

Macroeconomic Effects of Financial Uncertainty

Grzegorz Długoszek*

February 15, 2018

Abstract

This paper investigates the macroeconomic effects of uncertainty originating in the financial sector by using the DSGE framework developed by Gertler and Karadi (2011). The model generates macroeconomic dynamics that are consistent with the empirical evidence. In particular, an increase in the financial uncertainty raises the risk premium and leads to a decline in output, consumption, investment and hours worked. This outcome arises mainly because of an endogenous tightening of the financial constraint, which in turn triggers the financial accelerator mechanism. Finally, nominal and real rigidities act as additional amplification mechanisms for financial uncertainty shocks.

Keywords: Stochastic Volatility, Financial Frictions, Financial Uncertainty

JEL Classification Numbers: E32, E44

*Humboldt-Universität zu Berlin, School of Business and Economics, Spandauer Straße 1, 10178 Berlin,
Email: dlugoszg@hu-berlin.de.

1 Introduction

There exists a rapidly growing literature on the macroeconomic implications of uncertainty shocks. Interest in this topic has been sparked by the robust observation that uncertainty rises in recessions (see, e.g., Bloom (2009), Jurado et al. (2015)). The DSGE literature on this issue focuses on the real economic uncertainty, i.e., uncertainty surrounding economic fundamentals, such as total factor productivity or economic policy.¹ Even studies assessing the role of financial frictions as a propagator of economic uncertainty investigate uncertainty originating in the real sector.² However, Ng and Wright (2013) document that all the post-1982 recessions have origins in the financial markets. Moreover, Ludvigson et al. (2015) argue that changes in the financial market uncertainty are most likely the source of economic fluctuations, while movements in macroeconomic uncertainty seem to be an endogenous response to fundamentals.

The aim of this study is to contribute to the existing literature by investigating the macroeconomic implications and transmission mechanism of financial uncertainty, i.e., uncertainty originating from the financial sector. My contribution is twofold: firstly I estimate a Vector Autoregressive (VAR) model and show that financial uncertainty reduce main macroeconomic aggregates. Secondly, to uncover the transmission mechanism of financial uncertainty shocks, I introduce time-varying volatility of financial disturbances to the DSGE model developed by Gertler and Karadi (2011). Since this framework embeds financial intermediaries operating under funding constraints, it is suitable to investigate the effects of uncertainty regarding disturbances originating in the financial sector. The model is shown to be able to generate dynamics of the macroeconomic variables that are consistent with the empirical evidence. In particular, output, investment, consump-

¹The DSGE literature has investigated a variety of types of real uncertainty. Caldara et al. (2012) consider total factor productivity, whereas Fernández-Villaverde et al. (2011) focus on foreign interest rate in a small-open economy setup. Moreover, Born and Pfeifer (2014) investigate the fiscal uncertainty while Mumtaz and Zanetti (2013) look at uncertainty surrounding monetary policy.

²See, among others, Christiano et al. (2014), Gilchrist et al. (2014), Arellano et al. (2016) and Bonciani and Van Roye (2016).

tion and hours worked drop while risk premium rises in response to an increase in financial uncertainty. The key feature of the model responsible for this outcome is the endogenous tightening of the endogenous leverage constraint, which in turn triggers the financial accelerator mechanism. Specifically, due to an increase in financial uncertainty households provide less funding to the financial intermediaries. This reduces the aggregate investment and thus asset prices fall. As a consequence, financial position of the intermediaries deteriorates even further, which forces them to reduce their lending again. Finally, nominal and real rigidities act as additional amplification mechanisms for financial uncertainty shocks.

This paper is organized as follows. Section 2 presents the empirical evidence on macroeconomic effects of financial uncertainty. The theoretical model is presented in section 3. In section 4, I discuss the method used to solve the model and present the chosen calibration. Section 5 presents the results. In particular, I document the dynamics implied by the model and assess the importance of various features of the framework for the transmission mechanism. Finally, section 6 concludes.

2 Empirical Evidence

To provide empirical evidence on the relevance of financial uncertainty on economic fluctuations, I estimate a VAR model using quarterly U.S. data for the period 1986:Q1-2015:Q3. The structural model is given by

$$A_0 y_t = A_1 y_{t-1} + \dots + A_{t-p} y_{t-p} + \epsilon_t \quad (1)$$

where y_t is an $n \times 1$ vector of variables of interest and $\epsilon_t \sim \mathcal{N}(0, I_n)$. The corresponding reduced-form VAR can then be written as

$$y_t = B_1 y_{t-1} + \dots + B_p y_{t-p} + u_t \quad (2)$$

with $B_j \equiv A_0^{-1}A_j$ and $u_t \equiv A_0^{-1}\epsilon_t \sim \mathcal{N}(0, \Sigma_u)$.

I include ten variables in the estimation: a measure of financial uncertainty, a measure of macroeconomic uncertainty, per capita real GDP, per capita consumption, per capita investment, hours worked, the GDP implicit price deflator, risk premium measured by the difference between BAA corporate bond yield and 10 year treasury yield, the S&P 500 index, and the federal fund rate. A detailed description of the data can be found in the appendix. All variables except the GDP deflator, the risk premium and the federal funds rate enter the VAR in log levels and are detrended by applying the HP filter with a smoothing parameter of 1600.

The series of financial uncertainty is taken from Ludvigson et al. (2015), whereas the index for macroeconomic uncertainty is constructed by Jurado et al. (2015). Both uncertainty measures aggregate a large number of estimated uncertainties constructed from a large set of data including a variety of economic or financial indicators. Uncertainty associated with an individual series x_t is defined as volatility of its h -period ahead forecast error (Ludvigson et al., 2015):

$$U_x(h) \equiv \sqrt{E_t \left[(x_{t+h} - E_t[x_{t+h}])^2 \right]} \quad (3)$$

where E_t denotes the expectation operator given the information set in period t .³ As argued by Jurado et al. (2015), the advantage of these measures is that they can truly capture the degree to which the economy has become more or less predictable, i.e., uncertain. In contrast, other existing proxies reflect rather time-varying dispersion or volatility of the economic indicators. Moreover, they can often provide misleading information. For example, stock market volatility can fluctuate even if uncertainty remains constant due to changes in investors' risk aversion or sentiment.

Following a large body of empirical literature, financial uncertainty shocks are iden-

³The data sets constructed by Jurado et al. (2015) and Ludvigson et al. (2015) include three different forecast horizons: one month, one quarter and one year. In the following, I use quarterly forecasts to match the frequency of the other time series.

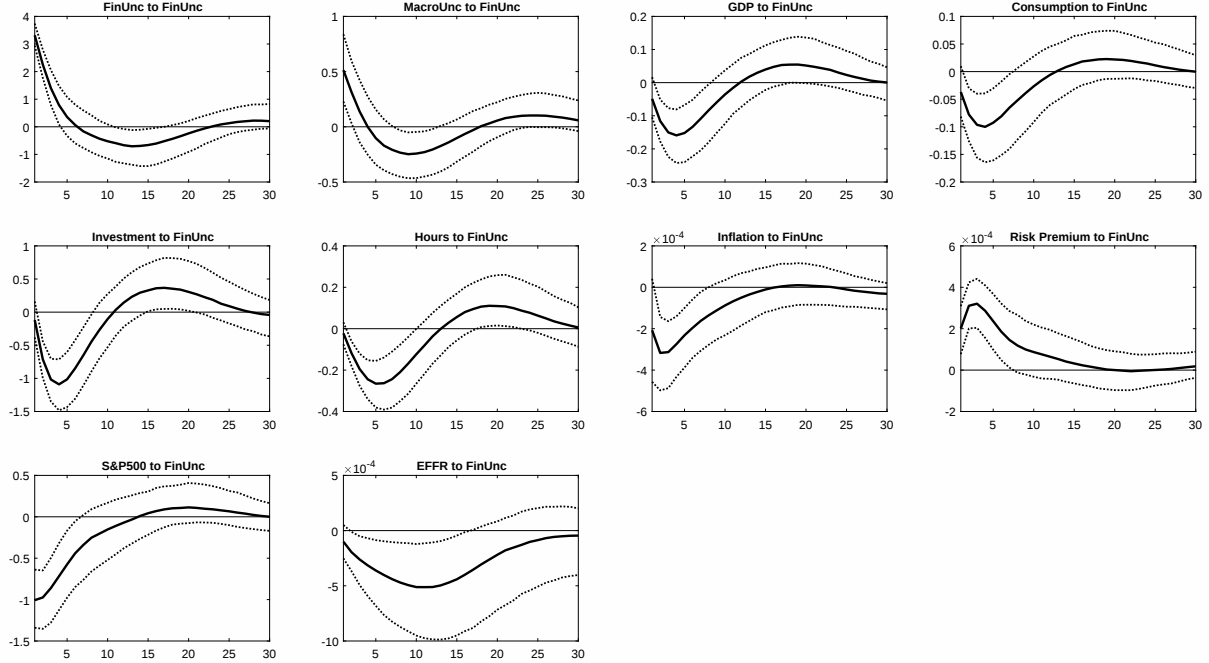


Figure 1: Dynamic consequences of one-standard-deviation increase in the financial uncertainty. Responses of all variables except the GDP deflator, the risk premium and the federal funds rate are expressed in percentage points.

tified using a Cholesky decomposition.⁴ The variables are ordered in the same way they were previously presented. Thus, the measure of financial uncertainty is ordered first and is followed by the macroeconomic uncertainty and the remaining macroeconomic variables.⁵ This ordering is consistent with the theoretical model discussed in section 3 and the underlying intuition is in line with the main findings of Ludvigson et al. (2015).⁶ In particular, these authors construct a novel measure of financial uncertainty and conduct an empirical investigation by employing correlation and event constraints. They find evidence that financial uncertainty has significant contemporaneous effects on both

⁴See, among others, Bloom (2009), Bachmann and Bayer (2013), Basu and Bundick (2017) and Jurado et al. (2015).

