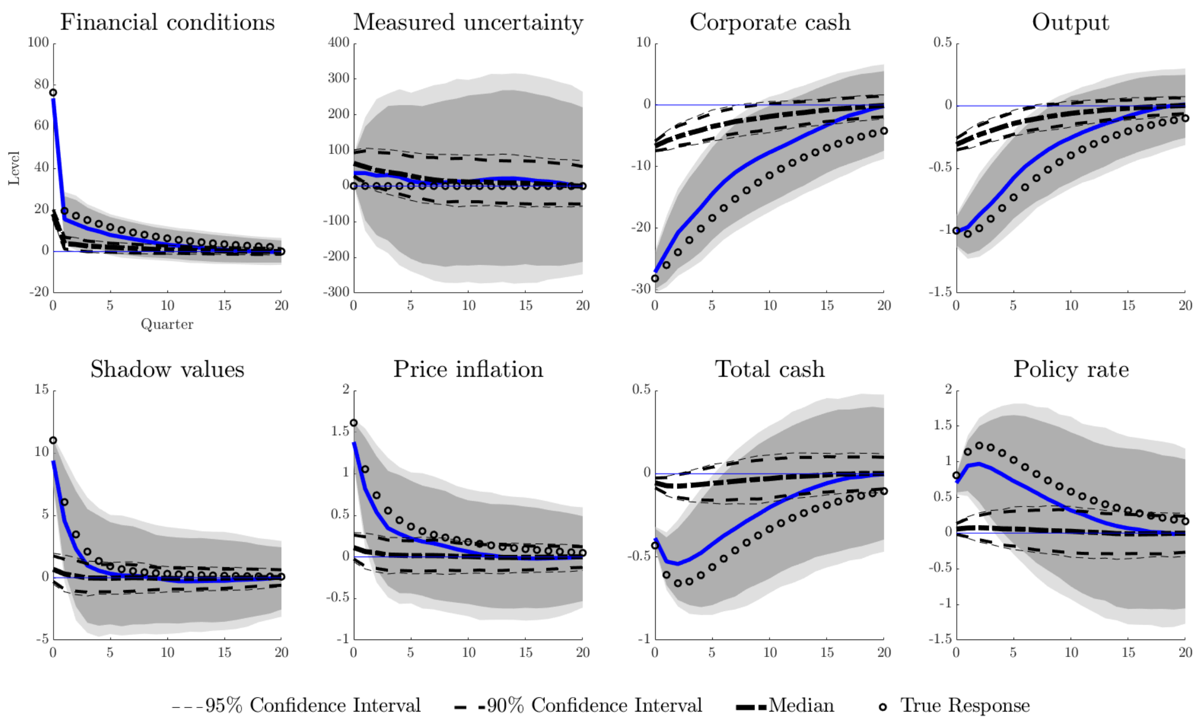
In Figure 11, I compare the identification strategy presented in Section 3 with sign restrictions. Using the same simulated data used to obtain Figure 10, I implement the following algorithm. For each simulation s, estimate C_s using the Cholesky decomposition. Then, draw a random orthogonal matrix Q such that $Q'Q$ is an identity matrix. Generate candidate impact responses from C_sQ and verify if they satisfy the identifying assumptions described in Section 3. If the sign restrictions are not satisfied then disregard Q, if the sign restrictions are satisfied then generate and store its related impulse response functions. Repeat this procedure until N impulse responses are stored and take the simple mean. Repeat this procedure for any simulation s and obtain 2000 mean impulse responses. Derive median and confidence intervals.

Figure 11: Estimated responses on simulated data: comparison with sign restrictions

(a) Uncertainty shocks



(b) Financial shocks



Note: “B20" stands for Brianti (2020) and refers to the identification strategy presented in Section 3. “Sign Restrictions" refers to the sign restriction identification scheme as described in the main text.

