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Abstract

Higher uncertainty about government spending generates a persistent decline in the economic activity in the Euro Area. This paper emphasizes the transmission channels explaining this empirical fact. First, a Stochastic Volatility model is estimated on European government consumption to build a measure of government spending uncertainty. Plugging this measure into a SVAR model, we stress that government spending uncertainty shocks have recessionary, persistent and humped-shaped effects. Second, we develop a New Keynesian model with financial frictions applying to a portfolio of equity and long-term government bonds. We argue that a portfolio effect – resulting from the imperfect substitutability among both assets – acts as a critical amplifier of the usual transmission channels.

JEL classification: E62; E52.

Keywords: Government spending uncertainty, stochastic volatility, portfolio adjustment cost.

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1 Introduction

The large fiscal stimulus packages as well as the austerity plans adopted by several governments after the Great Recession have renewed interest in fiscal policy analysis. While the impact of fiscal-level shocks on the real economy has been widely documented in the literature, the effects of uncertainty about fiscal policy are still relatively unexplored.[1] In reality, policy decisions on government expenditure and taxation are subject to uncertainty, characterized in this paper by unexpected movements in the volatility of fiscal instruments. This uncertainty – which generate shifts in the distribution of fiscal shocks – might arise either from modification in the fiscal stance over time, from changes in the legislation (budget rules) or from political instability triggered byThus elections.[2] Because government expenditure accounts for about 50% of total spending in the Euro Area, it constitutes a key policy instrument for economic stabilization purpose, notably in periods of high uncertainty (see C. Largarde's speech, President of the ECB, November 11$^{\text{th}}$, 2020). Thus, understanding the impact of government spending uncertainty is of primary interest for policy makers.

The transmission channels of macroeconomic uncertainty shocks are well established in the literature, namely for instance the real option effect, the precautionary saving effect or the effect of price stickiness.[3] Most papers that investigate the macroeconomic effects of uncertainty focus on TFP-driven or preference-driven uncertainty. In this paper, we characterize the effects of government spending uncertainty shocks. We proceed in two steps. First, we document the effects of government spending uncertainty shocks in the Euro Area by disentangling government spending levels and government spending volatility shocks using a Stochastic Volatility estimator.[4] We then plug these second-order moment innovations into a structural VAR (SVAR) model, and find that they trigger persistent, negative and humped-shaped responses of GDP, private consumption, private investment in the Euro Area. These shocks contribute by 10% of the variance of GDP over 4 years, a rather large number compared to previous studies.

Second, we offer new insights regarding the transmission channels of government spending uncertainty shocks, shedding light on the role of financial frictions. Precisely, we build a

[1] On the empirical macroeconomic effects of fiscal-level shocks, see Blanchard and Perotti (2002) or Ramey and Zubairy (2018) among many others.

[2] Over the past years, the Euro Area has faced several events that might have led to higher fiscal uncertainty. The most recent one at the worldwide level could be the uncertainty surrounding the fiscal stimulus plans implemented by several countries to counteract the Covid-19 crisis' economic damages.

[3] See the literature survey by Fernandez-Villaverde and Guerron-Quintana (2020).

[4] This methodology follows Born and Pfeifer (2014) and Fernandez-Villaverde et al. (2015) who estimate a Stochastic Volatility model on several fiscal instruments in the US.

typical New-Keynesian model enriched with financial frictions *à la* Bernanke et al. (1999), so as to replicate the empirical facts and to rationalize the transmission channels of these shocks. The originality of this model is that financial frictions apply to a portfolio of two assets: long-term government bonds and private equity. The financial sector consists in a continuum of risk-neutral portfolio investors who can invest in government bonds and private equity to build their portfolio. Portfolio investors borrow from a representative lender who is in charge of collecting households' deposits, and face an idiosyncratic risk of default. Thus, financial frictions between the representative lender and the portfolio investor stem from the asymmetric information regarding the default risk of the latter, as in Bernanke et al. (1999). As usual in this literature, this gives rise to a risk premium, *i.e.* a premium portfolio investors have to pay when they borrow, which is measured as the spread between the return of the portfolio and the risk-free interest rate. Our portfolio structure with two assets enriches the standard financial accelerator mechanism with a "portfolio channel": the risk premium now depends on the differential of expected returns between private equity and government bonds. When the expected return of the two assets differ, portfolio investors rebalance the composition of their portfolio towards the asset with the highest relative return, which in turn affects the leverage ratio and the probability investors defaulting, and magnifies the financial accelerator mechanism. The strength of the portfolio channel varies with the degree of substitutability between the two assets, captured by a quadratic portfolio adjustment cost in the spirit of Jermann and Quadrini (2012) or Iacoviello (2015) that induces slow adjustments of the composition of the portfolio.

We argue that the "portfolio channel" plays a key role in the transmission channels of government spending uncertainty shocks. As higher government spending uncertainty is recessionary, portfolio investors face a negative wealth effect through deterioration in their balance sheet. The demand for both assets is reduced leading to a decrease in the price of both equity and government bonds. Importantly, higher uncertainty lowers the level of government spending – an empirically robust effect of spending uncertainty shocks – which in turn reduces government bond issuance. Therefore, the price of government bonds is reduced by less than the price of private equity, which makes the latter more attractive as the relative expected return of capital increases, and pulls the trigger of the portfolio channel. The portfolio external risk premium depends on this rebalancing effect through two opposite forces. On the one hand, shifting the portfolio composition towards equity (featuring a higher return than government bonds) reduces the risk premium by making investors wealthier. On the other hand, this portfolio rebalancing behavior leads investors to rely more on borrowing, raises the leverage ratio and increases their external finance premium. We stress that the second effect dominates and therefore the portfolio channel increases the risk of default of portfolio investors. These effects come on top of the usual financial accelerator mechanism, they drives private investment further down and aggravate the subsequent recession.

The model is estimated against European data using a mix of Minimum Distance Estimation (MDE) methods and Simulated Method of Moments (SMM) in the spirit of Basu and Bundick (2017). We find that the theoretical model does a good job of replicating the impulse response functions obtained in the SVAR model as well as a set of unconditional moments. Our estimates suggest that the size of the portfolio adjustment cost needs to be large to replicate the responses of output and investment to higher spending uncertainty. This result implies that the portfolio channel is a key element to understanding the transmission channels of government spending uncertainty shocks. In particular, a set of counterfactual exercises highlights the critical importance of the amplification effect induced by the portfolio channel. First, this channel is shut down by assuming that the portfolio investor can only invest in private equity, as assumed in the standard financial accelerator model. Second, a counterfactual exercise consists in assuming that the two assets are perfect substitutes in the portfolio. For given estimated values of our parameters, both alternative models produce responses to government spending uncertainty shocks that are severely dampened, and fall short of replicating the empirical evidence. Third, we find conclusive empirical support of the portfolio channel using local projection methods: a rise in government spending uncertainty is found to be associated with a rise in the share of equity in portfolios, as predicted by the model. We conclude that the portfolio channel is key to matching the empirical effects of a government spending uncertainty shock quantitatively.

The contribution of this paper lies in the introduction of a novel transmission channel of government spending uncertainty shocks that we label the portfolio channel. It resonates with the liquidity channel of government policy highlighted by Bayer et al. (2020). They emphasize that *higher* government spending increases government debt and lowers the spread difference between illiquid (capital) and liquid (bonds) assets. In our paper, higher government spending uncertainty acts in the opposite direction as it *reduces* government spending as well as government bond issuance. Therefore, the spread between capital and government bond returns increases and give rises to portfolio rebalancing behaviors towards capital. We argue that portfolio diversification combined with a financial accelerator mechanisms is critical in accounting for the effects of government spending uncertainty on real economic activity. This mechanism acts on top of other transmission channels through which uncertainty generally affects macroeconomic aggregates, that are also present in the model. The inverse Oi–Hartman–Abel effect (see Born and Pfeifer, 2014 among others) and the Basu-Bundick effect (see Basu and Bundick, 2017) based on sticky prices, predict that consumption and investment fall jointly. In addition, financial frictions amplify the quantitative importance of both transmission mechanisms (see Cesa-Bianchi and Fernandez-Corugedo, 2017).

This paper relates to the literature on the impact of uncertainty on economic activity. The interest in the aggregate effects of uncertainty has been growing since the financial crisis of 2007–2009 and the importance of uncertainty for the business cycle has been investigated in the literature. The seminal paper by Bloom (2009) turned attention to uncertainty by documenting that shocks to the volatility of aggregate productivity produce large fluctuations in output and employment. However, only few studies focus on the contribution of fiscal policy uncertainty on the business cycle. Fernandez-Villaverde et al. (2011) show that fiscal volatility shocks have detrimental effects on output, especially when the central bank is constrained by the zero-lower bound. Born and Pfeifer (2014) provide more contrasted results, and argue that fiscal uncertainty shocks are not sizable enough to contribute significantly to the business cycle. In contrast to these authors focus on US data, we show that public spending uncertainty contributes to GDP volatility in the Euro Area and we are interested in the role financial market imperfections play in the transmission of these shocks.

We also relate to a literature that studies the role of financial frictions on fluctuations. After the financial crisis of 2007–2009, the importance of both financial market imperfections and time-varying volatility for real activity has been emphasized. A strand of literature shows that financial market frictions amplify the negative effects of uncertainty on macroeconomic outcomes. Differently from us, it studies idiosyncratic – or firm-level – uncertainty (Arellano et al., 2019; Christiano et al., 2014; Gilchrist et al., 2014; Balke et al., 2017) or TFP uncertainty (Alfaro et al., 2018; Cesa-Bianchi and Fernandez-Corugedo, 2017) and abstracts from fiscal policy uncertainty. Related to our paper, Bonciani and Van Roye (2016) investigates the effects of macroeconomic uncertainty focusing on the supply-side of the financial market. Incorporating frictions in the banking sector, they show that frictions in the process of financial intermediation magnifies the effects of such shocks. However, they focus on a preference-driven uncertainty shock and abstract from the fiscal side of the economy. Bretscher et al. (2019) develop a model where fiscal volatility shocks cause the major part of fluctuations in term premia. However, they disregard financial frictions, and look at the term premia, while our model considers corporate and sovereign spreads, as well as their interaction in magnifying the negative effects of uncertainty. Saijo (2020) is also interested in fiscal uncertainty shocks and he shows that limited capital participation amplifies their negative impact on GDP, focusing on the redistribution effects of these shocks. In contrast to these papers, we offer a novel transmission channel related to financial frictions and portfolio adjustment behaviors. Another strand of the literature, known as the intermediary asset pricing literature, shows that the net worth of financial intermediaries can affect portfolio decisions when the financial market features some frictions (Brunnermeier et al., 2013 for a survey and He and Krishnamurthy, 2018). Ultimately, portfolio choices depend on preferences of financial intermediates, *i.e.* their degree of risk aversion. In this paper, we contribute to this literature by assuming that portfolio investors are risk-neutral, in the spirit of Silva (2020) while they face a portfolio adjustment cost. This breaks the Modigliani-Miller theorem and opens the doors of portfolio rebalancing effects. We emphasize the importance of portfolio adjustments under government spending uncertainty. Finally, our paper relates to Gertler and Karadi (2011) and Gertler and Karadi (2012) who focus on the financial frictions arising from the financial contract between the depositors and the banks. We offer an alternative way of modeling financial frictions in which portfolio investors can be seeing as financial entrepreneurs facing limited asset participation issues.

Section 2 presents our measure of government spending uncertainty shocks and its empirical effects. Section 3 describes the model setup and Section 4 the parametrization, solution and estimation methods. Section 5 explains the main results produced by the benchmark estimation. Section 6 takes a closer look at the portfolio transmission channel and offers various counterfactual exercises to highlight its contribution to account for the effects of government spending uncertainty shocks. Section 7 concludes.

2 The Effects of Government Spending Uncertainty Shocks

In this section, we document the effects of government spending uncertainty on the economic activity of the Euro Area. We proceed in two steps. First, we extract a measure of government spending uncertainty over time in the Euro Area from the data using a time-varying volatility Bayesian estimator. Second, we plug the resulting measure of uncertainty into a SVAR model to quantify the impact of government spending uncertainty shocks on a set of key macroeconomic variables.