⁵As a robustness test, I consider an alternative ordering of variables where the uncertainty measures are ordered last. The results can be found in the appendix. They do not substantially differ from the ones reported here.

⁶This ordering is also similar to the one used by Richter and Throckmorton (2017). These authors develop a new method to quantify the effects of uncertainty using estimates from a nonlinear DSGE model. In their study, they also distinguish between financial and macroeconomic uncertainty. However, their framework does not include an explicit financial sector and they model financial uncertainty as a second-moment shock to the return on the nominal bond.

real activity and macro uncertainty. Simultaneously, they argue that it is not affected by real level and uncertainty shocks. Therefore, changes in the financial uncertainty are most likely a source of economic fluctuations and not an endogenous response to other disturbances. This idea underlies both my empirical and theoretical analysis.

I estimate the model up to four lags and determine the appropriate specification by using the Bayesian information criterion, according to which the data prefers the model with one lag. Figure 7 plots the impulse responses to an identified financial uncertainty shock along with the 90 % confidence intervals. A one-standard-deviation increase in the financial uncertainty tightens financial conditions in the economy as shown by the rise in the risk premium and a drop in the equity prices. It also leads to statistically significant declines in output, consumption, investment and hours worked. The peak response occurs after about a year and amounts in case of the GDP to a drop of 0.18%. The subsequent recovery is followed by a rebound - a phenomenon labeled by Bloom (2009) as *volatility overshoot*. For example, in case of the GDP the overshoot arises after about three years.

3 The Model

To shed light on the transmission mechanism of uncertainty shocks originating in the financial sector, I employ the New Keynesian model with financial frictions developed by Gertler and Karadi (2011). One period corresponds to one quarter and there are six types of agents in the model: households, financial intermediaries, intermediate goods producers, monopolistically competitive retailers, capital producers and a central bank, whose actions are described by a standard Taylor-rule.

3.1 Households

There exists a continuum of identical households of unity mass. Within each household, there are $1 - f$ workers and f bankers. Workers supply labor and earn wages whereas each banker manages a financial intermediary and accumulates funds ("net worth") which she transfers to the household upon exiting the business. To merge the within-household heterogeneity with the representative agent framework, I assume that there is perfect consumption sharing within each family.

Household's preferences are given by:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\gamma} (C_t - hC_{t-1})^{1-\gamma} - \frac{\chi}{1+\varphi} L_t^{1+\varphi} \right] \quad (4)$$

where C_t denotes consumption and L_t is labor supply. Moreover, $\beta \in (0, 1)$ refers to the discount factor, $h \in (0, 1)$ is parameter governing internal habit formation and γ represents the inverse of the intertemporal elasticity of substitution. Finally, φ is the inverse of Frish elasticity of labor supply and χ denotes the weight of disutility of labor supply.

Households do not have a direct access to the capital stock. Rather, they save by depositing funds at financial intermediaries. It is best to imagine that households supply funds to banks other than the ones they own. Bank deposits, denoted by D_t , are one period real riskless bonds paying the gross real return R_{t-1} from $t - 1$ to t . The budget constraint faced by the household is thus given by:

$$C_t + D_t = W_t L_t + R_{t-1} D_{t-1} + T_t \quad (5)$$

where W_t refers to the real wage and T_t are net profits from the ownership of both non-financial firms and financial intermediaries. Let U_{C_t} denote the marginal utility of consumption and $\Lambda_{t,t+1}$ the household's stochastic discount factor. Then maximizing

the life-time utility with respect to consumption, labor and savings subject to the flow of funds constraint (5) yields the following first-order conditions:

$$W_t U_{Ct} = \chi L_t^\varphi \quad (6)$$

with $U_{Ct} = (C_t - hC_{t-1})^{-\gamma} - \beta h E_t [(C_{t+1} - hC_t)^{-\gamma}]$ and

$$E_t [\Lambda_{t,t+1}] R_t = 1 \quad (7)$$

with $\Lambda_{t,t+1} \equiv \beta \frac{U_{Ct+1}}{U_{Ct}}$.

3.2 Nonfinancial Firms

There are three types of nonfinancial firms: intermediate goods producers, monopolistically competitive retailers and capital producers.

Intermediate Goods Producers

In period t competitive firms with identical constant returns to scale technology combine capital stock purchased at the end of period $t - 1$, K_{t-1} and labor, L_t , to produce intermediate goods, Y_{mt} . This process is governed by the following Cobb-Douglas production function:

$$Y_{mt} = A_t (\xi_t K_{t-1})^\alpha L_t^{1-\alpha} \quad (8)$$

where $\alpha \in (0, 1)$, A_t denotes the exogenously given technology level and ξ_t refers to the capital quality shock.⁷ There are no adjustment costs at the firm level and thus the intermediate capital producers' maximization problem is static. In particular, at the end of each period the firm sells the remaining capital stock used previously in the production process and purchase new capital that will be employed in the subsequent period.

⁷See, among others, Gertler and Kiyotaki (2010), Gertler and Karadi (2011) and Dedola et al. (2013).

To finance capital acquisition, the firm must obtain funds from financial intermediaries. To this end, it issues state contingent claims in the amount equal to the number of purchased capital units. Thus, the arbitrage requires that these claims are traded at the price of a unit of capital, Q_t . Given that R_{kt} denotes the gross real interest rate paid on the state contingent securities, the intermediate good producers choose production factors to maximize their (expected) profits:

$$E_t [P_{mt+1}Y_{mt+1} + Q_{t+1} (1 - \delta) K_t - W_{t+1}L_{t+1} - R_{kt+1}K_t] \quad (9)$$

where P_{mt} denotes the price of intermediate goods relative to the final consumption good and δ is the depreciation rate. Solving this maximization problem yields the following first-order conditions:

$$W_t = P_{mt} (1 - \alpha) (\xi_t K_{t-1})^\alpha L_t^{-\alpha}, \quad \forall t \quad (10)$$

$$R_{kt} = \frac{\alpha P_{mt} A_t \xi_t^\alpha K_{t-1}^{\alpha-1} L_t^{1-\alpha} + Q_t (1 - \delta)}{Q_{t-1}}, \quad \forall t \quad (11)$$

Note that under assumptions of competitive firms and constant returns to scale, the intermediate producers make zero profits in equilibrium.

Retailers

There exists a continuum of mass unity of monopolistically competitive retailers who repackage the intermediate output. They require one unit of the intermediate good to produce one unit of the retailer output. Hence, the marginal cost of the final good production is simply P_{mt} .

Final output, Y_t , is given by the CES aggregator of differentiated retailer goods, Y_{it} :

$$Y_t = \left[\int_0^1 Y_{it}^{\frac{\varrho-1}{\varrho}} di \right]^{\frac{\varrho}{\varrho-1}} \quad (12)$$

where $\varrho > 1$ is the elasticity of substitution between different retailer goods. Cost minimization by the final output user yields:

$$Y_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\varrho} Y_t \quad (13)$$

and

$$P_t = \left[\int_0^1 P_{it}^{1-\varrho} di \right]^{\frac{1}{1-\varrho}}. \quad (14)$$

Retailers face nominal rigidities à la Calvo (1983).⁸ In particular, each period a retailer is able to adjust her prices with probability $1 - \theta_{calvo}$. Therefore, a retailer, updating her price in period t , chooses the reset price, P_t^* , that maximizes the sum of expected discounted profits generated while the price remains valid:

$$\max E_t \left[\sum_{k=0}^{\infty} \theta_{calvo}^k \Lambda_{t,t+k} \left(\frac{P_t^*}{P_{t+k}} - P_{mt+k} \right) Y_{it+k} \right] \quad (15)$$

The corresponding first-order condition is given by:

$$E_t \left[\sum_{k=0}^{\infty} \theta_{calvo}^k \Lambda_{t,t+k} \left(\frac{P_t^*}{P_{t+k}} - \frac{\varrho-1}{\varrho} P_{mt+k} \right) \left(\frac{P_t^*}{P_{t+k}} \right)^{-\varrho} Y_{it+k} \right] = 0 \quad (16)$$

By rearranging (16) one can obtain following relationship:

$$\Pi_t^* = \frac{\varrho}{\varrho-1} \frac{X_{1,t}}{X_{2,t}} \Pi_t \quad (17)$$

with $\Pi_t^* \equiv \frac{P_t^*}{P_{t-1}}$ and $\Pi_t \equiv \frac{P_t}{P_{t-1}}$. $X_{1,t}$ and $X_{2,t}$ are defined recursively as:

$$X_{1,t} = Y_t P_{mt} + \theta_{calvo} E_t \left[\Lambda_{t,t+1} \Pi_{t+1}^{\varrho} X_{1,t+1} \right] \quad (18)$$

⁸Note that the heterogeneity introduced by the Calvo assumption may in general require tracking distributions when the model is solved with a higher-order perturbation (Born and Pfeifer, 2014). However, this is not the case in the underlying framework. The reason for this is that retailers only repackage goods and update their prices, whenever this is possible. They do not make any further decisions, especially regarding factors of production.

$$X_{2,t} = Y_t + \theta_{calvo} E_t \left[\Lambda_{t,t+1} \Pi_{t+1}^{\varrho-1} X_{2,t+1} \right] \quad (19)$$

The relationship between aggregate final output and aggregate intermediate production can be written as:

$$Y_t = Y_{mt} \Delta_{pt} \quad (20)$$

where Δ_{pt} is the dispersion of individual prices. Its law of motion is given by:

$$\Delta_{pt} = \theta_{calvo} \Delta_{pt-1} \Pi_t^{\varrho} + (1 - \theta_{calvo}) \left(\frac{\Pi_t^*}{\Pi_t} \right)^{-\varrho} \quad (21)$$