F Aggregate data

Table 6: Details on aggregate US data

Variable	Source and Construction	Transform
Credit spread: EBP	Excess bond premium by Gilchrist and Zakrajšek (2012) available on Simon Gilchrist's website. Aggregation method: average	level
Measured uncertainty	Macroeconomic uncertainty by Jurado et al. (2015) available on Sydney Ludvigson's website. Baseline specification: horizon is three months. Robustness checks: horizons are one month (MU1) and 12 months (MU12). Aggregation method: average	level
Corporate cash	Sum of (i) private foreign deposits (FDABSNNCB), (ii) checkable deposits and currency (NCBCDCA), (iii) total time and saving deposits (TSDABSNNCB), and (iv) money market mutual fund shares (MMFSABSNNCB); over Total assets (TABSNNCB) by FRED	level
GDP	Real gross domestic product (GDPC1) by FRED	log
Consumption	Consumption of non-durables (RCONND) plus consumption of services (RCONS) by Philadelphia Fed	log
Investment	Gross domestic investment (GDPIC1) by FRED plus consumption of durables (RCOND) by Philadelphia Fed	log
Hours	Hours of all persons for the nonfarm business sector (HOANBS) by FRED	log
GDP deflator	Implicit price deflator of the gross domestic product (GDPDEF) by FRED	log
Real M2	M2 money stock (M2) over GDP deflator (GDPDEF) by FRED	log
FFR	Effective federal funds rate (FEDFUNDS) by FRED	level
Volatility Index (VIX)	Volatility Index VIX (VIXCLS) by FRED. Aggregation method: average	log
Credit spread: GZ	GZ credit spread by Gilchrist and Zakrajšek (2012) available on Simon Gilchrist's website. Aggregation method: average	level
Credit spread: BAA10Y	Moody's Seasoned Baa Corporate Bond Yield Relative to Yield on 10-Year Treasury Constant Maturity, Percent, Quarterly, Not Seasonally Adjusted (BAA10Y) by FRED. Aggregation method: average	level
Measured uncertainty: FU3	Financial uncertainty by Jurado et al. (2015) available on Sydney Ludvigson's website. Horizon is three months. Aggregation method: average	level
Measured uncertainty: RU3	Real uncertainty by Jurado et al. (2015) available on Sydney Ludvigson's website. Horizon is three months. Aggregation method: average	level
Treasury	Treasury (TSABSNNCB) for the nonfinancial corporate business sector by FRED. Robustness check: add it to baseline corporate liquidity	level

G Model's derivations and details

G.1 Household cost minimization problem

Household cost minimization problem is:

$$\min_{c_{i,t}} \int_0^1 P_{i,t} c_{i,t} di \qquad \text{subject to:} \quad q_t = \left[\int_0^1 \left(\frac{c_{i,t}}{s_{i,t-1}^{\theta}} \right)^{1-\frac{1}{\eta}} \right]^{\frac{1}{1-\frac{1}{\eta}}}$$

Set up the Lagrangian

$$L = \int_0^1 P_{i,t} c_{i,t} di + \tilde{\psi}_t \left\{ q_t - \left[\int_0^1 \left(\frac{c_{i,t}}{s_{i,t-1}^{\theta}} \right)^{1-\frac{1}{\eta}} \right]^{\frac{1}{1-\frac{1}{\eta}}} \right\}$$

FOC for $c_{i,t}$ is:

$$P_{i,t} = \tilde{\psi}_t \left[\int_0^1 \left(\frac{c_{i,t}}{s_{i,t-1}^{\theta}} \right)^{1-\frac{1}{\eta}} \right]^{\frac{1}{1-\frac{1}{\eta}}-1} \left(\frac{c_{i,t}}{s_{i,t-1}^{\theta}} \right)^{-\frac{1}{\eta}} s_{i,t-1}^{-\theta}$$

which is

$$\left(\frac{c_{i,t}}{s_{i,t-1}^{\theta}} \right)^{\frac{1}{\eta}} = \frac{\tilde{\psi}_t}{P_{i,t}} \left[\int_0^1 \left(\frac{c_{i,t}}{s_{i,t-1}^{\theta}} \right)^{1-\frac{1}{\eta}} \right]^{\frac{1}{1-\frac{1}{\eta}}-1} s_{i,t-1}^{-\theta}$$

which is the good-specific demand in function $\tilde{\psi}_t$:

$$c_{i,t} = \left(\frac{P_{i,t}}{\tilde{\psi}_t} \right)^{-\eta} s_{i,t-1}^{\theta(1-\eta)} q_t$$