2.1 A Measure of Government Spending Uncertainty Shocks

We first estimate a fiscal rule for government spending with time-varying volatility based on the method of Fernandez-Villaverde et al. (2011) and Born and Pfeifer (2014). Let us assume a government spending rule in which government expenditure, denoted by g_t, react to their lagged value g_{t-1} and to the lagged output gap (y_{t-1}). The rule also features stochastic volatility shocks, as its time-varying standard deviation σ_t^g is assumed to follow an AR(1) process:

$$
\begin{aligned}
g_t &= \rho_g g_{t-1} + \rho_{gy} y_{t-1} + \exp(\sigma_t^g)\varepsilon_t^g, && (1)\\
\sigma_t^g &= (1-\rho_{\sigma^g})\,\sigma^g + \rho_{\sigma^g}\sigma_{t-1}^g + \eta_{\sigma^g}\varepsilon_t^{\sigma^g}, && (2)
\end{aligned}
$$

where $\varepsilon_t^g \sim \mathcal{N}(0,1)$ and $\varepsilon_t^{\sigma^g} \sim \mathcal{N}(0,1)$ and σ_t^g is our time-varying measure of government spending uncertainty. Parameters ρ_g and ρ_{σ^g} drive the persistence associated with the level (first-order) and the volatility (second-order) shocks, respectively, η_{σ^g} governs the magnitude of the government spending volatility shock and ρ_{gy} measures the feedback effect of the lagged output gap on government spending. We use quarterly data for the Euro Area over the sample 1970q1 to 2017q4 extracted from the Area Wide Model (AWM) database. Notice that g_t and y_t are computed by applying a one-sided HP-filter to the log of government consumption expenditure and GDP, respectively.[5]

The two processes (1)-(2) capture the government spending rule as well as the time-varying standard-deviation of government spending. Using the algorithm of Born and Pfeifer (2014), Equations (1)-(2) are estimated jointly with Bayesian methods. We obtain priors directly from the data using simple least squares regressions. The historical series of the unobserved volatility shock are extracted using a (non-linear) particle filter from the posterior distribution computed using the MCMC algorithm. The posterior distributions of parameters are computed from 20 000 draws, and we use 20 500 particles where the first 500 are discarded.

Table 1 reports the median point estimates along with the 10^{th} and 90^{th} percentiles in the baseline estimation (first column), together with point estimates resulting from two alternative estimations, to give a sense of the robustness of our baseline estimates. The first alternative estimation (second column) imposes $\rho_{gy} = 0$, meaning that we do not control for economic activity. The second one (third column) proxies the output gap by taking the log-difference of GDP ($\tilde{y}_t = \Delta y_t$) instead of a one-sided HP filter. For each alternative estimation, the Metropolis-Hastings parameter is adjusted to get an acceptance rate of roughly 25%. In the baseline estimation, government spending g_t exhibits quite a strong degree of persistence ($\rho_g = 0.86$) and is slightly pro-cyclical ($\rho_{gy} = 0.05$). The two other specifications provide persistence parameters of 0.89, and using GDP growth as an alternative measure of output

[5] Section 3.1 in the online appendix describes the data.

gap points to the weak countercyclicality of government spending in this case. In addition, the average standard deviation of the level government spending shock is $100 \times \exp(-5.87) \simeq 0.28\%$, which is slightly higher than in Fernandez-Villaverde et al. (2011) for U.S. data. This order of magnitude is robust across specifications. When it comes to the volatility series, we find that they are less persistent ($\rho_{\sigma^g} = 0.69$ in the baseline case) and a one standard deviation uncertainty shock increases the volatility of government spending from $\exp(-5.87) = 0.28\%$ to $\exp(-5.872 + 0.36) = 0.4\%$, *i.e.* a 43% increase in uncertainty.

Table 1. Estimated parameters of the stochastic volatility process

	Baseline	$\rho_{gy} = 0$	$\tilde{y}_t = \Delta y_t$
Persistence of g_t (ρ_g)	0.86 [0.86,0.86]	0.89 [0.88,0.89]	0.89 [0.88,0.89]
Persistence of σ_t^g (ρ_{σ^g})	0.69 [0.68,0.69]	0.66 [0.65,0.66]	0.65 [0.65,0.66]
Impact effect of shock on σ_t^g (η_{σ^g})	0.36 [0.36,0.36]	0.36 [0.36,0.36]	0.36 [0.36,0.37]
Log of the average σ_t^g (σ^g)	-5.87 [-5.87,-5.87]	-5.85 [-5.85,-5.84]	-5.85 [-5.85,-5.85]
Output gap response (ρ_{gy})	0.05 [0.05,0.05]	$-$	-0.02 [-0.02,-0.02]

Note: The main values correspond to the median estimates and values under brackets are the 10th and 90th percentiles. The first column is the estimation of the processes (1)-(2). In the second column, we impose $\rho_{gy} = 0$ and in the third column, output gap ($\tilde{y}_t$) is proxied by the real GDP output growth.

The upper panel of Figure 1 reports the historical (extracted) series of government spending uncertainty estimated in Equation (2). The solid line is the median historical smoothed estimate of σ_t^g and the dashed lines are the first and last deciles, respectively. The behavior of government spending volatility can be understood through the lens of institutional backgrounds. Between the mid-70's and mid-80's, government debt and deficits of European countries were quite high, leading to erratic variations in g_t and several episodes of high uncertainty. On the contrary, the volatility of government spending was relatively low between 1985 and 1990. The adoption of the Maastricht Treaty by European countries in 1992 and the Stability and Growth Pact in 1997 coincided with a strong decline in government spending, illustrating the need to comply with the guidelines imposed by the treaty. The Euro Zone became effective in 1999. These institutional changes led to a rise in uncertainty, especially around 1995. In the early 2000's, the observed broad decline in volatility can be explained by a stronger coordination of national fiscal policies. Importantly, the Great Recession starting in 2007 and the subsequent switch of several countries toward austerity plans after 2010 are barely visible in our measure of government spending uncertainty. Over these years, the variations in government spending in level were large but also very persistent, which is captured by the autocorrelation parameter of the autoregressive process in Equation (2).[6] The lower panel of Figure 1 reports the Kernel density of the uncertainty measure σ_t^g. The solid vertical line corresponds to the median and the left (right resp.) and the dashed vertical lines are the 5% (95%, resp.) percentile. The figure gives a broad picture of the distribution of uncertainty over our sample. We find that this distribution is asymmetric and rather dispersed with a long right tail. These periods of high uncertainty correspond to large volatility movements in the mid-80s' (characterized by high government debt) and in 1995 (with the adoption of the Maastricht Treaty). Overall, this figure confirms that the Euro Area has experienced several episodes of high government spending uncertainty over the last decades.

2.2 Empirical Macroeconomic Effects

We now quantify the effects of government spending uncertainty shocks on macroeconomic variables in the Euro Area. To do so, we imbed the series of smoothed estimates σ_t^g into a SVAR(p) model with the vector of observable

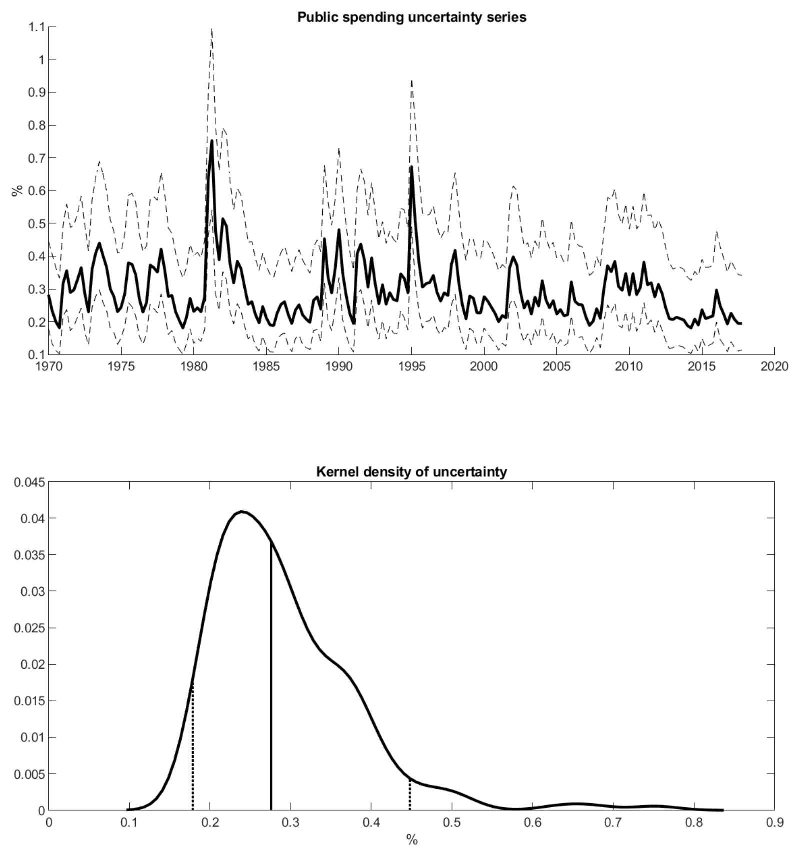
$$X_t = [\sigma_t^g \quad \log(y_t) \quad \log(i_t) \quad \log(c_t) \quad \pi_t]', \tag{3}$$

where σ_t^g is recovered from Equations (1)-(2), variable y_t denotes the real GDP, i_t real private investment, and c_t real private consumption. Variable π_t is the quarterly inflation rate of the GDP deflator. Data sources are detailed in the online appendix and the sample, as for the stochastic volatility estimation, ranges from 1970q1 to 2017q4. We use a Cholesky decomposition to orthogonalize the uncertainty shock and order the government spending uncertainty shock first. In line with several studies such as Bloom (2009), Fernandez-Villaverde et al. (2015), Leduc and Liu (2016) and Basu and Bundick (2017), this identification strategy implies that all macroeconomic variables included in the SVAR model are affected with delay of one quarter by the identified shock. Following the AIC criteria, the number of lags p is set to 4.[7]

[6] The series g_t is displayed in Figure 10 of the online appendix. Figure 11 of the online appendix also displays the government spending uncertainty series under the three specifications (baseline, $\rho_{gy} = 0$ and $\tilde{y}_t = \Delta y_t$). We find that the three series of government spending uncertainty are significantly correlated with a coefficient of correlation of 0.95.

[7] In Section 3.3 of the online appendix, we show that our results are robust to the number of lags and the ordering of variables.

Figure 1: Government spending uncertainty in the Euro Area.



Note: The upper panel displays the government spending uncertainty measure built from Equations (1) and (2). The solid line is the median point estimates and the dash lines are the 10th and 90th percentiles confidence intervals. The lower panel displays the Kernel density of this measure. The solid vertical line is the median and the dashed vertical lines are the 5th and 95th percentiles.

The SVAR model is estimated by OLS and confidence intervals are computed by bootstrapping the residuals. Figure 2 reports the Impulse Response Functions (IRFs) of all variables to a government spending volatility shock. The Figure shows the median bootstrapped IRFs (solid lines) and the 68% confidence interval. An exogenous increase in government spending uncertainty generates a negative and hump-shaped response of GDP for five years, with a peak occurring after eight quarters. Private consumption and investment also decrease in response to the shock, and also feature hump-shaped responses. Investment reacts over twice as much as output and consumption, and therefore appears to be an important driver of the aggregate response, which justifies the focus of our theoretical model on financial frictions. In this estimation, inflation does not respond significantly to a positive government spending uncertainty shock.[8]

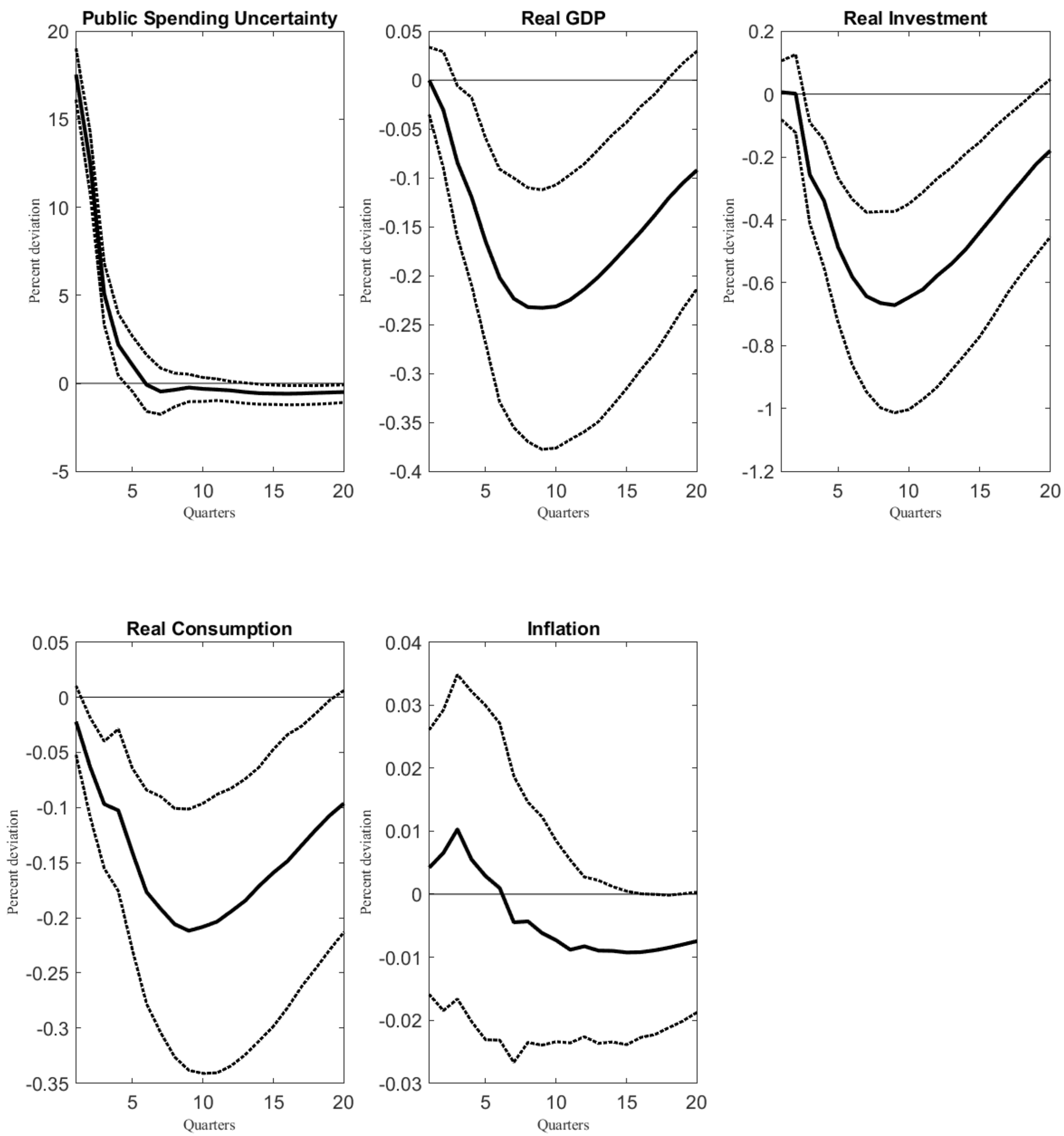
In Section 3.3 of the online appendix, we conduct a series of robustness exercises to check the validity of our results. In particular, we show that our results are robust to the introduction of additional variables. Interestingly, we find that the *level* of government spending decreases in response to an exogenous rise in government spending uncertainty. Additionally, the shock generates a reduction in the short-term interest rate in the medium run and a rise in the government bond spread. The next section shows that our theoretical model replicates these features, at least qualitatively. Finally, our results are robust to a sub-sample analysis, from 1999q1 to 2017q4, and to an alternative ordering of variables.