Moreover, the aggregate price index, given by (14), can be rewritten under the Calvo assumption as:

$$\Pi_t^{1-\varrho} = (1 - \theta_{calvo}) (\Pi_t^*)^{1-\varrho} \quad (22)$$

Finally, note that since P_{mt} represents the price of the intermediate goods relative to the final output, the markup of monopolistic retailers, X_t , is its inverse:

$$X_t = \frac{1}{P_{mt}}. \quad (23)$$

Capital Producers

Competitive capital producers transform the final output into new capital. To produce I_t units of new capital (i.e. investment), the firm needs to purchase $(1 + f_{inv}(\cdot)) I_t$ units of the final good. $f_{inv}(\cdot)$ denotes investment adjustment costs introduced to generate time-variation in the price of capital. Following Gertler and Kiyotaki (2010), I assume the following functional form for the adjustment costs:

$$f_{inv}(I_t, I_{t-1}) = \frac{\eta}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \quad (24)$$

with $\eta > 0$. The capital producers chooses I_t that maximizes expected lifetime profits given by:

$$E_t \left[\sum_{k=0}^{\infty} \Lambda_{t,t+k} (Q_{t+k} I_{t+k} - [1 + f_{inv}(I_{t+k}, I_{t+k-1})] I_{t+k}) \right] \quad (25)$$

The corresponding first-order condition determines the price of one unit of capital:

$$Q_t = 1 + \frac{\eta}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 + \eta \left(\frac{I_t}{I_{t-1}} - 1 \right) \frac{I_t}{I_{t-1}} - \eta E_t \left[\Lambda_{t,t+1} \left(\frac{I_{t+1}}{I_t} - 1 \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \right]. \quad (26)$$

Finally, note that capital producers can earn non-zero profits outside of the steady state. These profits are assumed to be redistributed lump sum to households.

3.3 Financial Intermediaries

Financial intermediaries (or banks) provide funds to producers of intermediate goods. Their operations are financed by a combination of deposits, D_t , held by households, and their net worth, N_t , which is accumulated from retained earnings. Hence, the balance sheet of the financial intermediary j is given by:

$$Q_t K_{jt} = D_{jt} + N_{jt}. \quad (27)$$

As noted above, deposits made with the bank at time t pay the non-contingent real gross return R_t in the subsequent period. In contrast, assets held by the intermediary earn the stochastic return R_{kt} over the same period. Then, the law of motion for the net worth of the intermediary j is given by:

$$\begin{aligned} N_{jt} &= R_{kt} Q_{t-1} K_{jt-1} - R_{t-1} D_{jt-1} \\ &= (R_{kt} - R_{t-1}) Q_{t-1} K_{jt-1} + R_{t-1} N_{jt-1} \end{aligned} \quad (28)$$

where the second equality follows from the balance sheet condition.

The intermediary has an incentive to operate in period t only if the expected discounted rate of return on assets does not lie below costs of borrowing. By applying the household's discount factor, this condition can be written as:

$$E_t [\Lambda_{t,t+1} (R_{kt+1} - R_t)] \geq 0. \quad (29)$$

Under frictionless capital markets, (29) holds always with equality. In contrast, the discounted spread between the two rates is positive in presence of financial frictions, as they limit the ability of financial intermediaries to obtain funds. Thus, given financial constraints, a bank has an incentive to invest all its funds and retain all earnings until the time it exits the business. The event of exit occurs with time-varying probability $1 - \theta_t$, where $\theta_t \equiv \bar{\theta} \vartheta_t$ with ϑ_t being the disturbance to the banks' survival probability.⁹ Upon exiting, a banker transfers its terminal wealth to the household and becomes a worker.¹⁰ Accordingly, financial intermediary j determines optimal asset holdings and the amount of external funds to maximize its franchise value, given by

$$V_{jt} = \max E_t \left[\sum_{k=1}^{\infty} \Lambda_{t,t+k} \left(\prod_{i=t+1}^{t+k-1} \theta_i \right) (1 - \theta_{t+k}) N_{jt+k} \right] \quad (30)$$

with $(\prod_{i=t+1}^t \theta_i) \equiv 1$. Incorporating a finite horizon for financial intermediaries prevents them from accumulating enough net worth such that the financial constraint is no longer binding.

Following Gertler and Karadi (2011), I introduce a moral hazard problem to motivate a limited ability of obtaining funds by financial intermediaries. In particular, at the beginning of each period, a banker can divert a non-bank specific fraction, λ , of her assets and transfers it to her household. In this situation, depositors can force her

⁹This shock can be interpreted as a net worth shock as it reduces the internal funds of the banking system. See e.g., Afrin (2017) or Aoki and Sudo (2012).

¹⁰By applying the law of large numbers, $f(1 - \theta_t)$ bankers exit the business in period t . They are replaced by workers who randomly become bankers. As a result, the size of each group remains constant over time.

into bankruptcy and recover the remaining fraction of assets, $1 - \lambda$. Hence, households are willing to supply funds to the intermediary j only if the continuation value of its operations is greater (or equal) than the gain from diverting the assets, i.e.

$$V_{jt} \geq \lambda Q_t K_t. \quad (31)$$

To solve the model, I firstly write (30) recursively:

$$V_{jt} = \max E_t [\Lambda_{t,t+1} ((1 - \theta_{t+1}) N_{j,t+1} + \theta_{t+1} V_{t+1})], \quad (32)$$

and conjecture that the solution is linear in value of assets and deposits:

$$\begin{aligned} V_{jt} &= v_t^k Q_t K_{jt} - v_t D_{jt} \\ &= \mu_t Q_t K_{jt} + v_t N_{jt}. \end{aligned} \quad (33)$$

where the second equality follows from the balance sheet condition. v_t^k is the marginal gain of holding assets, whereas v_t is the marginal cost of deposits and can be also interpreted as marginal value of net worth, holding the assets constant.¹¹ Thus, $\mu_t \equiv v_t^k - v_t$ can be interpreted as the marginal gain of expanding assets by one unit financed via deposits.¹² Then, the financial constraint can be written as:

$$\mu_t Q_t K_{jt} + v_t N_{jt} \geq \lambda Q_t K_t. \quad (34)$$

Maximizing (33) subject to (34) under the assumption that the financial constraint always binds, yields the following conditions:

$$\mu_t(1 + \psi_t) = \lambda \psi_t, \quad (35)$$

¹¹Given bank's asset holdings, an additional unit of net worth leads to savings in borrowing costs.

¹²Note that the marginal values are not bank specific. The underlying assumption is that there are no structural differences across financial intermediaries.

and

$$Q_t K_{jt} = \phi_t N_{jt} \quad (36)$$

where ψ_t is the Lagrange multiplier on the incentive constraint. Furthermore, ϕ_t denotes the leverage ratio and is given by:

$$\phi_t \equiv \frac{v_t}{\lambda - \mu_t} \quad (37)$$

Note that, holding the net worth constant, the constraint binds more tightly, when the intermediary can divert a higher fraction of assets, λ , and the excess value of bank assets is low. With low excess value, the franchise value of the intermediary is lower and the managing banker has strong incentive to divert funds.

To determine expressions for shadow values of assets and deposits (i.e. time-varying coefficients in the value function), I insert the law of motion of net worth into the Bellman equation, (32) and verify that the initial guess for the value function is correct for:

$$v_t^k = E_t [\Lambda_{t,t+1} \Omega_{t+1} R_{kt+1}] \quad (38)$$

$$v_t = E_t [\Lambda_{t,t+1} \Omega_{t+1}] R_t \quad (39)$$

$$\mu_t \equiv v_t^k - v_t = E_t [\Lambda_{t,t+1} \Omega_{t+1} (R_{kt+1} - R_t)] \quad (40)$$

where Ω_{t+1} is the stochastic marginal value of net worth in period $t + 1$, defined in the following way:

$$\Omega_{t+1} \equiv 1 - \theta_{t+1} + \theta_{t+1} (v_{t+1} + \phi_{t+1} \mu_{t+1}) \quad (41)$$

Due to the presence of financial frictions, bankers do not only care about consumption level of their households (reflected by $\Lambda_{t,t+1}$) but they also consider their funding conditions (reflected by Ω_{t+1}).

Since the leverage ratio does not depend on bank specific factors (see (37)), we can

sum across all individual banks to obtain the aggregate leverage constraint:

$$Q_t K_t = \phi_t N_t. \quad (42)$$

To obtain law of motion for the net worth of the entire banking system, one has to recognize that it is the sum of net worth of surviving intermediaries, N_{ot} , and net worth of new bankers, N_{nt} :

$$N_t = N_{ot} + N_{nt} \quad (43)$$

As already discussed, a fraction $1 - \theta_t$ of financial intermediaries exit the market in period t and are replaced by workers who randomly become bankers. New bankers require a start-up capital to be able to attract funds from depositors. Following Gertler and Karadi (2011), I assume that the household transfers a fraction, $\frac{\omega}{1-\theta_t}$, of the value of assets of exiting intermediaries. Hence,

$$N_{nt} = \omega Q_t K_t \quad (44)$$

The net worth of the remaining θ_t bankers is given by:

$$N_{ot} = \theta_t [(R_{kt} - R_{t-1}) \phi_{t-1} + R_{t-1}] N_{t-1} \quad (45)$$

3.4 Aggregate Resource Constraint, Monetary Policy and Equilibrium

Final Output is divided between consumption and investment:

$$Y_t = C_t + [1 + f_{inv}(I_t, I_{t-1})] I_t \quad (46)$$

where the law of motion for capital is given by

$$K_t = (1 - \delta) K_{t-1} + I_t \quad (47)$$

Following Gertler and Karadi (2011), I assume that the monetary policy is described by the following Taylor-rule:

$$1 + i_t = (1 + i_{t-1})^{\rho_i} \left[(1 + i_{SS}) \Pi_t^{\kappa_\pi} \left(\frac{X_t}{X} \right)^{\kappa_y} \right]^{1-\rho_i} \quad (48)$$

where i_t denotes the net nominal interest rate with a deterministic steady state value of i_{SS} . $\rho_i \in (0, 1)$ is the smoothing parameter, and the parameters κ_π and κ_y capture the responsiveness of nominal interest rate to movements in inflation and output.