Now substitute this equation into the definition for q_t:

$$q_t = \left[\int_0^1 \left(P_{i,t}^{-\eta} \, \psi_t^{\eta} \, s_{i,t-1}^{\theta(1-\eta)} \, q_t \right)^{\frac{\eta-1}{\eta}} s_{i,t-1}^{\frac{\theta(1-\eta)}{\eta}} \, di \right]^{\frac{\eta}{\eta-1}}$$

which is

$$\tilde{\psi}_t = \left[\int_0^1 \left(P_{i,t}^{-\eta} \, s_{i,t-1}^{\theta(1-\eta)} \right)^{\frac{\eta-1}{\eta}} s_{i,t-1}^{\frac{\theta(1-\eta)}{\eta}} \, di \right]^{\frac{1}{1-\eta}}$$

which delivers

$$\tilde{\psi}_t = \left[\int_0^1 (\, P_{i,t} \, s_{i,t-1}^{\theta} \,)^{1-\eta} \, di \right]^{\frac{1}{1-\eta}}$$

Define $p_{i,t} = P_{i,t}/P_t$ as the variety i price $P_{i,t}$ in terms of the price index $P_t = [\int_0^1 P_{i,t}^{1-\eta} di]^{\frac{1}{1-\eta}}$. This yields

$$\tilde{\psi}_t = \left[\int_0^1 (\ p_{i,t}\ s_{i,t-1}^{\theta}\ )^{1-\eta}\ di \right]^{\frac{1}{1-\eta}} P_t$$

where

$$\frac{\tilde{\psi}_t}{P_t} = \left[\int_0^1 (\ p_{i,t}\ s_{i,t-1}^{\theta}\ )^{1-\eta}\ di \right]^{\frac{1}{1-\eta}} \equiv \tilde{p}_t$$

This implies that

$$c_{i,t} = \left(\frac{P_{i,t}}{\tilde{\psi}_t}\right)^{-\eta} s_{i,t-1}^{\theta(1-\eta)} q_t = \left(\frac{P_{i,t}/P_t}{\tilde{\psi}_t/P_t}\right)^{-\eta} s_{i,t-1}^{\theta(1-\eta)} q_t = \left(\frac{p_{i,t}}{\tilde{p}_t}\right)^{-\eta} s_{i,t-1}^{\theta(1-\eta)} q_t$$

G.2 Household utility maximization problem

Household maximization problem is:

$$\max_{q_t, n_t, b_t} \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left[\frac{(q_{t+s})^{1-\gamma_q}}{1-\gamma_q} + \chi_n \log(1-n_{t+s}) + \chi_x \log\left(\frac{X_{t+s-1}}{P_t}\right) \right]; \quad 0 < \beta < 1$$

subject to

$$\tilde{p}_t q_t + \frac{B_t}{P_t} + \frac{X_t^h}{P_t} = w_t n_t + R_{t-1}\frac{B_{t-1}}{P_t} + R_{t-1}^x \frac{X_{t-1}^h}{P_t} + \tau_t$$

where τ_t represents a series of payments –not internalized by the household– that firms and the fiscal authority transfer to the household such that $c_t = y_t$ in every period. In addition, notice that the budget constraint is in real terms because everything is divided over P_t. You can notice that because

$$\begin{aligned}
\int_0^1 \frac{P_{i,t}}{P_t} c_{i,t} di &= \int_0^1 p_{i,t} c_{i,t} di \\
&= \int_0^1 p_{i,t} \left(\frac{p_{i,t}}{\tilde{p}_t}\right)^{-\eta} s_{i,t-1}^{\theta(1-\eta)} q_t di \\
&= \tilde{p}_t^{\eta} q_t \int_0^1 p_{i,t}^{1-\eta} s_{i,t-1}^{\theta(1-\eta)} di \\
&= \tilde{p}_t^{\eta} q_t \tilde{p}_t^{1-\eta} \\
&= \tilde{p}_t q_t
\end{aligned}$$