To check the validity of our exogeneity assumption of government spending uncertainty shocks, we run a Granger causality test. The nil hypothesis states that GDP, investment, consumption or inflation do not Granger cause government spending uncertainty. The hypothesis is not rejected if the forecast of uncertainty is not improved by the lagged values of one of these four variables. Consistent with the SVAR analysis, we assume four lags. We find that none of the variables does Granger-cause uncertainty at the 1 percent level, supporting our assumption of exogeneity.

Table 2 reports the forecast error variance decomposition of the uncertainty shock computed from the IRFs at several horizons. In line with the above causality analysis, the variance decomposition shows that government spending uncertainty shocks explain most of its own

[8] We show in Figure 14 in the online appendix that the uncertainty shock behaves as a negative demand shock (*i.e.* inflation decreases significantly) when the sample starts from the creation of the Euro Area in 1999. All other IRFs are not unaffected by this sub-sample analysis. It suggests that the behavior of the central bank matters in the transmission channels of this shock as this sample corresponds to a unified monetary policy period. Interestingly, Leduc and Liu (2016) and Basu and Bundick (2017) have already pointed out this property of uncertainty shocks for the US.

Figure 2: IRFs to a one standard-deviation government spending uncertainty shock.



Note: Solid lines correspond to the median-IRFs while dashed lines are the 14th and 86th percentile. Horizontal axes indicate quarters. All responses are multiplied by 100.

Table 2. Forecast error variance decomposition of uncertainty shock

	σ_t^g	$\log(y_t)$	$\log(i_t)$	$\log(c_t)$	π_t
1 quarter	1.000	0.000	0.000	0.028	0.002
4 quarters	0.952	0.015	0.026	0.030	0.001
8 quarters	0.918	0.063	0.094	0.075	0.001
16 quarters	0.864	0.101	0.141	0.110	0.006
40 quarters	0.820	0.078	0.125	0.093	0.012

variance. In addition, government spending uncertainty shocks account for around 10% of fluctuations of real variables (GDP, investment and consumption) over medium-run horizons (about 4 years). On the contrary, it appears that government spending uncertainty shocks are negligible determinants of the forecast variance of inflation at all horizons. These results are in line with the literature arguing that macroeconomic uncertainty is an important driver of the business cycle (Caggiano and Groshenny (2014); Jurado and Serena (2015), among others). To the best of our knowledge, we are the first to quantify the contribution of government spending uncertainty to aggregate fluctuations in the Euro Area.

3 The Model

We build a New-Keynesian model enriched with a financial accelerator mechanism *à la* Bernanke et al. (1999). One innovation of the model is that financial frictions not only affect capital assets (or equity) but also long-term government bonds. Indeed, in our model, a representative lender distributes households' deposits to a continuum of financial intermediaries called portfolio investors. Those financial intermediaries use deposits to buy (i) equity – private capital rented to firms producing intermediate goods – and (ii) long-term government bonds. Portfolio investors make two successive decisions. In a first stage, they choose the total size of the portfolio taking into account the possibility of idiosyncratic default. Each portfolio investor may indeed go bankrupt as a result of an idiosyncratic shock on the *ex-post* return of their portfolio, as in Bernanke et al. (1999). Financial frictions thus arise from the presence of asymmetric information between the private lender and each portfolio investor regarding the realization of the idiosyncratic shock. In a second stage, portfolio investors take the size of the portfolio as given and determine the share of each asset – equity and long-term bonds – in the portfolio to maximize its value, taking into account a quadratic adjustment cost implying that the two assets are imperfect substitutes. The rest of the model is a standard New-Keynesian model with households, capital producers, final and intermediate goods producers, a government and a central bank.

3.1 Households

The economy is populated by a continuum of identical households. A representative household chooses a sequence of consumption (c_t), labor supply (ℓ_t^h) and deposits (A_t) to maximize the discounted lifetime utility *à la* Jaimovich and Rebelo (2009)

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{1-\sigma} \left[\left(c_t - \psi \left(\ell_t^h \right)^{\omega_w} X_t \right)^{1-\sigma} - 1 \right] \right\}, \tag{4}$$

where E_0 is the expectation operator conditional to the information available in period 0, $\beta \in (0,1)$ is the subjective discount factor, $(\omega_w - 1)^{-1}$ is the Frisch elasticity on labor supply under Greenwood et al. (1988) preferences, ψ is a scale parameter, σ is the intertemporal elasticity of substitution, and where

$$X_t = c_t^{\sigma_X} X_{t-1}^{1-\sigma_X}. \tag{5}$$

Parameter σ_X drives the strength of the wealth effect on labor supply. Imposing $\sigma_X = 1$ gives rise to the King et al. (1988) preferences while assuming $\sigma_X = 0$ gives rise to Greenwood et al. (1988) preferences, where the wealth effect on labor supply is shut down. As explained by Basu and Bundick (2017), removing the wealth effect rules out the "precautionary labor supply" effect and therefore amplifies the size of uncertainty-driven recessions. As shown later, our approach is to let the data speak regarding the value of σ_X, given its importance and the lack of empirical evidence regarding its value. The representative household maximizes (4) subject to the budget constraint

$$c_t + A_t \leq w_t \ell_t^h + R_{t-1} \frac{A_{t-1}}{\pi_t} + \frac{\Pi_t}{P_t} - \frac{\mathrm{T}_t}{P_t} + \mathrm{div}_t, \tag{6}$$

where $w_t \equiv W_t/P_t$ is the real wage rate, with P_t the price of final goods. In addition, $\pi_t = P_t/P_{t-1}$ is the gross inflation rate, A_t denotes the holdings of net deposits in nominal terms, and R_t is the gross nominal interest rate associated with one-period-maturity nominal deposits. We assume that the household does not hold government long-term bonds directly but provides deposits to the lender, who contracts with a portfolio investor to invest in equity and long-term government bonds. Finally, $\mathrm{div}_t, \mathrm{T}_t$, and Π_t respectively stand for nominal profits from monopolistic firms, lump-sum taxes paid to the government and transfers from portfolio investors. The FOCs with respect to A_t, c_t, X_t and ℓ_t^h are

$$\begin{aligned}
\beta \mathrm{E}_t \left\{ \lambda_{t+1} \frac{R_t}{\pi_{t+1}} \right\} &= \lambda_t, & (7)\\
\left(c_t - \psi X_t \left(\ell_t^h\right)^{\omega_w}\right)^{-\sigma} + \sigma_X \upsilon_t c_t^{\sigma_X - 1} X_{t-1}^{1-\sigma_X} &= \lambda_t, & (8)\\
\upsilon_t + \psi \left(\ell_t^h\right)^{\omega_w} \left(c_t - \psi \left(\ell_t^h\right)^{\omega_w} X_t\right)^{-\sigma} &= \beta \left(1 - \sigma_X\right) \mathrm{E}_t \left\{ \upsilon_{t+1} c_{t+1}^{\sigma_X} X_t^{-\sigma_X} \right\}, & (9)\\
\psi \omega_w \left(\ell_t^h\right)^{\omega_w - 1} X_t \left(c_t - \psi X_t \left(\ell_t^h\right)^{\omega_w}\right)^{-\sigma} &= \lambda_t w_t, & (10)
\end{aligned}$$

where υ_t and λ_t are the Lagrangian multipliers associated to Equations (5) and (6), respectively. Equation (7) is the Euler equation on nominal deposits and determines the intertemporal dynamics of the marginal utility of consumption as a function of the real return on deposits. Equation (8) describes the evolution of consumption as a function of the marginal disutility of hours worked, and the dynamics of the wealth effect on labor supply. Equation (9) determines the dynamics of the wealth effect on labor supply and Equation (10) is the labor supply equation. A representative lender collects deposits from the representative household, pays a nominal return R_t and transfers the deposits to portfolio investors. The latter repays them back at nominal rate R_t^L if they do not experience any bankruptcy, as explain below.

3.2 Financial sector

In the financial sector, decisions are made in two steps. First, each portfolio investor determines the total size of its portfolio, given the moral hazard problem. Second, she determines the structure of the portfolio by choosing the relative weight of the two assets, equity and long-term government bonds, while facing a portfolio adjustment cost.

3.2.1 Portfolio decisions

Portfolio size There is a continuum of risk neutral portfolio investors indexed by $e \in [0, 1]$, that make decisions in a perfectly competitive market but facing an idiosyncratic shock.[9] At time t, type–e portfolio investor invests in a portfolio $\mathcal{P}_{e,t}$ using deposits from the representative lender, $D_{e,t}$, and internal funds, $N_{e,t}$

$$\mathcal{P}_{e,t} = D_{e,t} + N_{e,t}, \tag{11}$$

where the composition of $\mathcal{P}_{e,t}$ is described below. Each type–e portfolio investor faces an idiosyncratic shock, denoted by $\varepsilon_{e,t+1}$. The shock is distributed as a log-normal and there is a threshold from which the portfolio investor goes bankrupt, $\bar{\varepsilon}_{e,t+1}$ such that

$$\mathrm{E}_t \left\{ \bar{\varepsilon}_{e,t+1} R^p_{t+1} \mathcal{P}_{e,t} \right\} = \mathrm{E}_t \left\{ R^L_{e,t+1} D_{e,t} \right\}, \tag{12}$$

where $R^L_{e,t}$ is the gross non-default loan rate and R^p_t is the portfolio return. If $\varepsilon_{e,t+1} > \bar{\varepsilon}_{e,t+1}$, the portfolio investor can reimburse the representative private lender and pay interests. We assume that $\varepsilon_{e,t+1}$ is an i.i.d. random variable across time and types, with a continuous and once-differentiable c.d.f., $F(\varepsilon)$, over a non-negative support. We also consider that $\varepsilon_{e,t}$ is unknown to both the lender and the portfolio investor before the investment decision, with $\mathrm{E}(\varepsilon_{e,t}) = 1$ and $\mathrm{V}(\varepsilon_{e,t}) = \sigma_{\varepsilon,t}$. However, the realization of $\varepsilon_{e,t+1}$ is private information, such that information is asymmetric between the lender and the portfolio investor regarding the realized return of the portfolio. We follow the costly state verification environment of Townsend (1979), in which the representative lender bears a fixed monitoring cost in order to observe an individual portfolio's realized return, while the portfolio investor observes it for free. For convenience, following Bernanke et al. (1999), we assume that the monitoring cost is a proportion $\mu \in [0, 1]$ of the realized gross payoff to the investor's portfolio, $\mu \varepsilon_{e,t+1} R^p_t \mathcal{P}_{e,t}$. We assume that the lender perfectly diversifies the idiosyncratic risk involved in lending.