Finally, the nominal interest rate affects the real economy via the Fisher equation:

$$1 + i_t = R_t E_t [\Pi_{t+1}] \quad (49)$$

3.5 Shock Processes

There are three first-moment shock processes present in the model: technology, A_t , capital quality, ξ_t , and a disturbance to the survival probability of financial intermediaries, ϑ_t .

$$A_t = (1 - \rho_A) + \rho_A A_{t-1} + \sigma^A \epsilon_t^A \quad (50)$$

$$\xi_t = (1 - \rho_\xi) + \rho_\xi \xi_{t-1} + \sigma^\xi \epsilon_t^\xi \quad (51)$$

$$\vartheta_t = (1 - \rho_\vartheta) + \rho_\vartheta \vartheta_{t-1} + e^{\sigma_\vartheta} \epsilon_t^\vartheta \quad (52)$$

The financial uncertainty is introduced into the model by assuming that the volatility of shocks to the survival probability of bankers vary over time. The corresponding second-moment process is given by:

$$\sigma_t^\vartheta = (1 - \rho_{\sigma^\vartheta}) \bar{\sigma}^\vartheta + \rho_{\sigma^\vartheta} \sigma_{t-1}^\vartheta + \tau_{\sigma^\vartheta} \epsilon_t^{\sigma^\vartheta} \quad (53)$$

where $\bar{\sigma}^\theta$ refers to the unconditional mean level of σ_t^θ , ρ_{σ^θ} is the persistence parameter and τ_{σ^i} is the standard deviation of volatility innovations. The standard deviations of the remaining two level shocks are assumed to be constant.¹³

All innovations are independent and follow a symmetric distribution with bounded support, zero mean and unit variance. The first-moment processes are specified in levels, rather than logs to prevent changes in volatility from affecting their mean values through a Jensen's equality effect.

4 Solution Method and Calibration

Due to nonlinearities present in the model, an exact solution is not feasible and thus one must rely on approximation methods. This section firstly describes the technique used to solve the model and then discusses the calibration underlying the analysis conducted in this paper.

4.1 Perturbation Methods

As shown by Fernández-Villaverde et al. (2011), at least third-order approximation is necessary to investigate impulse responses to volatility shocks. I use the nonlinear moving average perturbation developed by Lan and Meyer-Gohde (2013). This technique has two advantages in a setup with time-varying risk. Firstly, it starts the approximation at the stochastic steady state. Secondly, it delivers stable nonlinear impulse responses and simulations and thus no ad-hoc pruning algorithm is necessary.

To explain the method, I will cast the underlying model into a general form:

$$E_t [f(y_{t+1}, y_t, y_{t-1}, \epsilon_t)] = 0 \quad (54)$$

¹³In the appendix, I also discuss model responses to stochastic volatility shocks associated with capital quality. The goal of this exercise is to assess whether different types of uncertainty shocks imply different dynamics. Moreover, it enables a comparison with the literature investigating the propagation of real uncertainty shocks under financial frictions (e.g. Bonciani and Van Roye (2016)).

where $f : \mathbb{R}^{ny} \times \mathbb{R}^{ny} \times \mathbb{R}^{ny} \times \mathbb{R}^{ne} \rightarrow \mathbb{R}^{ny}$ is assumed to be analytic, $y_t \in \mathbb{R}^{ny}$ stands for the vector containing both endogenous and exogenous variables, and $\epsilon_t \in \mathbb{R}^{ne}$ is a vector of zero-mean iid shocks. The nonlinear moving average represents a solution to (54) as a direct mapping of the history of shocks to model variables, i.e.,

$$y_t = y(\sigma, \epsilon_t, \epsilon_{t-1}, \dots) \quad (55)$$

where σ is the perturbation parameter, governing the size of risk in the model. $\sigma = 0$ implies a deterministic setup, whereas $\sigma = 1$ refers to fully stochastic world. The third-order Taylor approximation of this policy function, given normally distributed shocks and $\sigma = 1$, is given by:

$$\begin{aligned} y_t^{(3)} = & y_{SS} + \frac{1}{2}y_{\sigma^2} + \sum_{i=0}^{\infty} \left(y_i + \frac{1}{2}y_{\sigma^2 i} \right) \epsilon_{t-i} + \frac{1}{2} \sum_{i_1=0}^{\infty} \sum_{i_2=0}^{\infty} y_{i_1, i_2} (\epsilon_{t-i_1} \otimes \epsilon_{t-i_2}) \\ & + \frac{1}{6} \sum_{i_1=0}^{\infty} \sum_{i_2=0}^{\infty} \sum_{i_3=0}^{\infty} y_{i_1, i_2, i_3} (\epsilon_{t-i_1} \otimes \epsilon_{t-i_2} \otimes \epsilon_{t-i_3}) \end{aligned} \quad (56)$$

where y_{SS} denotes the deterministic steady state of the model and $y_i, y_{i_1, i_2}, y_{i_1, i_2, i_3}, y_{\sigma^2}, y_{\sigma^2, i}$ refer to partial derivatives of the policy function evaluated at the deterministic steady state. The expression $y_{SS} + \frac{1}{2}y_{\sigma^2}$ corresponds to the third-order accurate stochastic steady state.¹⁴ Moreover, $y_{\sigma^2, i}$ adjusts the approximate responses of endogenous variables to shock realizations for the risk of future disturbances.

4.2 Calibration

Table 1 reports the benchmark calibration. For all parameters I choose reasonably conventional values, previously used in the literature, with Gertler and Karadi (2011) being the major source.

¹⁴As shown by Andreasen (2012), the third-order constant term, y_{σ^3} , corrects the approximation for the skewness of the shocks. Since I assume normally distributed innovations, it is equal to zero and thus omitted from (56).

The inverse of Frish elasticity of labor supply, φ , is set to 0.276 whereas parameter governing the habit formation, h , is 0.815. The choice of the value for χ ensures that labor supply in deterministic steady state equals 0.33.

The capital share, α , in production is 0.33 and the depreciation rate, δ , is set to 0.025. Following Born and Pfeifer (2014) I set the elasticity of substitution between intermediate goods, ϱ , to 10, implying a markup of 11 % in the deterministic steady state. Moreover, the price rigidity parameter, θ_{calvo} , takes the value of 0.779, resulting in an average lifetime of a price of 4 and a half quarters.

Parameterization of the financial sector follows closely Gertler and Karadi (2011). In particular, λ , ω and θ are chosen to target the following three targets: an average horizon of bankers of around eight years, interest rate spread of one hundred basis points per year and banks' leverage ratio of four in the deterministic steady state.

The autocorrelation parameters of the level shocks are set in accordance with Gertler and Karadi (2011) and Afrin (2017). Moreover, standard deviation of the respective level disturbance is 0.01 which is a standard value for the TFP shock.¹⁵ To parametrize the second-moment process for the survival probability of bankers, I assume, in accordance with Ludvigson et al. (2015) that fluctuations in financial uncertainty are exogenous. Given this assumption, the financial uncertainty measure corresponds directly to the stochastic volatility process (53). To see this, consider the error associated with the one-step-ahead forecast of θ :

$$U_\theta \equiv \sqrt{E_t \left[(\theta_{t+1} - E_t [\theta_{t+1}])^2 \right]} = e^{\sigma_t^\theta} \quad (57)$$

Taking natural logarithm of (57) yields:

$$\ln (U_\theta) = \sigma_t^\theta \quad (58)$$

¹⁵Gertler and Karadi (2011) assume a standard deviation of 0.05 for the capital quality shock. Note however that they require a higher value to construct a crisis situation.

Therefore, I can use the financial uncertainty series to directly estimate the parameters of the stochastic volatility process for the survival probability of banks. The estimated autocorrelation parameter is 0.92, whereas the implied standard deviation is 0.055.¹⁶

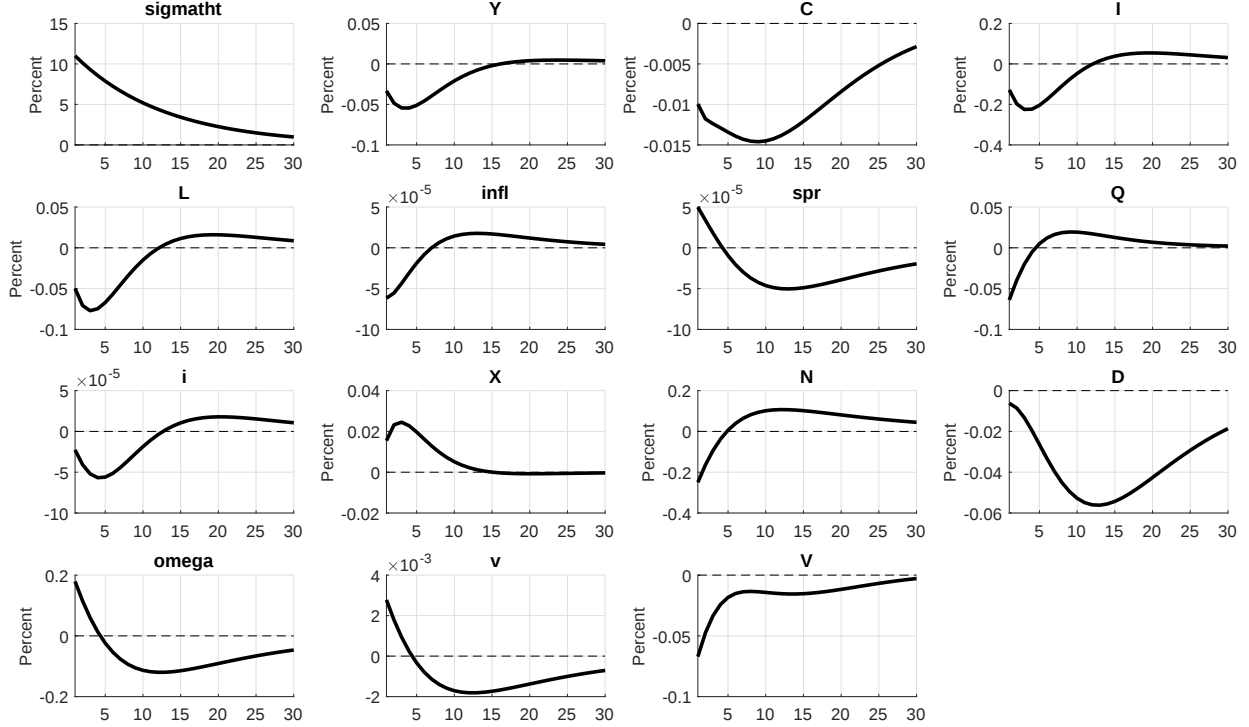


Figure 2: Dynamic consequences of financial uncertainty shocks.