Moreover, it can be also proved that

$$\tilde{p}_t q_t = c_t = y_t$$

The first equality holds because –invoking symmetry– we have that $\tilde{p}_t = s^{\theta}_{t-1}$ and $s^{\theta}_{t-1} q_t = c_t$. The second equality holds because it is assumed that the firm is committing to produce $y_{i,t} = c_{i,t}$ regardless of $a_{i,t}$.
Set up the Lagrangian,

$$L = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \Bigg\{ \frac{q_{t+s}^{1-\gamma_q}}{1-\gamma_q} + \chi_n \log(1 - n_{t+s}) + \chi_x \log\left(\frac{X^h_{t+s-1}}{P_{t+s}}\right)$$
$$+ \lambda_{t+s} \left[w_{t+s} n_{t+s} + R_{t+s-1} \frac{B_{t+s-1}}{P_{t+s}} + R^x_{t+s-1} \frac{X^h_{t+s-1}}{P_{t+s}} + \tau_{t+s} - \tilde{p}_{t+s} q_{t+s} - \frac{B_{t+s}}{P_{t+s}} - \frac{X^h_{t+s}}{P_{t+s}} \right] \Bigg\}$$

FOC for q_t is,

$$q_t^{-\gamma_q} - \lambda_t \tilde{p}_t = 0 \qquad \Rightarrow \qquad \lambda_t = \frac{q_t^{-\gamma_q}}{\tilde{p}_t}.$$

FOC for n_t is,

$$-\frac{\chi_n}{1-n_t} + \lambda_t w_t = 0 \qquad \Rightarrow \qquad \frac{w_t}{\tilde{p}_t} = q_t^{\gamma_q} \frac{\chi_n}{1-n_t}.$$

FOC for B_t is,

$$-\lambda_t \frac{1}{P_t} + \beta\, \mathbb{E}_t \left[\lambda_{t+1} \frac{R_t}{P_{t+1}} \right] = 0 \quad \Rightarrow \quad 1 = \mathbb{E}_t \left[m_{t+1} \frac{R_t}{\pi_{t+1}} \right]$$

where $\pi_{t+1} = P_{t+1}/P_t$ and $m_{t+1} = \beta\ \tilde{p}_t/\tilde{p}_{t+1}\ (q_{t+1}/q_t)^{-\gamma_q}$.
FOC for X^h_t is,

$$\beta \frac{\chi_x}{X^h_t} - \lambda_t \frac{1}{P_t} + \beta\, \mathbb{E}_t \left[\lambda_{t+1} \frac{1}{P_{t+1}} R^x_t \right] = 0 \quad \Rightarrow \quad 1 = \beta \chi_x \frac{\tilde{p}_t q_t^{\gamma_q}}{x^h_t} + \frac{R^x_t}{R_t}.$$

where $x^h_t = \frac{X^h_t}{P_t}$ and $R_t = \pi_{t+1}/m_{t+1}$. This yields the following demand for real liquid assets:

$$x^h_t = \beta \chi_x \frac{R_t}{R_t - R^x_t} \lambda_t^{-1}.$$

G.3 Firm profit maximization problem

Set up the Lagrangian

$$
\begin{aligned}
L = \mathbb{E}_0 \sum_{t=0}^{\infty} m_t \Bigg\{ & d_{i,t} + \kappa_{i,t}\left[\left(\frac{A_t}{a_{i,t}} n_{i,t}\right)^{\alpha} - \phi - c_{i,t}\right] \\
& + \xi_{i,t}\left[p_{i,t}c_{i,t} - w_t n_{i,t} - \frac{\gamma_p}{2}\left(\pi_t \frac{p_{i,t}}{p_{i,t-1}} - \pi_{ss}\right)^2 c_t + R^x_{t-1}\frac{X^f_{i,t-1}}{P_t} + g\left(\frac{X^f_{i,t-1}}{P_t}\right)\right. \\
& \left. - \frac{X^f_{i,t}}{P_t} - d_{i,t} + \varphi_t \min\{0, d_{i,t}\}\right] \\
& + \nu_{i,t}\left[\left(\frac{p_{i,t}}{\tilde{p}_t}\right)^{-\eta} s_{i,t-1}^{\theta(1-\eta)} q_t - c_{i,t}\right] + \lambda_{i,t}\left[\rho s_{i,t-1} + (1-\rho)c_{i,t} - s_{i,t}\right]\Bigg\}
\end{aligned}
$$