The portfolio investor chooses the value of portfolio, $\mathcal{P}_{e,t}$, and the associated level of loaned funds needed $D_{e,t}$, before the realization of the idiosyncratic shock $\varepsilon_{e,t+1}$. Solving the optimal contract gives the expression of the portfolio external risk premium at the symmetric equilibrium, denoted by $\mathrm{E}_t \left\{ R^p_{t+1} / R_t \right\}$

$$\mathrm{E}_t \left\{ \frac{R^p_{t+1}}{R_t} \right\} = x \left(\frac{\mathcal{P}_t}{N_t}, \bar{\varepsilon}_{t+1} \right), \tag{13}$$

[9] In most setups that use contracts with agency costs to model the financial accelerator, financial frictions apply to firms, that are considered risk-neutral. An exception is Candian and Dmitriev (2020), who consider risk-averse agents and show that their precautionary behavior leads them to be more resilient to idiosyncratic risk, dampening the importance of financial frictions and therefore of the associated financial accelerator mechanism. In our model, the financial contract applies to financial entrepreneurs, which we believe are more likely to be risk-neutral or less likely to be risk-averse than households or producing firms.

where $x(\cdot)$ is a function with $\frac{\partial x(\cdot)}{\partial x_t} > 0$. Equation (13) corresponds to the standard expression in the financial accelerator model for the risk premium applied here to portfolio investors: the borrowing cost paid by investors increases with the aggregate leverage ratio, $\mathcal{P}_t/N_t$, and with the default's threshold.

Portfolio composition Once each type–e portfolio investor has chosen the size of the portfolio; she chooses her composition. A type-e portfolio, $\mathcal{P}_{e,t}$, is composed of capital asset, $k_{e,t}$ acquired at nominal price Q_t and long-term government bonds, $b_{e,t}$ acquired at nominal price Q_t^c: [10]

$$\mathcal{P}_{e,t} = Q_t k_{e,t} + Q_t^c b_{e,t}, \tag{14}$$

Let $\omega_{e,t} \equiv Q_t k_{e,t}/\mathcal{P}_{e,t}$ denote the equity share, *i.e.* the share of equity in the portfolio, while $1 - \omega_{e,t}$ denotes the share of long-term government bonds. The total gross return on the portfolio composed at time t and redeemed in period $t+1$ is denoted by $R_{t+1}^p \mathcal{P}_{e,t}$ and defined as

$$R_{t+1}^p \mathcal{P}_{e,t} = R_{t+1}^k Q_t k_{e,t} + R_{t+1}^b Q_t^c b_{e,t} - \frac{\varpi}{2} \left(\omega_{e,t} - \omega\right)^2 \mathcal{P}_{e,t}, \tag{15}$$

where $\frac{\varpi}{2} \left(\omega_{e,t} - \omega\right)^2$ is a portfolio adjustment cost with ω, the steady-state value of ω_t and $\varpi \geq 0$, as assumed in Andres et al. (2004). In the spirit of Jermann and Quadrini (2012) or Iacoviello (2015), this cost is a reduced-form way of capturing deeper behavioral assumptions that affect the substitution between assets, namely equity and government bonds in this setup. In particular, it may capture a form habit in trading or a collection of behavioral biases leading to temporary misvaluation (see Daniel et al., 2002) and hence to sluggish adjustments in the composition of the portfolio.[11]

Dividing Equation (15) by $\mathcal{P}_{e,t}$ yields

$$R_{t+1}^p = \omega_t R_{t+1}^k + \left(1 - \omega_t\right) R_{t+1}^b - \frac{\varpi}{2} \left(\omega_t - \bar{\omega}\right)^2. \tag{16}$$

Since index–e does not appear in the equation except for $\omega_{e,t}$, the optimal composition of the portfolio is symmetric and we simply drop the e index: $\omega_{e,t} = \omega_{t\cdot}$. The portfolio manager chooses the optimal weight ω_t to maximize the portfolio returns, which gives

$$\mathrm{E}_t \left\{R_{t+1}^k\right\} - \mathrm{E}_t \left\{R_{t+1}^b\right\} = \varpi \left(\omega_t - \bar{\omega}\right). \tag{17}$$

[10] As in Gertler and Karadi (2011), investors issue claims to acquire the capital stock, where the number of claims equals the number of units of capital acquired, each of which has a market price Q_t. There is thus an equivalence between the stock of physical capital and the stock of equity, that we ignore for simplicity.

[11] Prospect theory (Johnson and Thaler, 1990) applied to the choice of a financial portfolio (Benartzi and Thaler, 1995, Barberis et al., 2001) may also be invoked to rationalize sluggish portfolio adjustments.

Therefore, the portfolio adjustment cost generates a wedge between the two expected returns which breaks the Modigliani-Miller theorem. Any difference in returns between equity and bonds pushes portfolio investors to rebalance the portfolio towards the asset with the highest return. This is what we call the portfolio channel. This rebalancing effect raises the portfolio external risk premium, $\mathrm{E}_t\left\{R_{t+1}^p/R_t\right\}$ and amplifies the financial accelerator mechanism. The strength of this amplification effect depends on the portfolio adjustment costs, ϖ. Indeed, larger adjustment costs introduce larger deviations in the relative returns of both assets, which in turn trigger larger rebalancing effects – larger movements in the equity share ω_t – and then a stronger amplification effect on the portfolio risk premium. This intuition is developed in further details in Section 6.1.

3.2.2 Net worth

We follow Bernanke et al. (1999) and consider that portfolio investors have finite life-time horizons. Each of them faces a probability $1-\gamma$ to exit the economy. The nominal aggregate net worth at the end of period t, N_t, is given by

$$N_t = \gamma V_t + W_t^p, \tag{18}$$

and V_t is the portfolio investor's value in period t. The dynamics of $v_t \equiv V_t/P_t$ is

$$v_t = \frac{R_t^p}{\pi_t}\frac{\mathcal{P}_{t-1}}{P_t}\left(1-\mu G(\bar{\varepsilon}_t)\right) - \frac{R_{t-1}}{\pi_t}d_{t-1}, \tag{19}$$

where $\mu G(\bar{\varepsilon}_t) = \mu\int_0^{\bar{\varepsilon}} \varepsilon f(\varepsilon)d\varepsilon$. Following Bernanke et al. (1999) and Carlstrom and Fuerst (1997), portfolio investors participate in the general labor market.[12] We also assume that they supply one unit of labor each period and earn the nominal wage W_t^p. In Equation (18), γV_t is the nominal value held by surviving portfolio investors. Those who exit in t transfer their wage to the new portfolio investors and consume part ϱ of their value, such that $c_t^e = (1-\gamma)\varrho v_t$, while the rest $\Pi_t/P_t = (1-\gamma)(1-\varrho)v_t$, is transferred to the representative household.

3.2.3 Returns on capital and government bonds

At the end of period t, type$-e$ portfolio manager buys the stock of capital $k_{e,t}$ at price Q_t to capital producers. In time $t+1$, and after observing all the shocks, the capital stock is rented

[12] We denote $1-\Omega$ the proportion of investors among all workers. This is a purely technical trick since it is necessary for the portfolio investor to start off with some net worth in order to allow them to begin operations.

to intermediate goods producers at a real rate z_{t+1}. Later on, the undepreciated capital is sold to the capital producers. In a model with investment adjustment costs and capital depreciation, we need to distinguish between the return on capital, R_t^k, and the rental rate of capital, z_t. The former depends on the latter, as well as on the value of the capital stock net of depreciation, adjusted for asset price valuation effects (fluctuations in the real price of capital, $q_t \equiv Q_t/P_t$). The gross nominal rate of capital returns, R_t^k, is equal to

$$\frac{R_t^k}{\pi_t} = \frac{z_t + (1-\delta)q_t}{q_{t-1}}, \tag{20}$$

where δ is the capital depreciation rate. In our model, the second type of asset is a long-term government bond. Following Woodford (2001), we assume that the government issues bonds each period with a maturity larger than one to finance its stream of expenditure. A government bond issued in period t pays ρ euros $j+1$ periods later, for each $j \geq 0$ and some decay factor $0 \leq \rho \leq \beta^{-1}$. The average maturity of the bond is therefore $\mathcal{M} = (1-\beta\rho)^{-1}$, which allows us to analyze bonds of arbitrary durations. As mentioned in Woodford (2001), a bond issued j periods ago has the same equilibrium price that ρ^j new bonds do. Given these assumptions, the gross real one-period return on a bond is defined as follows

$$r_t^b = \frac{1+\rho q_t^c}{q_{t-1}^c}, \tag{21}$$

where $q_t^c \equiv Q_t^c/P_t$ is the real price of government bonds.

3.3 Capital producers

At time t, capital producers sell the capital stock k_t to portfolio investors. The latter has been built by combining investment goods, i_t with the past undepreciated capital stock

$$k_t = (1-\delta)\,k_{t-1} + \left[1 - \frac{\varkappa}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right] i_t, \tag{22}$$

where $\varkappa \geq 0$ controls the size of investment adjustment costs. In equilibrium, the relative price of capital, q_t, is given by

$$q_t = \left[\phi_{1,t} + \beta \mathrm{E}_t\left\{\frac{\lambda_{t+1}q_{t+1}}{\lambda_t q_t}\phi_{2,t}\right\}\right]^{-1}, \tag{23}$$

with $\phi_{1,t} \equiv 1 - \frac{\varkappa}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 - \varkappa\left(\frac{i_t}{i_{t-1}} - 1\right)\frac{i_t}{i_{t-1}}$ and $\phi_{2,t} \equiv \varkappa\left(\frac{i_{t+1}}{i_t} - 1\right)\left(\frac{i_{t+1}}{i_t}\right)^2$.

3.4 Final good producer

The final good y_t, used for consumption and investment, is produced in a competitive market by combining a continuum of intermediate goods indexed by $j \in [0, 1]$, via the following CES production function

$$y_t = \left(\int_0^1 y_{j,t}^{\frac{\theta_p - 1}{\theta_p}} \mathrm{d}j \right)^{\frac{\theta_p}{\theta_p - 1}}, \tag{24}$$

where $y_{j,t}$ denotes the overall demand addressed to the producer of an intermediate good j and θ_p is the elasticity of substitution between intermediate goods. Profit maximization yields the following standard demand functions

$$y_{j,t} = \left(\frac{P_{j,t}}{P_t} \right)^{-\theta_p} y_t, \quad \text{with } P_t = \left(\int_0^1 P_{j,t}^{1-\theta_p} \mathrm{d}j \right)^{\frac{1}{1-\theta_p}}, \tag{25}$$

where $P_{j,t}$ denotes the price of an intermediate good produced by firm j.

3.5 Intermediate good producers

A unit continuum of intermediate producers assembles labor and capital services to produce differentiated varieties of goods. Varieties are then sold on monopolistically competitive markets subject to Rotemberg (1982) adjustment costs. Capital services are rented from portfolio investors, who own the capital stock on behalf of the representative household. The total labor input of firm j, $\ell_{j,t}$ is made of labor supplied by the representative household, $\ell^h_{j,t}$, and of labor supplied by the portfolio investor, $\ell^p_{j,t}$, according to $\ell_{j,t} = [\ell^h_{j,t}]^{\Xi}[\ell^p_{j,t}]^{1-\Xi}$. The amount of intermediate good produced by firm j is then given by

$$y_{j,t} = \mathcal{Z}_t \ell_{j,t}^{1-\alpha} k_{j,t-1}^{\alpha}, \tag{26}$$

where $\mathcal{Z}_t$ is a total factor productivity (TFP) shock following an AR(1) process

$$\hat{\mathcal{Z}}_t = \rho_{\mathcal{Z}} \hat{\mathcal{Z}}_{t-1} + \sigma^{\mathcal{Z}} \varepsilon_t^{\mathcal{Z}}. \tag{27}$$

Furthermore, the price of the good produced by firm j is chosen to maximize the present value of its profits subject to a Rotemberg (1982) quadratic price adjustment cost, given the demand for intermediate goods by final good producers. The New Keynesian Phillips Curve at the symmetric equilibrium yields

$$1 - \kappa_p (\pi_t - 1) \pi_t + \kappa_p \beta \mathrm{E}_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} (\pi_{t+1} - 1) \pi_{t+1} \frac{y_{t+1}}{y_t} \right\} = \theta_p (1 - s_t), \tag{28}$$

where s_t is the real marginal cost and $\kappa_p > 0$ measures the degree of price rigidity.

3.6 Government, central bank and equilibrium

The budget constraint of the government in real terms is given by

$$q_t^c b_t + \mathrm{T}_t/P_t = r_t^b q_{t-1}^c b_{t-1} + g_t - \frac{R_t^p}{\pi_t}\mathfrak{p}_{t-1}\mu G(\bar{\varepsilon}_t), \tag{29}$$

where $\mathfrak{p}_t = \mathcal{P}_t/P_t = q_t k_t + q_t^c b_t$ is the real value of the portfolio. In addition, the amount of government spending, g_t, follows the processes introduced in Equations (1)-(2). Furthermore, T_t is the nominal amount of lump-sum taxes, evolving according to the following feedback rule

$$\log\left((\mathrm{T}_t/P_t) \,/\, \left(\bar{\mathrm{T}}/\bar{P}\right)\right) = \phi_b \log\left(b_{t-1}/b\right) + \phi_y \log\left(y_t/y\right), \tag{30}$$

where variables without subscript refer to steady-state values. We also assume that the central bank follows a simple Taylor rule

$$R_t/R = \left(R_{t-1}/R\right)^{\rho_R} \left(\pi_t/\pi\right)^{(1-\rho_R)\phi_\pi}, \tag{31}$$

where $\rho_R \in (0,1)$ is a smoothing parameter, ϕ_π is the elasticity of R_t with respect to inflation.