5 Results

In this section, I firstly trace out aggregate effects of financial uncertainty shocks in the underlying framework. Then, I modify the calibration in several ways to assess the importance of individual features of the model.

¹⁶These values are consistent with the estimates of Richter and Throckmorton (2017).

Parameter		Value	Justification
Household			
Discount factor	β	0.99	Gertler Karadi (2011)
Habit parameter	h	0.815	Gertler Karadi (2011)
Inverse of intertemporal elasticity of substitution	γ	1	Gertler Karadi (2011)
Inv. Frish elasticity of labor supply	φ	0.276	Gertler Karadi (2011)
Relative utility weight of labor	χ	3.1870	$L_{SS} = \frac{1}{3}$
Nonfinancial Firms			
Effective capital share	α	0.3	Gertler Karadi (2011)
Depreciation rate	δ	0.025	Gertler Karadi (2011)
Inv. elasticity of invest. to the price of capital	η	1.5	Gertler Kiyotaki (2011)
Elasticity of substitution	e	10	Born Pfeifer (2014)
Calvo parameter	θ_{calvo}	0.779	Gertler Karadi (2011)
Financial Sector			
Divertable fraction in stst	λ	0.381	Gertler Karadi (2011)
Starting-up transfer	ω	0.002	Gertler Karadi (2011)
Survival rate of bankers	θ	0.972	Gertler Karadi (2011)
Taylor Rule			
Interest Rate Smoothing Parameter	ρ_i	0.8	Gertler Karadi (2011)
Inflation coefficient in Taylor rule	κ_π	1.5	Gertler Karadi (2011)
Output coefficient in Taylor rule	κ_y	-0.125	Gertler Karadi (2011)
Shock Processes			
Persistence - TFP	ρ_A	0.95	Gertler Karadi (2011)
Persistence - Capital quality	ρ_ξ	0.66	Gertler Karadi (2011)
Persistence - Survival probability	ρ_θ	0.85	Afrin (2016)
Persistence - Stochastic volatility	ρ_{σ^θ}	0.92	
Unconditional mean of log-S.D.	$\log(\bar{\sigma}^i)$	$\ln(0.01)$	Gertler Karadi (2011) for TFP
S.D. - Stochastic volatility	τ_{σ^θ}	0.055	

Table 1: Calibration

5.1 Financial Uncertainty Shocks

Figure 2 depicts the response of the model economy to an adverse realization of the financial uncertainty shock. Following the DSGE literature on stochastic volatility, I define a financial uncertainty shock as a two-standard deviation increase in the volatility of the disturbance to the survival probability of banks (see, e.g., Born and Pfeifer (2014)).

An adverse financial uncertainty shock implies an increase in the expected stochastic marginal value of net worth in the subsequent period. This leads to a rise in the shadow costs of deposits today which in turn reduces the franchise value of intermediaries and thus reduces household's demand for the riskless bond, i.e., deposits. As a consequence, the real return on deposits increases. Simultaneously, current consumption drops given that expectation of the future consumption affect today's marginal utility via the internal habit formation. Tighter funding conditions force the banks to reduce their lending and as a consequence investment goes down. Lower investment leads to a reduction in the price of capital which deteriorates the financial position of banks even further (*financial accelerator*). In particular, lower price of capital translates into lower rate of return on bank investment and net worth of the banking system drops. In addition, because of higher uncertainty retailers raise their markups (see Born and Pfeifer (2014) or Born and Pfeifer (2017)). This precautionary pricing behavior contributes to the drop in the aggregate demand. Price of the intermediate goods (i.e. marginal costs of retailers) falls and thus the inflation rate drops despite higher average markup. Falling aggregate demand for goods implies finally a reduction of hours worked and a drop in the production level. The peak response of output occurs after about one year and amounts to a drop of 0.05 % of production in the stochastic steady state. The subsequent recovery is followed by a rebound which is caused by the fact that capital stock needs to be replenished when the shock dies out. Therefore, the model can generate the *volatility overshoot* that can be found in the data. Finally note that the model has difficulty with replicating the magnitude of the dynamic responses to financial second-moment shocks (see figure

3). On the other hand, the theoretical response of output to a two-standard deviation increase in the financial uncertainty shocks can reach the upper bound of the 90 % interval associated with the empirical evidence. Most importantly however, the theoretical impulse responses are qualitatively consistent with their empirical counterparts.

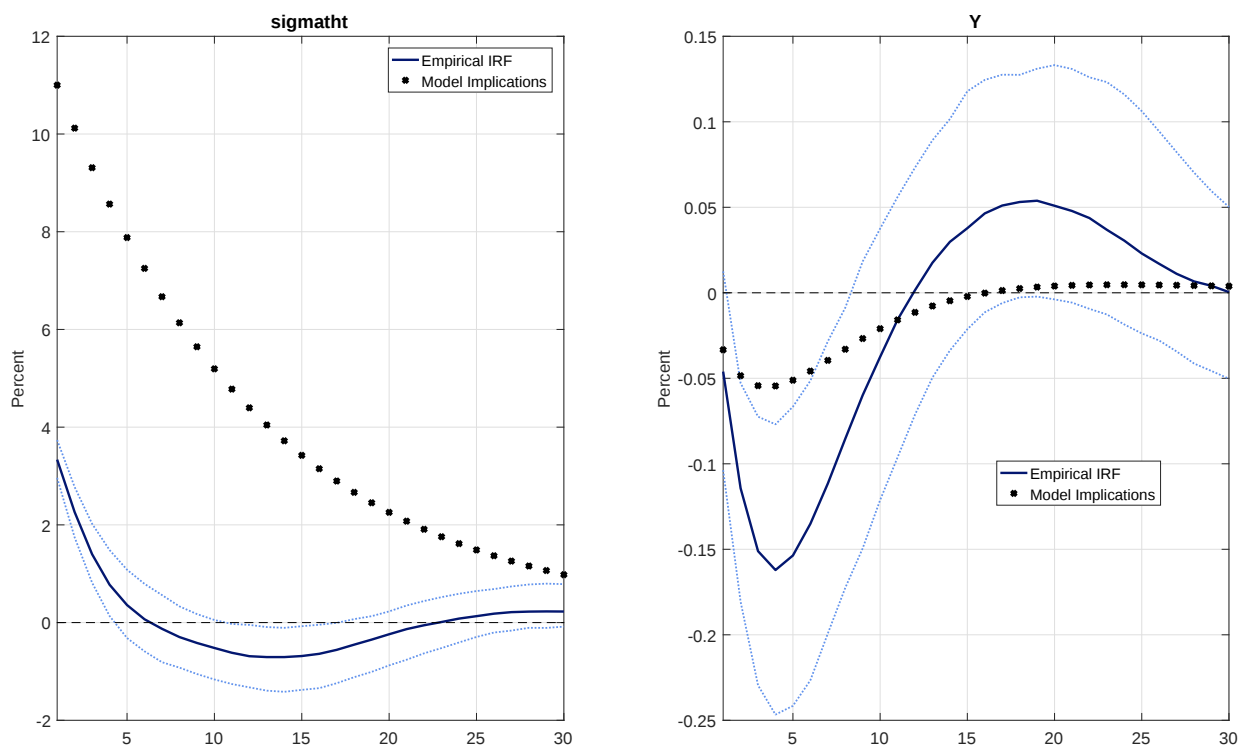


Figure 3: Empirical and Theoretical IRFs.

5.2 Dissecting the Transmission Channels of Financial Uncertainty

This section assesses the importance of different model features for the transmission mechanism of the financial uncertainty. In particular, I discuss the role of nominal rigidities, internal habit formation and financial frictions.