FOC for $d_{i,t}$:

$$
\xi_{i,t} = \begin{cases} 1 \ \text{ if } \ d_{i,t} \geq 0 \\ 1/(1-\varphi_t) \ \text{ if } \ d_{i,t} < 0 \end{cases}
$$

where, in aggregate,

$$
\xi_t = \mathbb{E}^a_t[\xi_{i,t}] = \int_0^{\bar{a}_t} dF(a) + \int_{\bar{a}_t}^{\infty} \frac{1}{1-\varphi_t} dF(a) = 1 + \left[\frac{\varphi_t}{1-\varphi_t}\right][1 - \Phi(\bar{z}_t)]
$$

where $\bar{a}_t$ is the value of idiosyncratic productivity $a_{i,t}$ such that $d_{i,t} = 0$:

$$
c_t - w_t n_t - \frac{\gamma_p}{2}(\pi_t - \pi_{ss})^2 c_t + R^x_{t-1} x^f_{t-1} + g(x^f_{t-1}) - x^f_t = 0,
$$

from the production function,

$$
n_t = \frac{a_t}{A_t}(c_t + \phi)^{\frac{1}{\alpha}}.
$$

Substitute n_t into the flow-of-funds constraint with $d_t = 0$. This yields,

$$
c_t - w_t \frac{\bar{a}_t}{A_t}(c_t + \phi)^{\frac{1}{\alpha}} - \frac{\gamma_p}{2}(\pi_t - \pi_{ss})^2 c_t + R^x_{t-1} x^f_{t-1} + g(x^f_{t-1}) - x^f_t = 0,
$$

which is

$$
\bar{a}_t = \frac{1}{(c_t + \phi)^{\frac{1}{\alpha}}} \frac{A_t}{w_t} \left\{ c_t \left[1 - \frac{\gamma_p}{2}(\pi_t - \pi_{ss})\right] + R^x_{t-1} x^f_{t-1} + g(x^f_{t-1}) - x^f_t \right\}
$$

and, finally, since $\log a_t \sim N(-0.5\sigma^2, \sigma^2)$

$$\bar{z}_t = \frac{1}{\sigma}(\log \bar{a}_t + 0.5\sigma^2).$$

FOC for $n_{i,t}$:

$$\kappa_{i,t}\alpha\left(\frac{A_t}{a_{i,t}}n_{i,t}\right)^{\alpha-1}\frac{A_t}{a_{i,t}} - \xi_{i,t}w_t = 0$$

which is

$$\kappa_{i,t} = \xi_{i,t}a_{i,t}\left(\frac{w_t}{\alpha A_t}\right)(c_{i,t}+\phi)^{\frac{1-\alpha}{\alpha}}$$

which, in aggregate, is

$$\kappa_t = \mathbb{E}_t^a[\xi_{i,t}a_{i,t}]\left(\frac{w_t}{\alpha A_t}\right)(c_t+\phi)^{\frac{1-\alpha}{\alpha}}$$

where $E_t^a[\xi_{i,t}a_{i,t}] = 1 + \varphi_t/(1-\varphi_t)[1-\Phi(\bar{z}_t - \sigma)]$.