A competitive equilibrium in this economy is defined as a sequence of prices and quantities such that (i) for a given sequence of prices, the first-order conditions of all agents/sectors are satisfied, and (ii) for a given sequence of quantities, prices adjust so that all markets clear. In particular, the final good market clearing condition is given by

$$y_t = c_t + c_t^e + i_t + g_t + \frac{\varpi}{2}\left(\omega_{t-1} - \bar{\omega}\right)^2 \frac{\mathfrak{p}_{t-1}}{\pi_t} + \frac{\kappa_p}{2}\left(\pi_t - \bar{\pi}\right)^2 y_t. \tag{32}$$

4 Parametrization

In line with the literature on the effects of time-varying volatility, we solve and simulate the model using a third-order approximation of the policy functions around the deterministic steady state.[13] While a subset of parameters is set using some empirical evidence, previous

[13]With a first-order approximation, volatility shocks do not affect any variable of the model. A second-order approximation only captures volatility indirectly, *via* cross-products, and volatility only has an effect if the level of government spending changes. Therefore, a third-order approximation of the policy functions is required, as it allows for volatility (second-order moments) shocks to have an independent role in the approximated policy functions. Following the literature, we define an uncertainty shock as a one-standard deviation increase in the level shock's volatility.

studies or matching steady-state targets, another subset of parameters is estimated using a mixture of Simulated Method of Moments (SMM) and Minimum Distance Estimation (MDE), as in Basu and Bundick (2017). The SMM part minimizes the distance between empirical first and second-order moments computed from the data and their model-based counterparts, while the MDE part minimizes the distance between the empirical and model-based IRFs. Hence, our estimation strategy relies on the ability of the model to match both unconditional and conditional moments of the data.

4.1 Calibrated parameters

Due to the scale of our model, not all parameters can be parametrized with a moment-matching procedure. Therefore, we partition the parameters into two subsets. The first subset contains parameters which are calibrated on a quarterly basis either based on values commonly used in the literature or by matching empirical targets in the steady-state. They are summarized in Table 3. The subjective discount factor, β, is set to 0.99, implying a steady-state annual real interest rate of approximately 4 percent. When it comes to preferences, the intertemporal elasticity of substitution is set to 1.14 and the labor supply elasticity is set to $1/\left(\omega_w - 1\right) = 5$, a relatively high value in line with the macroeconomic literature, in line with King and Rebelo (1999) among others. The scale parameter υ is chosen to ensure that household's labor in the steady state, ℓ^h, equals to $1/3$. Furthermore, the Cobb-Douglas parameter associated with capital, α, is set to 0.36, the depreciation rate is $\delta = 0.02$ and we assume a markup of 10 percent in the intermediate sector ($\theta_p = 11$).

Due to the lack of empirical evidence regarding the portfolio sector, we mostly follow Bernanke et al. (1999). We impose $R^p/R = 1.02^{0.25}$, corresponding to an annual risk spread of 200 basis-points for the portfolio. The deterministic steady state of the model implies that all assets share the same return in the absence of shock ($R^k = R^b = R^p$). In addition, the steady-state portfolio-to-net-worth ratio x, is calibrated to 2, the annual business failure rate is set to $F(\overline{\varepsilon}) = 3\%$, and the idiosyncratic productivity shock, ε_t, is distributed as a log-normal with an unconditional expectation of 1 and a standard deviation σ_ε. Altogether, these targeted moments imply that $\gamma = 0.98$, $\mu = 0.12$, $\sigma_\varepsilon = 0.28$ and $\overline{\varepsilon} = 0.50$. Finally, the entrepreneurial labor-income share is set to 0.01, implying a value of $\Omega = 0.9846$ and the transfers from defaulted investors to households ensure the model's stability $(1 - \varrho = 0.999)$.

We now turn to the calibrated values of fiscal policy parameters. Based on our dataset used in Section 2, the steady-state level of government spending to output, g/y, is set to 0.194. In addition, in line with Euro Area data, we assume an average maturity of government bonds of 7 years, *i.e.* $\mathcal{M} = 28$ in our quarterly setup. The parameters of the tax feedback rule are $\phi_b = 3$ and $\phi_y = 0.34$ to ensure equilibrium determinacy. The Taylor rule is calibrated with a high degree of interest rate persistence reflecting the ECB inertia ($\rho_R = 0.95$) and a standard sensitivity to inflation ($\phi_\pi = 1.28$).

Table 3. Calibrated parameters

β	Discount factor	0.99
$1/(\omega_w - 1)$	Labor supply elasticity	5
σ	Intertemporal elasticity of substitution	1.14
ℓ^h	Household's labor steady state	0.33
α	Cobb-Douglas parameter for capital	0.36
δ	Capital depreciation rate	0.02
θ_p	Elasticity of substitution among goods	11.00
R^p/R	Steady-state portfolio spread	$1.02^{0.25}$
x	Steady-state ratio of capital to net worth	2
γ	Survival rate of portfolio investors	0.9834
μ	Monitoring cost	0.1175
σ_ε	Standard error of idiosyncratic shock	0.2764
$\bar{\varepsilon}$	Threshold value of idiosyncratic shock	0.4982
Ω	Proportion of household labor in aggr. labor	0.9846
$1 - \varrho$	Transfers from failed investors to households	0.9999
g/y	Share of government expenditure in output	0.194
$\mathcal{M}$	Average bond maturity	28
ϕ_b	Tax rule feedback parameter wrt debt	3
ϕ_y	Tax rule feedback parameter wrt output	0.34
ρ_R	Interest rate inertia	0.95
ϕ_π	Taylor rule parameter wrt inflation	1.28

4.2 Estimated parameters

We are left with eleven parameters to estimate, namely parameters related to productivity and government spending shocks $\left\{\eta_{\sigma^g}, \rho_{\sigma^g}, \sigma^g, \rho_g, \rho_{gy}, \sigma^{\mathcal{Z}}, \rho_{\mathcal{Z}}\right\}$ as well as the preference parameter driving the wealth effect of labor supply σ_X, the Rotemberg parameter κ_p that governs the extent of price stickiness, the investment adjustment cost parameter $\varkappa$, and the portfolio adjustment cost parameter ϖ. Let us write

$$\psi_i = \left\{\eta_{\sigma^g},\ \rho_{\sigma^g},\ \sigma^g,\ \rho_g,\ \rho_{gy},\ \sigma^{\mathcal{Z}},\ \rho_{\mathcal{Z}},\ \sigma_X,\ \kappa_p,\ \varkappa,\ \varpi\right\}, \tag{33}$$

as the vector of parameters to estimate. We match both (i) conditional moments (IRFs) which provides information regarding the transmission of government spending uncertainty shocks, and (ii) unconditional moments so as to produce reasonable business cycle moments. The vector of empirical IRFs is denoted by $\hat{\Phi}$ and extracted from the SVAR in Figure 2. The set of corresponding model-based IRFs, which we denote as $\Phi^m(\psi_i)$, is computed as the deviation from the *ergodic mean* of each variable after a government spending uncertainty shock. When it comes to the set of business cycle moments, we compute the variance of real GDP, investment, consumption, inflation as well as their covariance with real output, all preliminarily one-sided HP filtered both in the model and in the data. Let $\hat{M}$ denote the vector of empirical unconditional moments to be matched and define $M^m(\psi_i)$ as their model-based counterpart. Notice that the vector $M^m(\psi_i)$ is built by simulating the third-order approximated model, and that both conditional and unconditional moments are used simultaneously in our estimation procedure. Then, the set of estimated parameters $\hat{\psi}_i$ is computed so as to minimize the following Euclidean distance

$$\mathcal{J}(\psi_i) = \underbrace{[\Phi^m(\psi_i) - \hat{\Phi}]'\hat{W}^{\Phi}[\Phi^m(\psi_i) - \hat{\Phi}]}_{MDE} + \Lambda\underbrace{[M^m(\psi_i) - \hat{M}]'\hat{W}^{M}[M^m(\psi_i) - \hat{M}]}_{SMM}, \tag{34}$$

where $\hat{W}^{\Phi}$ and $\hat{W}^{M}$ are diagonal matrices with the inverse of the asymptotic variances of each element of $\hat{\Phi}$ and $\hat{M}$ respectively along the diagonals. Parameter Λ governs the relative importance of the second-order moments in the $\mathcal{J}$-stat. It is set so that both types of moments account for an equal fraction of the total distance.

5 Estimation results

We now discuss the estimation results and the overall goodness-of-fit of the model.

5.1 Parameter Estimates

We start by analyzing the estimation results of the baseline model, as reported in Table 4. The magnitude and the persistence of the government uncertainty shock ($\eta_{\sigma^g} = 0.18$ and $\rho_{\sigma^g} = 0.53$, respectively) are estimated to simply reproduce the response of σ_t^g to its own shock. Parameters related to the level (government spending and TFP) shocks are identified through the unconditional moments and we obtain $\sigma^g = -7.29$, $\rho_g = 0.94$, $\rho_{gy} = 0.012$, $\sigma^{\mathcal{Z}} = 0.0012$ and $\rho_{\mathcal{Z}} = 0.98$.[14] The estimation of the remaining parameters provides some insights regarding the transmission channels of government spending uncertainty. It is quite standard in the literature to remove the wealth effect on labor supply, *i.e.* to impose $\sigma_X = 0$, to shut down the precautionary labor supply effect and therefore magnify the response of output to uncertainty shocks (see Basu and Bundick, 2017). We let the data speak regarding the strength of the wealth effect on the labor supply, and obtain $\sigma_X = 0.102$. This suggests that our model is able to generate a recession as large as documented by the SVAR analysis even with a partially active – although relatively weak – wealth effect on labor supply. We believe it is due to the presence of additional interacting amplification mechanisms, that make the model less dependent on the absence of a wealth effect to amplify the recession. In particular, the joint estimated values of the investment cost parameter $\varkappa = 2.09$ and the portfolio parameter $\varpi = 21.56$ allow our model to match the variance and the response of investment to the government spending uncertainty shock. While $\varkappa = 2.09$ is a bit lower than usually estimated in New-Keynesian models, we show in Figure 7 in the online appendix that capital adjustment cost would provide similar dynamics with a larger value of $\varkappa$. In addition, our estimation of $\varpi = 21.56$ implies important restrictions in the substitutability between assets (equity and government bonds) for portfolio investors. We show in Section 6.1 that given our calibration, the value $\varpi = 21.56$ implies that a rise in the equity share by 1% generates a spread between the equity return and the portfolio return of 0.04 percentage point (abstracting from the second order terms). On top of that, this parameter interacts with the standard financial accelerator mechanism that affect the dynamics of investment to magnify its effects as shown in Section 6.1. Finally, the large estimated value of the Rotemberg parameter $\kappa_p = 534$ confirms that nominal rigidities matter in the transmission of uncertainty shocks (see Basu and Bundick, 2017). Our model is fully non-linear implying that the New Keynesian Phillips Curve under Calvo price setting is not observationally equivalent to the one obtained with Rotemberg adjustment costs. However, abstracting from the second order terms, the estimated value $\kappa_p = 534$ corresponds to an average frequency of price adjustment of two years (eight quarters), lining up well enough with available empirical evidence.

[14] Notice that the estimates of η_{σ^g}, ρ_{σ^g}, σ^g, ρ_g and ρ_{gy} differ from Section 2 because we use alternative procedures. In particular, the mix of SMM and MDE is a multivariate method based on simulations while the more direct method used in Section 2 to estimate these parameters is univariate.