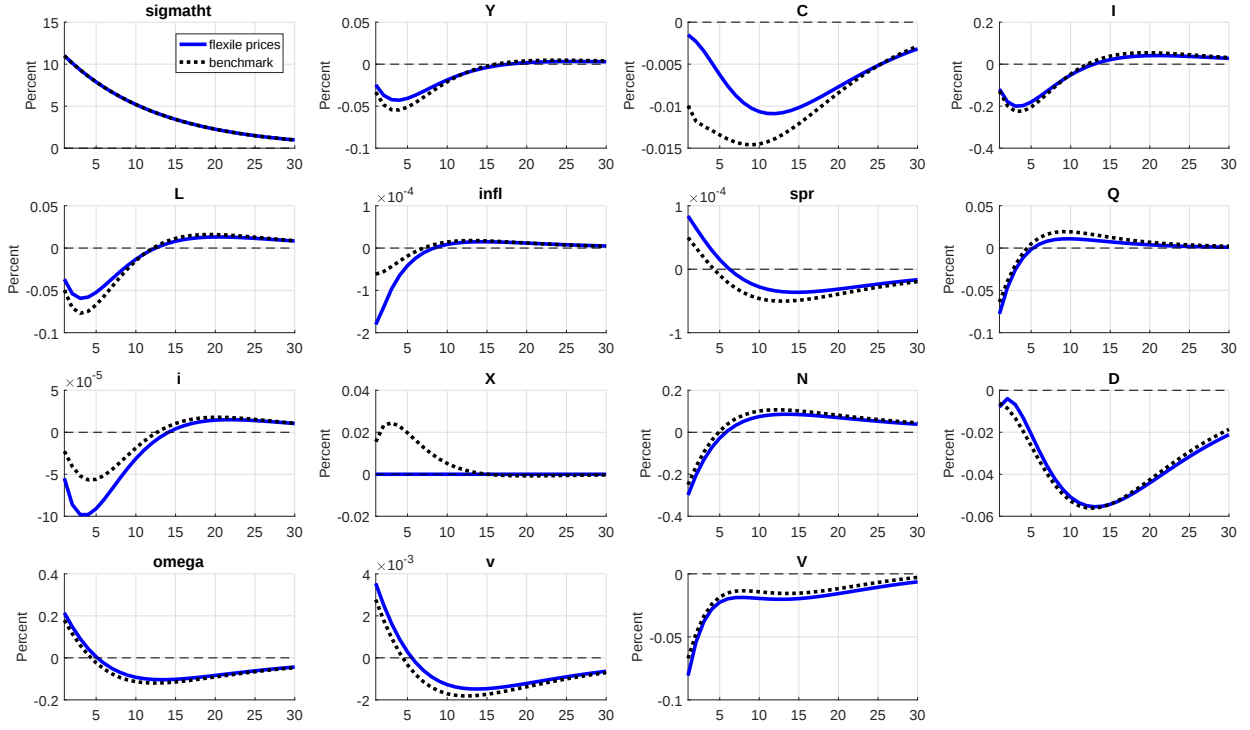


Figure 4: Assessing the importance of nominal rigidity. Dynamic consequences of a two-standard-deviations increase in the volatility of disturbances to the survival probability of banks.

5.2.1 Nominal Rigidity

Price rigidity affects the transmission of uncertainty shocks via the clearing condition for the labor market (Basu and Bundick, 2017, Born and Pfeifer (2014, 2017)):

$$\frac{1}{X_t} A_t (1 - \alpha) (\xi_t K_{t-1})^\alpha U_{Ct} = \chi L_t^{\varphi + \alpha} \quad (59)$$

In particular, a rise in volatility results in an increase of the markup which in turn diminishes the demand for goods and consequently output as well as labor demand.

As explained by Born and Pfeifer (2017), the rise in markup following an uncertainty shock is caused by precautionary pricing behavior of retailers. In particular, a firm, updating its price in a more uncertain environment, has an incentive to charge higher

markup because too high prices partly compensate low quantity sold. On the other hand, too low prices imply a higher demand but the higher quantity is sold at a lower price. This diminishes retailer's revenues. Because of the nonlinear nature of the pricing behavior, firms prefer the mistake on the side of too high prices.

Figure 4 compares the impulse responses to a financial uncertainty shock under the benchmark calibration with their counterparts under flexible prices. The precautionary pricing motive amplifies the effects of an increase in the volatility of disturbances to the survival probability of bankers. Interestingly, in contrast to the model employed by Basu and Bundick (2017), nominal rigidity is not necessary to replicate empirically observed co-movement among aggregate quantities in the underlying framework. Next section shows that internal habit formation is sufficient to generate this feature.

5.2.2 Internal Habit Formation

Internal habit formation implies that the household internalizes the consequences of today's consumption choice in subsequent periods. In other words, the marginal utility of consumption today depends on the expected future consumption levels, i.e., $U_{C_t} = (C_t - hC_{t-1})^{-\gamma} - \beta h E_t \left[(C_{t+1} - hC_t)^{-\gamma} \right]$. Thus, an increase in the uncertainty depresses, *ceteris paribus*, the marginal utility of today's consumption via the Jensen's inequality. As a result, the household will adjust its current consumption to avoid fluctuations in the consumption path. Furthermore, lower current marginal utility implies that the household derives less utility from a given wage. Therefore, the household has an incentive to reduce its labor supply.

To quantify the importance of the habit formation, I remove this feature by setting $h = 0$ and compare the implied model responses to the benchmark calibration. Figure 5 presents results of this exercise. Without habit formation, the model can no longer generate a co-movement among the macroeconomic aggregates. Because of the reduction in deposits, the household has now more resources that can be consumed. Thus, the

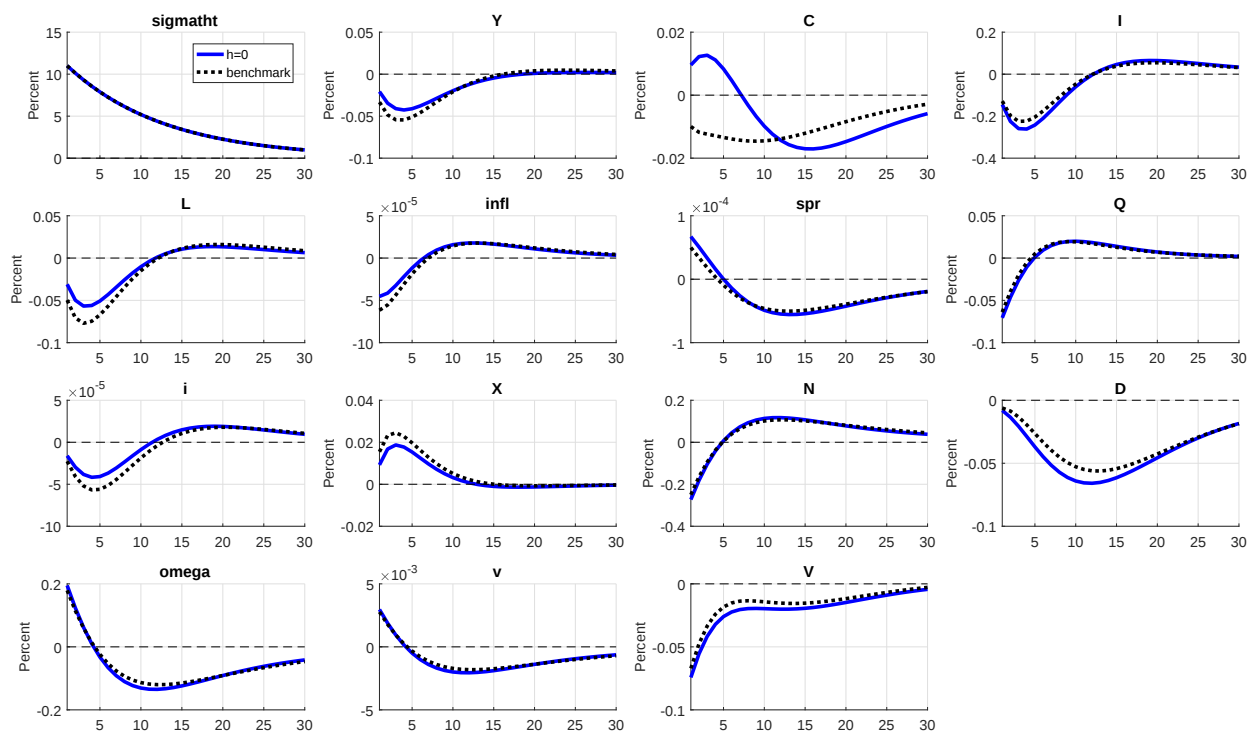


Figure 5: Assessing the importance of internal habit formation. Dynamic consequences of a two-standard-deviations increase in the volatility of disturbances to the survival probability of banks.

aggregate consumption raises on impact despite a drop in the production level. As a result, the negative effect of the financial shock on the aggregate activity is smaller.

5.2.3 Financial Frictions

In the next exercise, I remove both nominal rigidities and habit formation to focus on the effect of the presence of financial frictions. Figure 6 presents a picture similar to the one from the previous section with the only difference being even weaker effects. It is interesting however that investment, output and hours worked still decline. In a model without financial friction a rise of (real) uncertainty stimulates precautionary savings (Carroll and Kimball, 2006) and thus generates a boom in the economy. This

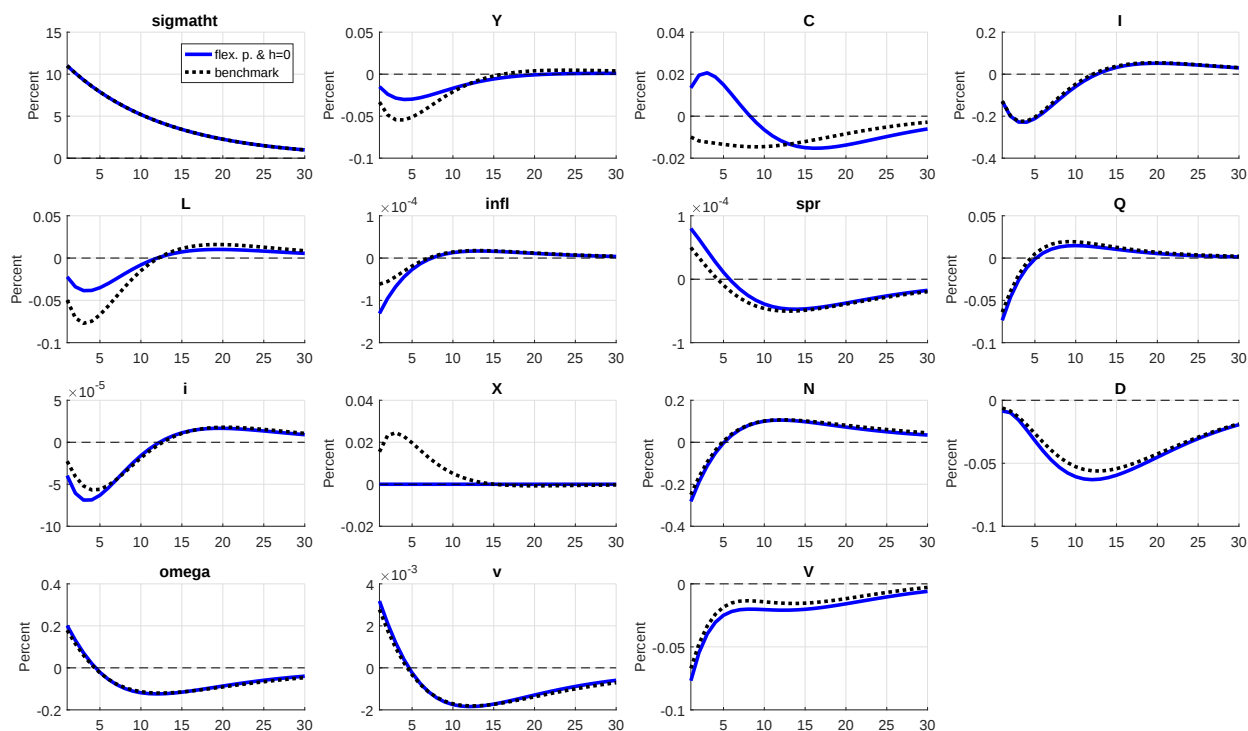


Figure 6: Assessing the role of financial frictions. Dynamic consequences of a two-standard-deviations increase in the volatility of survival probability shocks.