FOC for $c_{i,t}$:

$$-\mathbb{E}_t^a[\kappa_{i,t}] + \mathbb{E}_t^a[\xi_{i,t}]p_{i,t} - \mathbb{E}_t^a[\nu_{i,t}] + (1-\rho)\,\mathbb{E}_t^a[\lambda_{i,t}] = 0$$

which is

$$\mathbb{E}_t^a[\nu_{i,t}] = \mathbb{E}_t^a[\xi_{i,t}]p_{i,t} - \mathbb{E}_t^a[\kappa_{i,t}] + (1-\rho)\,\mathbb{E}_t^a[\lambda_{i,t}]$$

which, in aggregate, is

$$\nu_t = \xi_t - \kappa_t + (1-\rho)\lambda_t.$$

FOC for $s_{i,t}$:

$$\theta(1-\eta)\,\mathbb{E}_t^a\left[m_{t+1}\nu_{i,t+1}\left(\frac{p_{i,t+1}}{\tilde{p}_{t+1}}\right)^{-\eta}s_{i,t}^{\theta(1-\eta)-1}q_{t+1}\right] - \mathbb{E}_t^a[\lambda_{i,t}] + \rho\,\mathbb{E}_t^a[m_{t+1}\lambda_{i,t+1}] = 0$$

which is

$$\mathbb{E}_t^a[\lambda_{i,t}] = \rho\,\mathbb{E}_t^a[m_{t+1}\lambda_{i,t+1}] + \theta(1-\eta)\,\mathbb{E}_t^a\left[m_{t+1}\nu_{i,t+1}\frac{c_{i,t+1}}{s_{i,t}}\right]$$

which, in aggregate, is

$$\lambda_t = \rho\,\mathbb{E}_t[m_{t+1}\lambda_{t+1}] + \theta(1-\eta)\,\mathbb{E}_t\left[m_{t+1}\nu_{t+1}\frac{c_{t+1}}{s_t}\right].$$

FOC for $p_{i,t}$:

$$\mathbb{E}_t^a[\xi_{i,t}]\left[c_{i,t} - \gamma_p\left(\pi_t \frac{p_{i,t}}{p_{i,t-1}} - \pi_{ss}\right)\frac{\pi_t}{p_{i,t-1}} c_t\right]$$
$$- \mathbb{E}_t^a\left[m_{t+1}\xi_{i,t+1}\gamma_p\left(\pi_{t+1}\frac{p_{i,t+1}}{p_{i,t}} - \pi_{ss}\right)\pi_{t+1}\frac{p_{i,t+1}}{p_{i,t}^2}c_{t+1}\right] + \eta\,\mathbb{E}_t^a[\nu_{i,t}]\left(\frac{p_{i,t}}{\tilde{p}_t}\right)^{-\eta-1}\frac{1}{\tilde{p}_t}s_{i,t-1}^{\theta(1-\eta)}q_t = 0$$

which is

$$\mathbb{E}_t^a[\xi_{i,t}]\left[c_{i,t} - \gamma_p\left(\pi_t \frac{p_{i,t}}{p_{i,t-1}} - \pi_{ss}\right)\frac{\pi_t}{p_{i,t-1}} c_t\right]$$
$$- \mathbb{E}_t^a\left[m_{t+1}\xi_{i,t+1}\gamma_p\left(\pi_{t+1}\frac{p_{i,t+1}}{p_{i,t}} - \pi_{ss}\right)\pi_{t+1}\frac{p_{i,t+1}}{p_{i,t}^2}c_{t+1}\right] + \eta\,\mathbb{E}_t^a[\nu_{i,t}]\frac{c_{i,t}}{p_{i,t}} = 0$$

which, in aggregate, is

$$\xi_t\big[c_t - \gamma_p\big(\pi_t - \pi_{ss}\big)\pi_t c_t\big] - \mathbb{E}_t\left[m_{t+1}\xi_{t+1}\gamma_p\big(\pi_{t+1} - \pi_{ss}\big)\pi_{t+1}c_{t+1}\right] + \eta\nu_t c_t = 0$$

which is

$$\xi_t\big[1 - \gamma_p\big(\pi_t - \pi_{ss}\big)\pi_t\big] - \mathbb{E}_t\left[m_{t+1}\xi_{t+1}\gamma_p\big(\pi_{t+1} - \pi_{ss}\big)\pi_{t+1}\frac{c_{t+1}}{c_t}\right] + \eta\nu_t = 0$$

which is

$$1 = \gamma_p\big(\pi_t - \pi_{ss}\big)\pi_t - \mathbb{E}_t\left[m_{t+1}\frac{\xi_{t+1}}{\xi_t}\gamma_p\big(\pi_{t+1} - \pi_{ss}\big)\pi_{t+1}\frac{c_{t+1}}{c_t}\right] + \eta\frac{\nu_t}{\xi_t} = 0.$$