Table 4. Estimation results

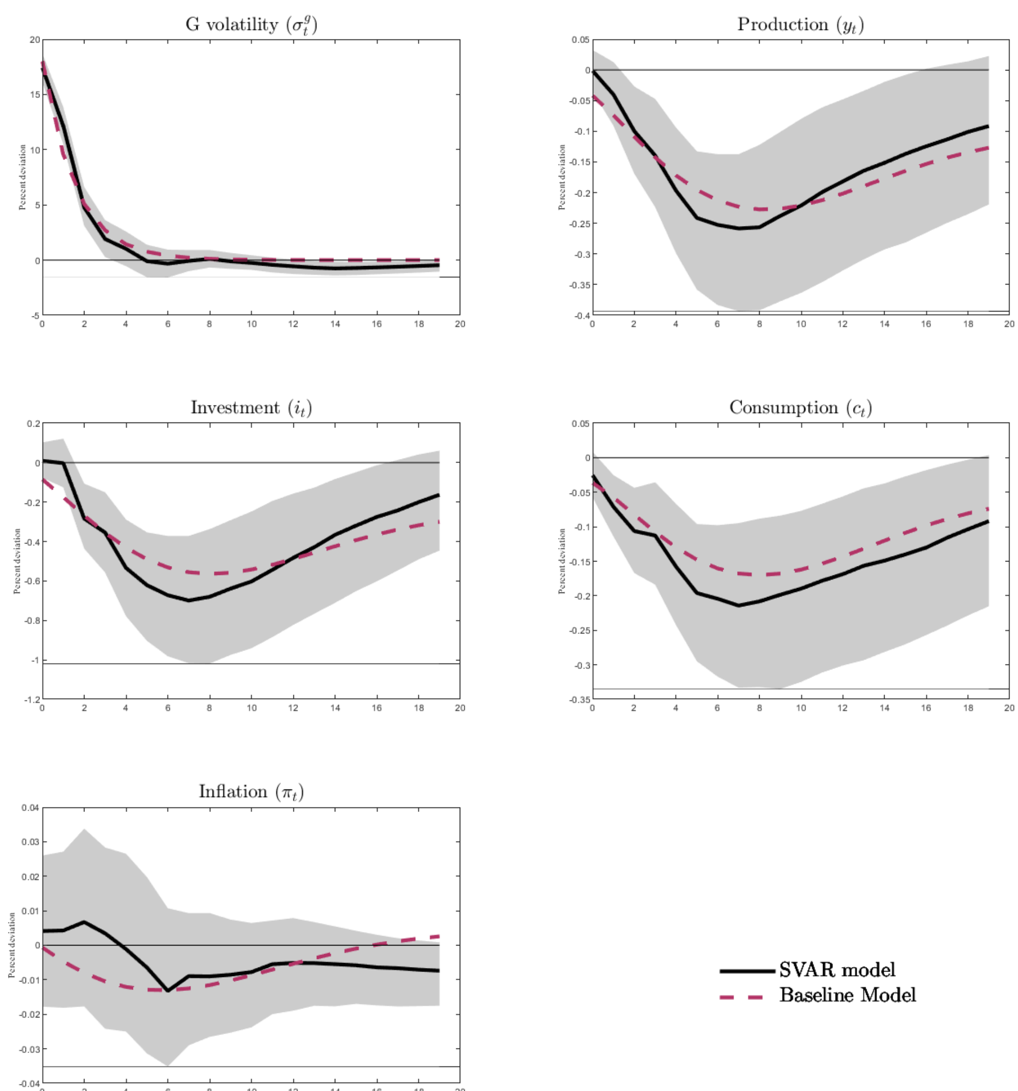
η_{σ^g}	Impact effect of spending volatility shocks	0.18 [0.182, 0.183]
ρ_{σ^g}	Persistence of spending volatility shocks	0.53 [0.526, 0.533]
σ^g	Impact effect of spending shocks	-7.29 [-7.74,-6.83]
ρ_g	Persistence of spending shocks	0.94 [0.932, 0.964]
ρ_{gy}	Output feedback coefficient	0.012 [0.011, 0.014]
$\sigma^{\mathcal{Z}}$	Impact effect of TFP shocks	0.0012 [0.0009, 0.0021]
$\rho_{\mathcal{Z}}$	Persistence of TFP shocks	0.98 [0.897, 1.069]
σ_X	Strength of the wealth effect on labor supply	0.102 [0.099, 0.105]
ϖ	Portfolio adjustment cost parameter	21.56 [20.83, 22.29]
$\varkappa$	Investment adjustment cost parameter	2.09 [2.050, 2.122]
κ_p	Rotemberg price adjustment parameter	534 [516, 551]

Note: Following Christiano et al. (2005), the standard errors of the estimated parameters are computed using the asymptotic delta function method.

5.2 Unconditional Moments

Table 5 shows that the baseline model reproduces observed second-order moments relatively well. In particular, it does a good job in reproducing the volatility of real variables since the simulated variance of output, consumption and investment ($\sigma_y = 1.53$, $\sigma_c = 0.90$ and $\sigma_i = 8.55$) align quite well with their empirical counterparts ($\sigma_y = 1.45$, $\sigma_c = 1.02$ and $\sigma_i = 9.31$). The volatility of inflation is lower in the model $\sigma_\pi = 0.03$ than in the data $\sigma_\pi = 0.08$ reflecting a high degree of nominal rigidities, as shown above. Finally, the theoretical model replicates covariance patterns well: the covariance of output with consumption (1.02 and 1.11 in the data and in the model respectively), of output with investment (3.39 in the data and 3.48 in the model respectively) and of output with inflation (0.12 in the data and 0.17 in the model respectively) are all closely matched.

Figure 3: Empirical and model-implied IRFs to a government spending uncertainty shock.



Note: Red dashed lines are model-implied IRFs; blue solid lines are empirical IRFs. Grey areas are the 14th and 86th percentiles. Horizontal axes indicate quarters. All responses are multiplied by 100.

Table 5. Simulated unconditional moments (×100).

Variance of:		Data	Model
	y_t	1.45	1.53
	c_t	1.02	0.90
	i_t	9.31	8.55
	π_t	0.08	0.03
Cov. of y_t with:			
	c_t	1.02	1.11
	i_t	3.39	3.48
	π_t	0.12	0.17

Note: All moments are computed from one-sided HP filtered data.

5.3 Transmission Channels of government spending Uncertainty Shocks

Figure 3 displays the SVAR-based (solid lines) as well as the model-based IRFs (dashed lines) of key variables to the government spending uncertainty shock. Overall, the model generates theoretical responses that are large enough to match their empirical counterparts, and all variables exhibit hump-shaped responses, as in the data. In particular, the model generates the negative effect of the government spending uncertainty shock on real output as well as consumption and investment. Further, in our model, higher government spending uncertainty looks like a demand shock as it generates a recession along with a drop in inflation.

One explanation of the satisfying goodness-of-fit of the model is the high estimated degree of price stickiness ($\kappa_p = 534$), which gives rise to the demand channel of the propagation of uncertainty. Indeed, firms decrease their demand for production inputs in response to the lower demand implied by the shock. The marginal product of capital falls, which leads to a fall in aggregate investment. If capital is predetermined, labor is the only input to production that can change. As prices adjust slowly, firms' markups do not fall as much as marginal costs. The wedge between marginal costs and markups thus increases.

From the perspective of the representative household, the real wage drops and this income risk increases precautionary savings, leading consumption to decrease and savings (deposits) to rise. On the one hand, the fall in the real wage pushes labor supply down and the reduction in consumption boosts labor supply through the wealth effect. Hence, depending on the strength of the latter, the recession can be larger or smaller, as already highlighted by Basu and Bundick (2017). Given the form of our utility function, the wealth effect is maximal in the case of King et al. (1988) household preferences ($\sigma_X = 1$), which would then offset the drop in labor demand and mitigate the recession. Instead, our estimate for $\sigma_X = 0.102$ suggests quite a weak wealth effect on labor supply, which implies a large reduction in labor and ultimately drives output down.

As mentioned above, the SVAR model does not provide clear evidence regarding the response of inflation to government spending uncertainty. Our theoretical model fails to replicate the initial (and statistically not significant) rise in inflation and it generates a reduction in inflation over the medium-run, as observed in the data. Fernandez-Villaverde et al. (2011) argue that uncertainty shocks generate a rise in inflation because the "upward pricing bias channel" (which pushes firms to set prices too high compared to their competitors) dominates the precautionary saving channel which generates a reduction in aggregate demand.[15] Our model imbeds additional transmission mechanisms – interacting financial frictions – which leads the central bank to lower its risk-free rate, explaining the drop in inflation.[16]

The above analysis suggests that the recession induced by the government spending uncertainty shock can be explained by the precautionary saving motive combined with price stickiness, which has been already identified in the literature (see Basu and Bundick, 2017 for instance).[17] On top of that, in line with Cesa-Bianchi and Fernandez-Corugedo (2017), the effects of a government spending uncertainty shock are amplified by the presence of financial frictions. However, these three channels (precautionary savings, price stickiness and financial frictions) are not enough to provide the explanation for the recession caused by the government spending uncertainty shock. We complement previous results in the next section, and argue that the portfolio channel acts as an important additional transmission channel of the government spending uncertainty shock.

[15] The "upward pricing bias channel" results from the presence of sticky prices. As the profit function is asymmetric, firms have an incentive to set prices too high, rather than too low, in order to prevent themselves against any price adjustment they would need to make in the future. This channel drives inflation upward and result in uncertainty shocks behaving like supply shocks.

[16] As shown in the online appendix on Figure 13, a SVAR that includes the risk-free rate points to a reduction of the latter in the medium run after a government spending uncertainty shock, as predicted by our model. Furthermore, Figure 14 of the online appendix reports the IRFs on a SVAR estimated on a shorter, post-1999 sample, and shows that inflation falls after a government spending uncertainty shock, a result that is consistent with the transmission mechanisms offered by our model.

[17] Section 2 in the online appendix provides a complete sensitivity analysis with respect to parameters that affect the strength of these transmission channels: the Frisch elasticity of labor supply, the strength of the wealth effect on labor supply, the response of the central bank to inflation, the use of Calvo contracts instead of Rotemberg adjustment costs, the degree of price stickiness and the use of capital adjustment cost. In Section 3.7, we provide a model extension by introducing distortionary labor tax. Unsurprisingly, having stabilizing taxes helps attenuate the fall in the value of portfolio and output, Figure 9 in the online appendix.

6 A Closer Look at the Portfolio Channel

One originality of our model is that financial frictions distort the allocation of *both* firms' equity and government bonds, those assets being imperfect substitutes due to the portfolio adjustment cost. In this section, we show how these features affect the transmission channels of government spending uncertainty shocks.

6.1 Dissecting the Portfolio Channel

We argue that linking equity and government bonds in the frictional financial market generates an additional amplification mechanism of government spending uncertainty shocks. To illustrate this point, we focus on the dynamics of equity and relate them to the traditional financial accelerator (FA) model. Consider Equations (13), (15) and (17) of the model, that respectively describe the dynamics of the portfolio external risk premium, $\mathrm{E}_t\{R^p_{t+1}/R_t\}$, as well as their tie to the bond and capital returns, $\mathrm{E}_t\{R^b_{t+1}\}$ and $\mathrm{E}_t\{R^k_{t+1}\}$. In the online appendix, we show that combining these equations and abstracting from (higher order) non-linear terms gives

$$\text{(FA mechanism)} \quad : \quad \mathrm{E}_t\{\hat{R}^p_{t+1} - \hat{R}_t\} = \chi \left[\hat{q}_t + \hat{k}_t - \hat{n}_t - \hat{\omega}_t\right], \tag{35}$$

$$\text{(Rebalancing effect)} \quad : \quad \mathrm{E}_t\{\hat{R}^k_{t+1} - \hat{R}_t\} - \mathrm{E}_t\{\hat{R}^p_{t+1} - \hat{R}_t\} = \frac{\varpi}{R^p}\omega\left(1-\omega\right)\hat{\omega}_t, \tag{36}$$

where we used the fact that $R^p = R^k$ in the steady state and where $\chi > 0$ is the elasticity of the portfolio risk premium to the leverage ratio.[18] The derivation of these equations also makes use of the definition of the share of equity in the portfolio, *i.e.* $\hat{\omega}_t = \hat{q}_t + \hat{k}_t - \hat{\mathfrak{p}}_t$. Now combining both equations yields

$$\text{(Enriched FA)} : \mathrm{E}_t\{\hat{R}^p_{t+1} - \hat{R}_t\} = \frac{\chi}{\vartheta - \chi}\left[\vartheta\left(\hat{q}_t + \hat{k}_t - \hat{n}_t\right) - \mathrm{E}_t\{\hat{R}^k_{t+1} - \hat{R}_t\}\right] \tag{37}$$

where $\vartheta \equiv \varpi\omega\left(1-\omega\right)/R^p \geq 0$.[19] Assume that $\varpi = 0$ (zero adjustment cost) or $\omega = 1$ (no government bonds in the portfolio) in the above equations. Then, in that case, $\vartheta = 0$ so Equation (36) gives $\mathrm{E}_t\{\hat{R}^p_{t+1} - \hat{R}_t\} = \mathrm{E}_t\{\hat{R}^k_{t+1} - \hat{R}_t\}$. Furthermore, Equation (35) gives $\mathrm{E}_t\{\hat{R}^k_{t+1} - \hat{R}_t\} = \chi\left[\hat{q}_t + \hat{k}_t - \hat{n}_t\right]$ and the leverage ratio is given by $\hat{x}_t = \hat{q}_t + \hat{k}_t - \hat{n}_t$ – instead of $\hat{x}_t = \hat{\mathfrak{p}}_t - \hat{n}_t$ in our case. This corresponds to the traditional financial accelerator

[18] Details of the computations are provided in Section 1.8 of the online appendix. Notice that all variables with a hat are log-deviation from the steady-state.