is not the case in the underlying setup, because higher uncertainty leads to a tighter financial constraint which prevents households from increasing their bond holdings.¹⁷

6 Conclusion

This paper fills the gap in the DSGE literature on uncertainty shocks by shedding more light on the macroeconomic effects of financial uncertainty. The goal is to determine the channels through which financial shocks affect real economy. To this end, I

¹⁷One could argue that the fall in investment is caused by the financial nature of the shock investigated in this paper and not due to the presence of financial uncertainty per se. To address this issue, I investigate a two-standard-deviation increase in the volatility of the capital quality shock. The results can be found in the appendix. It turns out, that also in this case hours worked, investment and output fall. On the other hand, the shock has significantly smaller effects in a framework with flexible prices and without habit formation. Thus, the propagation of the macro uncertainty relies more heavily on these features.

firstly provide an empirical evidence that financial uncertainty has significant impact on the real activity. Then, I employ the DSGE framework developed by Gertler and Karadi (2011) to explain the empirical findings. The dynamics generated by the model are in line with their empirical counterparts. In particular, a rise in financial uncertainty leads to an increase in the risk premium and to a reduction in aggregate quantities. Finally, I conduct a series of experiments to uncover the main propagators of the financial uncertainty. In the underlying setup, the key role is played by the endogenous leverage constraint faced by the bankers. Specifically, due to an increase in financial uncertainty households provide less funding to financial intermediaries and this triggers the financial accelerator mechanism. Finally, nominal rigidities and internal habit formation act as additional amplification mechanisms for financial uncertainty shocks.

References

- Afrin, S. (2017), ‘The role of financial shocks in business cycles with a liability side financial friction’, *Economic Modelling* **64**, 249–269.
- Alfaro, I., Bloom, N. and Lin, X. (2016), ‘The finance-uncertainty multiplier’, *unpublished paper, Economics Department, Stanford University, viewed October* .
- Andreasen, M. M. (2012), ‘On the effects of rare disasters and uncertainty shocks for risk premia in non-linear dsge models’, *Review of Economic Dynamics* **15**(3), 295–316.
- Aoki, K. and Sudo, N. (2012), Asset portfolio choice of banks and inflation dynamics, Technical report, Bank of Japan.
- Arellano, C., Bai, Y. and Kehoe, P. J. (2016), Financial frictions and fluctuations in volatility, Technical report, National Bureau of Economic Research.
- Bachmann, R. and Bayer, C. (2013), ‘wait-and-see business cycles?’, *Journal of Monetary Economics* **60**(6), 704–719.

- Basu, S. and Bundick, B. (2017), 'Uncertainty shocks in a model of effective demand', *Econometrica* **85**(3), 937–958.
- Bloom, N. (2009), 'The impact of uncertainty shocks', *econometrica* **77**(3), 623–685.
- Bonciani, D. and Van Roye, B. (2016), 'Uncertainty shocks, banking frictions and economic activity', *Journal of Economic Dynamics and Control* **73**, 200–219.
- Born, B. and Pfeifer, J. (2014), 'Policy risk and the business cycle', *Journal of Monetary Economics* **68**, 68–85.
- Born, B. and Pfeifer, J. (2017), 'Uncertainty-driven business cycles: assessing the markup channel'.
- Caldara, D., Fernandez-Villaverde, J., Rubio-Ramirez, J. F. and Yao, W. (2012), 'Computing dsge models with recursive preferences and stochastic volatility', *Review of Economic Dynamics* **15**(2), 188–206.
- Calvo, G. A. (1983), 'Staggered prices in a utility-maximizing framework', *Journal of monetary Economics* **12**(3), 383–398.
- Carroll, C. D. and Kimball, M. S. (2006), Precautionary saving and precautionary wealth, Technical report, CFS Working Paper.
- Christiano, L. J., Motto, R. and Rostagno, M. (2014), 'Risk shocks', *The American Economic Review* **104**(1), 27–65.
- Dedola, L., Karadi, P. and Lombardo, G. (2013), 'Global implications of national unconventional policies', *Journal of Monetary Economics* **60**(1), 66–85.
- Fernández-Villaverde, J., Guerrón-Quintana, P., Rubio-Ramírez, J. F. and Uribe, M. (2011), 'Risk matters: The real effects of volatility shocks', *The American Economic Review* **101**(6), 2530–2561.

- Gertler, M. and Karadi, P. (2011), 'A model of unconventional monetary policy', *Journal of monetary Economics* **58**(1), 17–34.
- Gertler, M. and Kiyotaki, N. (2010), 'Financial intermediation and credit policy in business cycle analysis', *Handbook of monetary economics* **3**(3), 547–599.
- Gilchrist, S., Sim, J. W. and Zakrajšek, E. (2014), Uncertainty, financial frictions, and investment dynamics, Technical report, National Bureau of Economic Research.
- Jurado, K., Ludvigson, S. C. and Ng, S. (2015), 'Measuring uncertainty', *American Economic Review* **105**(3), 1177–1216.
- Lan, H. and Meyer-Gohde, A. (2013), 'Solving dsge models with a nonlinear moving average', *Journal of Economic Dynamics and Control* **37**(12), 2643–2667.
- Ludvigson, S. C., Ma, S. and Ng, S. (2015), Uncertainty and business cycles: exogenous impulse or endogenous response?, Technical report, National Bureau of Economic Research.
- Mumtaz, H. and Zanetti, F. (2013), 'The impact of the volatility of monetary policy shocks', *Journal of Money, Credit and Banking* **45**(4), 535–558.
- Ng, S. and Wright, J. H. (2013), 'Facts and challenges from the great recession for forecasting and macroeconomic modeling', *Journal of Economic Literature* **51**(4), 1120–54.
- Richter, A. W., de Groot, O. and Throckmorton, N. A. (2017), 'Uncertainty shocks in a model of effective demand: Comment'.
- Richter, A. W. and Throckmorton, N. A. (2017), 'A new way to quantify the effect of uncertainty'.

Appendix

A. Data Sources

I use the following data sources to estimate my VAR model. The data is available on the Federal Reserve Economic Database (FRED) unless specified otherwise:

1. **Financial Uncertainty Measure** - Monthly - Source: Ludvigson et al. (2015) - Data available from: <https://www.sydneyludvigson.com/data-and-appendixes/>
2. **Macro Uncertainty Measure** - Monthly -Source: Jurado et al. (2015) - Data available from: <https://www.sydneyludvigson.com/data-and-appendixes/>
3. **Nominal GDP** - Quarterly, Seasonally adjusted
4. **Personal Consumption Expenditures, Nondurable Goods** - Quarterly, Seasonally Adjusted
5. **Personal Consumption Expenditures, Services** - Quarterly, Seasonally Adjusted
6. **Nominal Gross Private Investment** - Quarterly, Seasonally Adjusted
7. **Nonfarm Business Sector: Hours of all Persons** - Quarterly, Seasonally Adjusted, 2009=100
8. **GDP Deflator** - Quarterly, Seasonally Adjusted
9. **Moody's Seasoned Baa Corporate Bond Yield Relative to Yield on 10-Year Treasury Constant Maturity** - Quarterly
10. **S&P 500 Index** - Monthly - Source: <https://finance.yahoo.com>
11. **Effective Federal Funds Rate** - Quarterly

12. Civilian Noninstitutional Population - Quarterly

All variables reported at a monthly frequency are converted to a quarterly frequency by applying time averages. All nominal variables are converted to real terms by applying the GDP deflator. Finally, aggregate quantities are converted to per-capita terms by dividing the civilian noninstitutional population.

B. Robustness of the VAR Results

Different ordering of the variables: uncertainty measures are ordered last.