FOC for $X_{i,t}^f$:

$$-\mathbb{E}_t^a[\xi_{i,t}^f]\frac{1}{P_t} + \mathbb{E}_t^a\left\{m_{t+1}\xi_{i,t+1}^f\left[R_t^x\frac{1}{P_{t+1}} + g'\left(\frac{X_{i,t}^f}{P_t}\right)\frac{1}{P_{t+1}}\right]\right\} = 0$$

which is

$$1 = \mathbb{E}_t^a\left\{\frac{m_{t+1}}{\pi_{t+1}}\frac{\xi_{i,t+1}}{\xi_{i,t}}\big[R_t^x + g'(x_{i,t}^f)\big]\right\},$$

where $x_t^f = X_t^f/P_t$. This, in aggregate, yields

$$1 = \mathbb{E}_t\left\{\frac{\xi_{t+1}}{\xi_t}\frac{R_t^x + g'(x_t^f)}{R_t}\right\},$$

where $g(x) = \zeta_x x^{1-\iota}/(1-\iota)$ with $\iota \in (0,1)$. We can isolate the real value of liquid assets x_t^f to obtain the demand for liquid assets,

$$x_t^f = \mathbb{E}_t \left\{ \zeta_x^{\frac{1}{\omega}} \left[\frac{\xi_{t+1}}{\xi_t R_t - \xi_{t+1} R_t^x} \right]^{\frac{1}{\omega}} \right\}$$

where x_t^f is increasing in ζ_x (firm has more appetite for x_t^f), $E_t^a[\xi_{t+1}]$ (firm needs more resources in future), and R_t^x (interest on liquid assets pay better); and is decreasing in ξ_t (firm needs more resources today) and R_t (the households wants more resources from the firm today since they want to save in bonds as they pay better).

G.4 Derivation of the Phillips curve

Given the first order condition, after aggregation, for $p_{i,t}$:

$$\gamma_p \big(\pi_t - \pi_{ss} \big) \pi_t = \mathbb{E}_t \left[m_{t+1} \frac{\xi_{t+1}}{\xi_t} \gamma_p \big(\pi_{t+1} - \pi_{ss} \big) \pi_{t+1} \frac{c_{t+1}}{c_t} \right] - \eta \frac{\nu_t}{\xi_t} = 0,$$

take the total differential:

$$\gamma_p \big[\pi_{ss} \partial \pi_t + (\pi_{ss} - \pi_{ss}) \partial \pi_t \big] = \mathbb{E}_t \left[m_{ss} \frac{\xi_{ss}}{\xi_{ss}} \gamma_p \partial \pi_{t+1} \pi_{ss} \frac{c_{ss}}{c_{ss}} + (\pi_{ss} - \pi_{ss}) \Theta_t \right] + \eta \frac{\nu_{ss}}{\xi_{ss}} \left(\frac{\partial \xi_t}{\xi_{ss}} - \frac{\partial \nu_t}{\nu_{ss}} \right)$$

which is,

$$\hat{\pi}_t = \beta \, \mathbb{E}_t \left[\hat{\pi}_{t+1} \right] + \tilde{\eta} (\hat{\xi}_t - \hat{\nu}_t)$$

where ∂x_t is the differential of variable x_t, $\hat{x}_t = \partial x_t / x_{ss}$, π_{ss} is equal to one, m_{ss} is equal to β, and $\tilde{\eta} = (\eta \nu_{ss})/(\gamma_p \xi_{ss}) > 0$.

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