[19] According to our calibration, $\chi = 0.08$, $\varpi = 21.56$, $R^p = 1.0151$ and $\omega = 0.7444 > 0$, implying $\vartheta > 0$. Notice that this calibration implies $\frac{\varpi}{R^p}\omega\left(1-\omega\right) = 0.04$, meaning that the elasticity of the spread with respect to the share of equity is 0.04.

mechanism, described Bernanke et al. (1999), by which any shock that increases the leverage ratio raises the external risk premium, which in turn makes firms more likely to default as the default threshold $\widehat{\bar{\varepsilon}}_t$ increases.[20] Now if $\varpi > 0$ and $\vartheta > \chi$, which is the case of our baseline calibration, the financial accelerator mechanism is enriched with a portfolio channel.

To start with, Equation (36) captures the effect of portfolio rebalancing on the wedge between the capital return relative to risk-free rate ($\mathrm{E}_t\{\hat{R}^k_{t+1} - \hat{R}_t\}$) and the portfolio external risk premium ($\mathrm{E}_t\{\hat{R}^p_{t+1} - \hat{R}_t\}$). Portfolio investors rebalance their asset holdings in favor of the asset that provides the highest relative return. As such, when the relative return of capital rises above the average relative return of the portfolio, investors increase the equity share in the portfolio $\hat{\omega}_t$. For a given wedge in relative returns, larger adjustment costs ϖ imply less rebalancing – since this is costly – and hence smaller changes in $\hat{\omega}_t$. Taken alone, this effect would lead to conclude that portfolio adjustment costs dampen the movements in the external finance premium compared to a standard FA model (see Equation (35)). However, the "enriched" financial accelerator mechanism described by Equation (37) shows that portfolio costs can result in amplified variations of the external finance premium.

Indeed, Equation (37) shows that the external portfolio finance premium $\mathrm{E}_t\{\hat{R}^p_{t+1} - \hat{R}_t\}$, which relates positively with the default threshold, is increasing with the equity-based leverage ratio $(\hat{q}_t + \hat{k}_t - \hat{n}_t)$ and decreasing with the expected relative capital return, $\mathrm{E}_t\{\hat{R}^k_{t+1} - \hat{R}_t\}$. On the one hand, more leveraged investors are riskier and therefore have to pay a higher premium to borrow. This corresponds to the first term in the right bracket in Equation (37). We label this effect the leverage effect and its intensity is given by $\chi\vartheta/(\vartheta - \chi)$. On the other hand, when the relative return of capital is high, this makes the funded projects more profitable and therefore, tends to reduces the external finance premium. This corresponds to the second term in the right bracket in Equation (37). We label it the profitability effect and its intensity is given by $\chi/(\vartheta - \chi)$. As such, the relative size of these two counter-balancing effects is given by the value of $\vartheta = \varpi\omega(1-\omega)/R^p \geq 0$, which is increasing in the value of portfolio adjustment costs. Provided the latter is large enough, the leverage effect dominates the profitability effect and the portfolio channel results in amplified fluctuations of the portfolio external finance premium compared to the traditional financial accelerator – a

[20]Before it is combined to give Equation (35), the linearized condition for the interaction between the default threshold and the external finance premium implies

$$\mathrm{E}_t\{\hat{R}^p_{t+1} - \hat{R}_t\} = f_0 f_1 \widehat{\bar{\varepsilon}}_t,$$

where $f_0 > 0$ and $f_1 > 0$ are defined in the Appendix. With $\varpi = 0$ and $\omega = 1$, $\mathrm{E}_t\{\hat{R}^p_{t+1} - \hat{R}_t\} = \mathrm{E}_t\{\hat{R}^k_{t+1} - \hat{R}_t\}$ so that $\mathrm{E}_t\{\hat{R}^k_{t+1} - \hat{R}_t\} = f_0 f_1 \widehat{\bar{\varepsilon}}_t$.

situation where $\varpi = 0$ and $\omega = 1$. In general equilibrium, a shock that triggers a rebalancing of the portfolio towards capital $\hat{\omega}_t > 0$ results in a larger increase of the portfolio external finance premium further amplifying the relative return of equity. This in turn generates a larger increase in the default threshold (through a dominant leverage effect) and the financial accelerator mechanism is magnified by the portfolio channel.

6.2 Impulse Response Functions Analysis

In this section, we highlight the respective quantitative roles of the portfolio channel and the portfolio adjustment cost. To do this, we report and analyze the theoretical IRFs under two different specifications: one that shuts down the portfolio channel by abstracting from government bonds in the portfolio ($\omega_t = 1$), and one in which we consider alternative degrees of substitutability between the two assets by varying the portfolio adjustment cost ϖ.

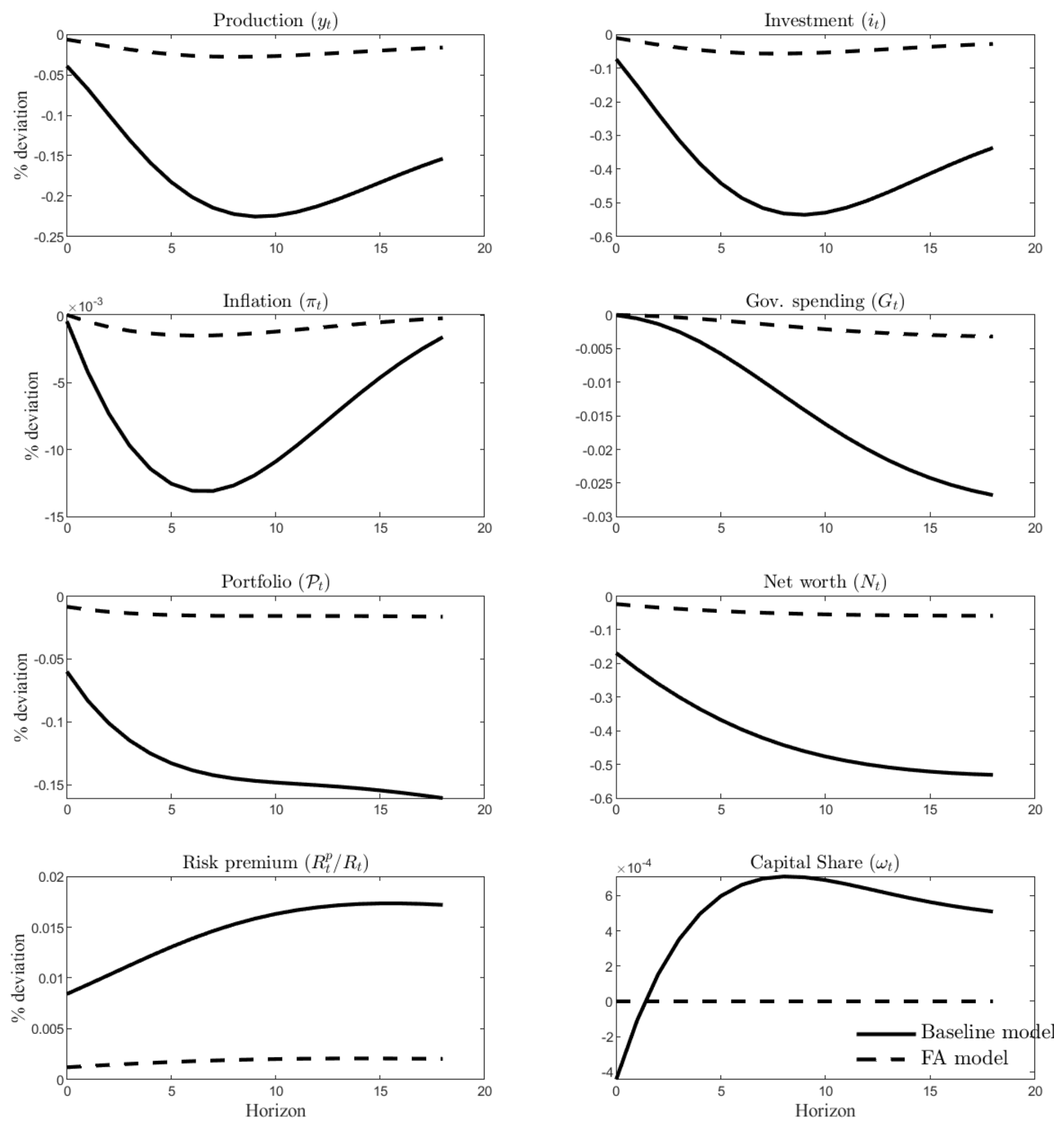
Shutting down the Portfolio Channel Figure 4 complements Figure 3 and displays model-based IRFs to a one standard deviation increase in government spending uncertainty shock, $\varepsilon_t^{\sigma^g}$. The solid lines correspond to the baseline model. The dashed lines depict the IRFs of the typical financial accelerator model (FA model) that abstracts from government bonds in the portfolio ($\omega_t = 1$, *i.e.* $\mathcal{P}_t = Q_t k_t$ and by construction $\varpi = 0$). In that case, the portfolio premium is given by Equation (35) with $\hat{\omega}_t = 0$ and $\varpi = 0$, and government bonds are bought directly by the representative household.

One striking result is that extending financial frictions to government bonds substantially amplifies the reduction in investment in response to government spending uncertainty shocks. The recession generated by higher uncertainty leads to a reduction in net worth through a deterioration of portfolios' balance sheets.[21] In the typical financial accelerator model that leaves government bonds aside from the portfolio of investors, the reduction in net worth is only driven by the drop in capital demand and a subsequent reduction in the price of capital. Enriching the model with a portfolio structure of both equity and government bonds produces a reduction in the price of both assets because of the balance sheet deterioration. The portfolio channel then is at work to amplify the effects of financial frictions.

It turns out that government spending (g_t) falls conditional on a government spending un-

[21] Notice that the Fisher effect plays an additional driver of balance sheet deterioration. Indeed, as financial contracts are written in nominal terms, the reduction in inflation increases the value of debt held by portfolio investors which generates an additional reduction in investment (see Fernandez-Villaverde et al., 2011). As we show in Figure 4 of the online appendix, this effect is magnified when the coefficient attached to inflation in the Taylor rule is low as inflation reacts more to the uncertainty shock.

Figure 4: IRFs to a government spending uncertainty shock.



Note: IRFs to a government spending uncertainty shock. The solid lines correspond to the baseline model. The dashed lines correspond to the typical financial accelerator model (ϖ=0 and ω=1). Horizontal axes indicate quarters. All responses are multiplied by 100.

certainty shock.[22] The cut in government spending lowers the issuance of government bonds, which reduces their price by less than the price of private capital. Consequently, the return of capital falls less than the return of bonds, or put differently, the spread on capital rises more than the spread on bonds, which triggers the two effects described above: the leverage effect and the profitability effect. The latter dominates on impact and the equity share ω_t falls on impact. However, the leverage effect quickly overturns the profitability effect, and the share of equity ω_t then rises after 2 quarters, leading portfolio investors to rebalance portfolios towards equity. The rise in the share of equity in turn magnifies the financial accelerator mechanism, as explained in Section 6.1. Furthermore, we show in the next paragraph that the rise in the share of equity in the portfolio after a shock on government spending uncertainty is qualitatively supported by empirical evidence. The combination of a rising risk premium on the portfolio $E_t \left\{ R^p_{t+1}/R_t \right\}$ – portfolio investors are more likely to default – and fall in net worth (and portfolio size) are thus observed and typical in financial accelerator models. However, both are substantially amplified in a setup in which financial frictions apply to a portfolio combining government bonds and equity.