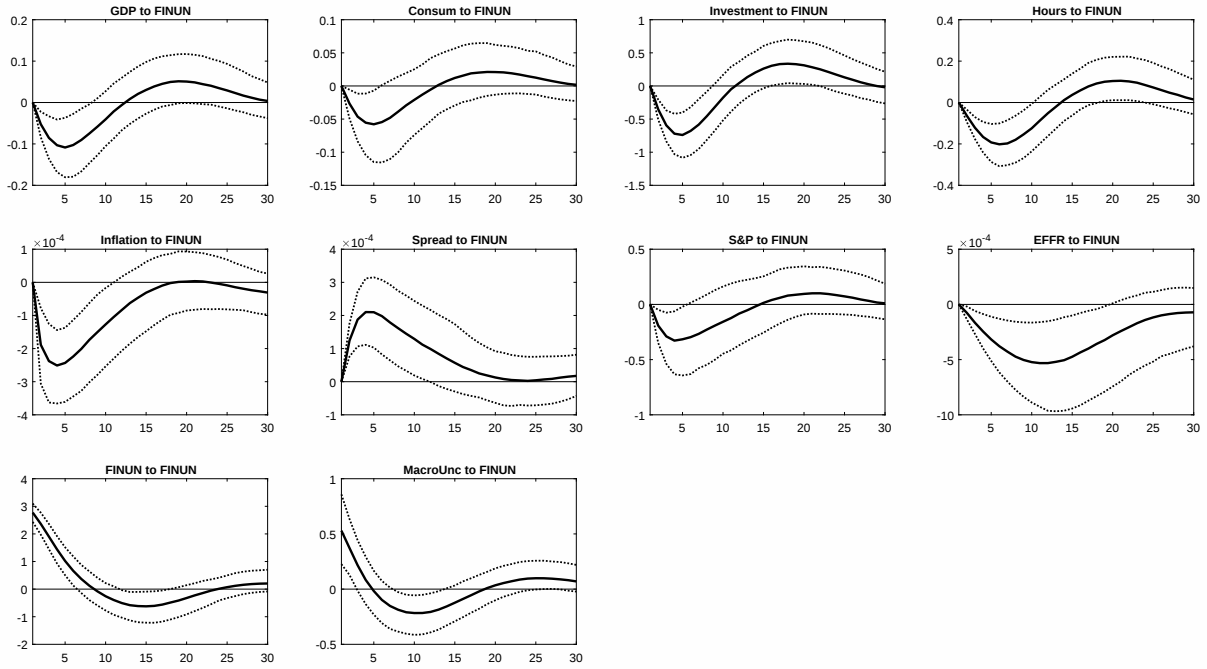


Figure 7: Dynamic consequences of one-standard-deviation increase in the financial uncertainty. Responses of all variables except the GDP deflator, the risk premium and the federal funds rate are expressed in percentage points.

C. The Effects of Macroeconomic Uncertainty

In this section, I extend the model by introducing time-varying volatility of the capital quality shock which serves as a proxy for the macroeconomic uncertainty. Since

Ludvigson et al. (2015) provides evidence that fluctuations in the macroeconomic uncertainty is rather an endogenous response to movements in the financial uncertainty and changes to fundamentals, I cannot estimate the parameters governing the process as I did in case of the financial uncertainty. Therefore, I simply use the same values for parameters of the second-moment process of capital quality shock. Figure 8 depicts the response of the model economy to an adverse realization of the macroeconomic uncertainty shock in the underlying model and compares it to its counterpart in a framework without financial frictions. Similar to the models used by Alfaro et al. (2016) and Bonciani and Van Roye (2016), the version of Gertler-Karadi framework employed in this study exhibits “finance-uncertainty multiplier”. According to figure 8, the financial accelerator is quite powerful with the response of GDP to the volatility disturbance being almost doubled in magnitude on impact. Note moreover, that in a model without financial frictions aggregate investment does not co-move with GDP, consumption and labor. This result stands in contrast to findings by Basu and Bundick (2017) who argue that nominal rigidities are sufficient to obtain co-movement among macroeconomic variables observed in the data.¹⁸ Moreover, it supports arguments of Richter et al. (2017) who show that the results of Basu and Bundick (2017) are mostly driven by their specification of Epstein-Zin preferences. Figure 9 assesses the importance of nominal rigidities and internal habit formation for the transmission mechanism of macroeconomic uncertainty. In contrast to the financial uncertainty, shocks to the volatility of capital quality are propagated mainly exactly through these two model features. If they are eliminated from the model, the impact of the uncertainty shock on the components of the aggregate demand is barely visible.

¹⁸The lack of comovement cannot be removed even for Calvo parameter of 0.99. Thus, the precautionary motive of the household always dominates in the underlying setup.

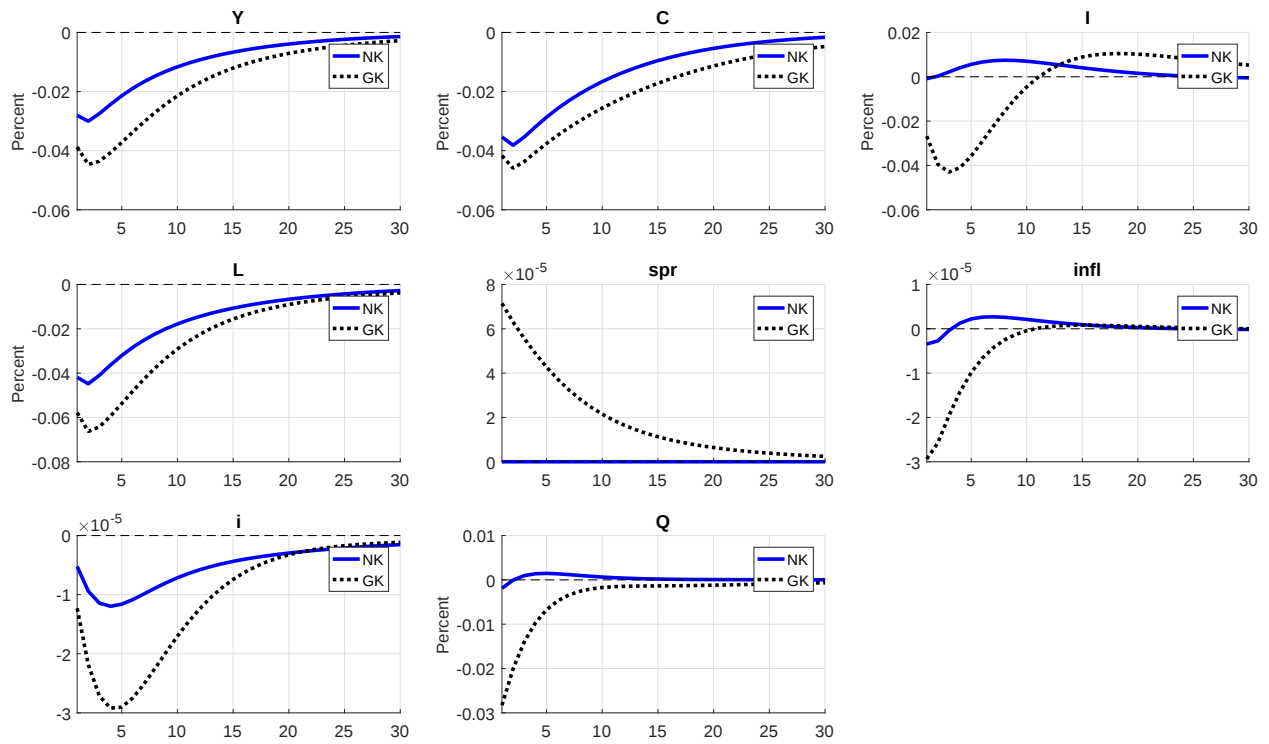


Figure 8: Financial Accelerator Dynamic consequences of a two-standard-deviation increase in volatility of capital quality shocks.

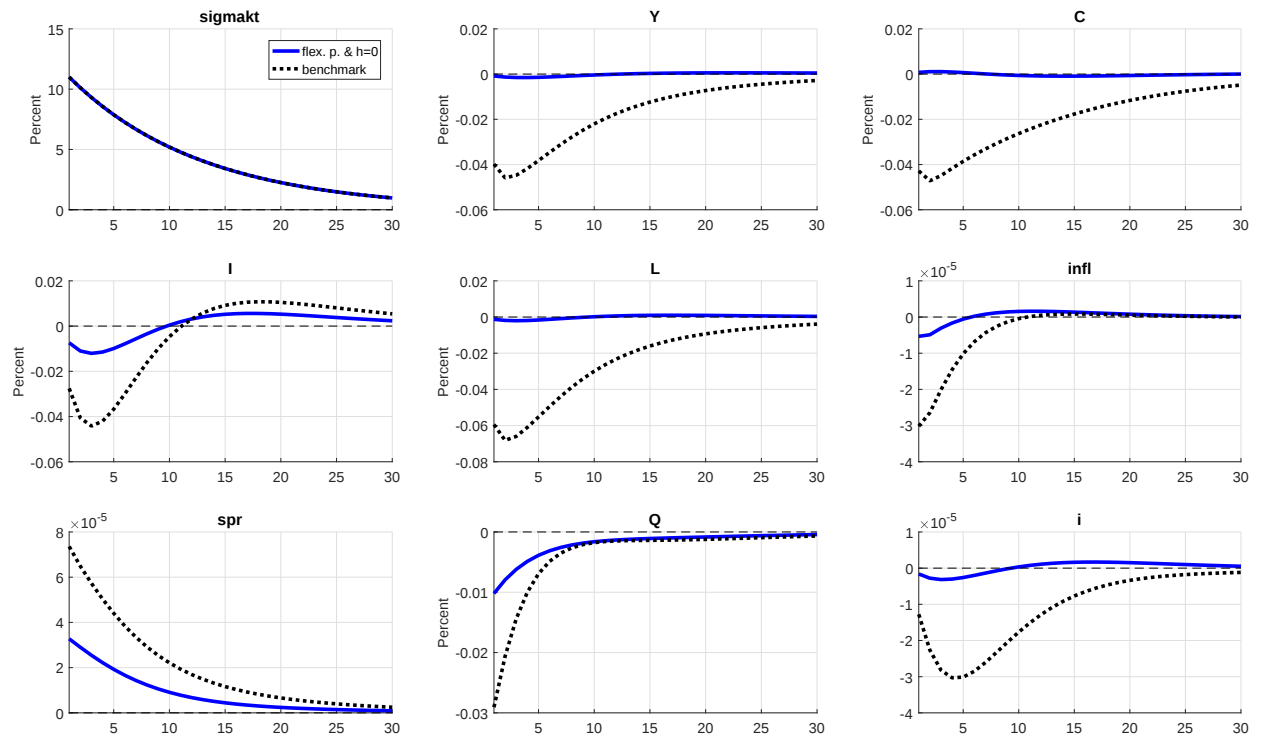


Figure 9: Assessing the role of financial frictions. Dynamic consequences of a two-standard-deviation increase in volatility of capital quality shocks.