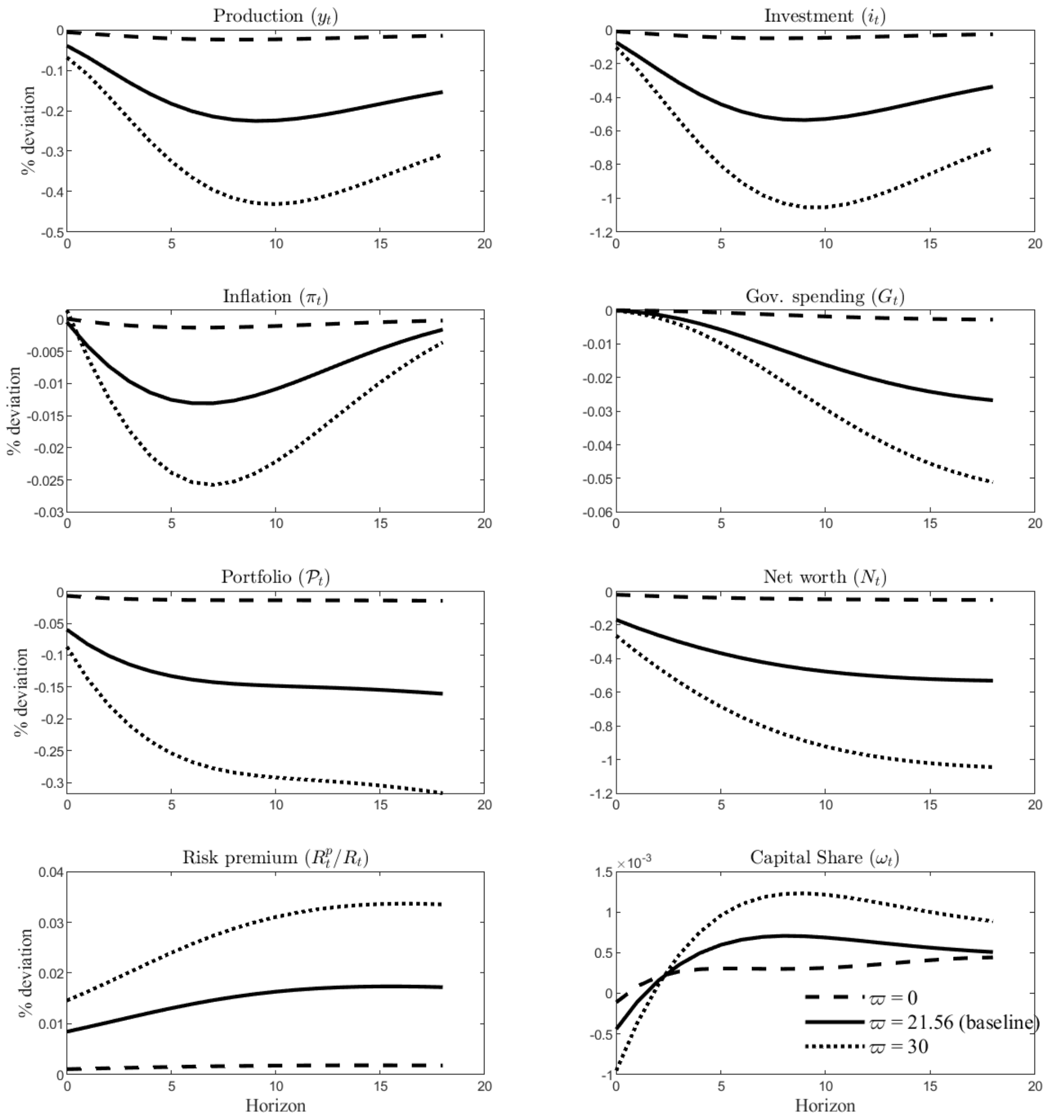
Imperfect Asset Substitutability The above discussion highlights the importance of the portfolio channel in the transmission of a government spending uncertainty shock. We now investigate the strength of the portfolio channel by looking at the responses of the macroeconomic variables under different values of the portfolio adjustment cost ϖ. Figure 5 displays the IRFs in the baseline model for our benchmark parametrization ($\varpi = 21.56$, solid line), when the portfolio adjustment channel is shut down ($\varpi = 0$, dashed line) and when this channel is made stronger than estimated in the data ($\varpi = 30$, dotted line).

Figure 5 confirms that the strength of the portfolio channel depends on the size of the portfolio adjustment cost, which in turn critically affects the transmission channels of uncertainty shocks to investment and on output. Abstracting from portfolio adjustment costs ($\varpi = 0$) implies that capital assets and government bonds are perfect substitutes. Hence, both assets provide the same expected returns because of no-arbitrage in this case (see Equation (17)). As such, risk diversification is perfect and private and government spreads only rise because the recession implies a higher external risk premium, materializing the higher probability of default of portfolio investors.

Notice that the model with $\varpi = 0$ generates responses that are almost identical to those of

[22] In Figure 12 in the online appendix, we confirm this intuition by running a SVAR expanded with a series of government expenditure: in line with our model's predictions, government spending *in level* significantly decreases in response to higher government spending uncertainty.

Figure 5: IRFs to a government spending uncertainty shock for alternative values of the portfolio adjustment cost.



Note: The solid line always depicts the response under the benchmark parametrization. Horizontal axes indicate quarters. All responses are multiplied by 100.

the typical financial accelerator model displayed in Figure 4. However, as seen in Equations (35) and (36), imposing $\varpi = 0$ does not completely shut down the portfolio channel as the term in $\hat{\omega}_t$ does not disappear. In other words, having both government bonds and equity in a portfolio that is subject to financial frictions is not sufficient to generate a full amplification mechanism. Positive portfolio adjustment costs $\varpi > 0$ instead are required.

To understand the role played by these costs, we now consider the IRFs in the baseline model ($\varpi = 21.56$) and with larger adjustment costs $\varpi = 30$. Larger adjustment costs both amplify the rise in the spread of each asset, and increase the difference in expected returns between assets. The portfolio rebalancing effect is thus magnified, amplifying the rise in the external risk premium $\mathrm{E}_t \left\{ R^p_{t+1}/R_t \right\}$ – consistent with Equations (35)-(36). As a result, the size of the recession is much larger because the portfolio transmission channel is stronger, but also because this channel interacts with all the other transmission channels of the model (nominal rigidities, precautionary savings, labor supply).

6.3 Assessing the Portfolio Channel in the Data

As explained above, the portfolio rebalancing channel emphasized in this paper acts as an amplification mechanism through a rise in the share of equity in the portfolio in response to a rise in government spending uncertainty. Higher spending uncertainty results in a shift of the portfolio composition towards equity, making portfolio investors more leveraged and therefore more likely to default. To check the empirical validity of our intuition, we estimate the effects of government spending uncertainty on the dynamics of the share of equity. To do so, we resort to the Local Projection method suggested by Jordà (2005), that consists in running a sequence of forecasting regressions of the share of equity on the uncertainty shock identified in Equation (2) for different prediction horizons. Precisely, we estimate the following regression[23]

$$EQSHARE_{t+h} = \beta_h shock_t + \sum_{i=1}^{p} \gamma_{i,h} X_{t-i} + \varepsilon_{h,t+h} \tag{38}$$

[23] As argued by Jordà (2005) and Barnichon and Brownless (2019), Local Projections methods have several advantages compared to SVAR models. First, they are more robust to the model's misspecifications. Second, they avoid estimating a large number of parameters with a limited number of observations so that we overcome the curse of dimensionality problem. Since we are interested here in the dynamic response of the equity share only, we abstract from the multivariate dimension inherent to SVAR models. It is worth noticing that Plagborg-Møller and Wolf (Forthcoming) show that the IRFs estimated by local projection are equivalent to those obtained using a SVAR(p) model, up to the number of lags, p.

for all $h = 1, ..., 20$, where $shock_t$ corresponds to the government spending uncertainty shock identified in Equation (2), $\varepsilon_{h,t}$ is a vector of residuals at horizon h, and $EQSHARE_{t+h}$ is an empirical measure of the share of equity in the portfolio of investment. In our theoretical model, the share of equity is defined as $\omega_t \equiv q_t k_t/(q_t k_t + q_t^c b_t)$. We therefore need to find the empirical counterparts for the value of equity ($q_t k_t$) and government bonds ($q_t^c b_t$). To do so, we use the aggregated balance sheet of Euro Area non-financial institutions available from the ECB Data Warehouse. We assume that $q_t k_t$ is measured by the holdings of equities and non-MMF investment funds shares and $q_t^c b_t$ is measured by the holdings of debt securities issued by Euro Area residents (general government).[24] The data are available from 1997q1 to 2017q4. Let X_{t-i} denote the vector of control variables where we set $p = 4$. It contains the lagged values of the share of equity to control of serial autocorrelation. We also control for various other variables that might affect the dynamics of the share of equity. First, we include a measure of the output gap in the vector X_{t-i}, using the real GDP expressed in logs and one-sided HP-filtered. Second, decisions about the share of equity are very likely affected by the dynamics of private investment, as it drives the available amount of capital, as well as the return of savings measured through the interest rates. Consequently, the vector of control variables also contains the real investment (expressed in log and one-sided HP-filtered) and a measure of spread – defined as the difference between the long-term and the lagged short-term interest rates.[25] Notice that we estimate Equation (38) by using the Smooth Local Projection recommended by Barnichon and Brownless (2019). The idea is to reduce the excess of variance of the estimates of β_h related to the Local Projection method estimated by OLS. Precisely, β_h is approximated by applying a linear B-spline basis function and the impulse response function is smoothed through a smoothing parameter. [26]

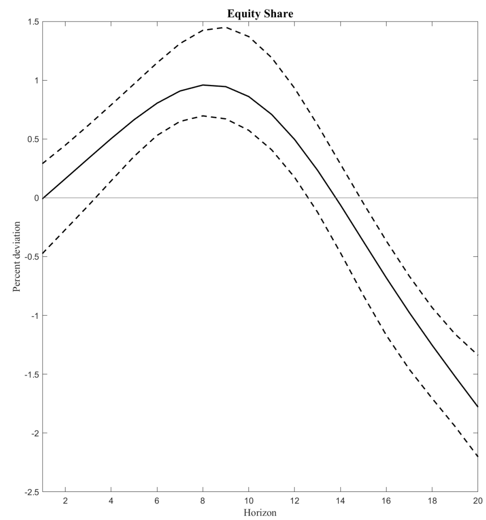
Figure 6 displays the estimated response of the portfolio share of equity to a rise in government spending uncertainty and the corresponding 90 percent confidence bands. It shows that our theoretical model's predictions are in line with the empirical evidence, at least qualitatively. Indeed, the share of equity increases over the short run in response to the shock. Importantly, the empirical response is less persistent than the theoretical one, although both feature a hump-shaped pattern. This rise in the share of equity in the data seems to validate our theoretical intuition and suggests that the portfolio channel plays a major role in the

[24] Data sources are detailed in Section 3.1 in the online appendix.

[25] Figure 17 in the online appendix shows the dynamics of the share of equity when adding the control variables one by one. The response of the share of equity displays the same pattern, although adding controls variables improves the precision of the estimation, narrowing the confidence interval.

[26] In Figure 18 in the online appendix, we show the dynamics of the equity share when the smoothing parameter equals zero, *i.e.* the estimator coincides with the OLS estimator. Unsurprisingly, the variance of the IRF is higher but the conclusion remains unchanged.

Figure 6: Response of the equity share to a positive government spending uncertainty shock.



Note: IRF estimated by smoothed local projection. Horizontal axes indicate quarters. Dashed-lines correspond to 90 percent confidence intervals.

transmission of government spending uncertainty shocks.

7 Conclusion

In this paper, we showed that government spending uncertainty depresses the economy and lowers output, investment and consumption. On the empirical side, these results were obtained by extracting a series of time-varying uncertainty from the government spending series of the Euro Area, and by plugging it into a SVAR model. Our results were robust to various alternative specifications (lags, variables, ordering of the measure of uncertainty). On the theoretical side, we matched these contractionary effects using a New-Keynesian model where financial frictions applied to a portfolio of equity and long-term government bonds, and where both assets were imperfect substitutes. We showed the critical importance of the portfolio channel and its interactions with the other traditional transmission channels of uncertainty shocks (nominal rigidities, precautionary savings, labor supply) in accounting for the effects of government spending uncertainty. Precisely, we shed light on a rise in share of equity in the portfolio in response to higher government spending uncertainty, which in turn increased the risk of default of portfolio entrepreneurs and magnified the financial accelerator mechanism.

References

I. Alfaro, N. Bloom, and X. Lin. The finance uncertainty multiplier. Technical report, NBER Working Paper 24571, 2018.

J. Andres, D. Lopez-Salido, and E. Nelson. Tobin's imperfect asset substitution in optimizing general equilibrium. *Journal of Monetary Economics*, 36:665–690, 2004.

M. Arellano, Y. Bai, and P. Kehoe. Financial frictions and fluctuations in volatility. *Journal of Political Economy*, 127:2049–2103, 2019.

N. S. Balke, E. Martinez-Garcia, and Z. Zeng. Understanding the aggregate effects of credit frictions and uncertainty. globalization and monetary policy. Technical report, Dallas Fed Working Paper 317, 2017.

N. Barberis, M. Huang, and T. Santos. Prospect theory and asset price. *Quarterly Journal of Economics*, 116:116–153, 2001.

R. Barnichon and C. Brownless. Impulse response estimation by smooth local projections. *Review of Economics and Statistics*, 101(3):522–530, 2019.

S. Basu and B. Bundick. Uncertainty shocks in a model of effective demand. *Econometrica*, 85:937–958, 2017.

C. Bayer, B. Born, and R. Luetticke. The liquidity channel of fiscal policy. Technical report, CEPR Discussion Paper 14883, 2020.

S. Benartzi and R. Thaler. Myopic loss-aversion and the equity premium puzzle. *Quarterly Journal of Economics*, 110:73–92, 1995.

B. S. Bernanke, M. Gertler, and S. Gilchrist. The financial accelerator in a quantitative business cycle framework. *Handbook of Macroeconomics, Elsevier, 1C*, 15:1341–1393, 1999.

O. Blanchard and R. Perotti. An empirical characterization of the dynamic effects of changes in government spending and taxes on output. *Quarterly Journal of Economics*, 117: 1329–1368, 2002.

N. Bloom. The impact of uncertainty shocks. *Econometrica,*, 77:623–685, 2009.

D. Bonciani and B. Van Roye. Uncertainty shocks, banking frictions and economic activity. *Journal of Economic Dynamics and Control*, 73:200–19, 2016.

B. Born and J. Pfeifer. Policy risk and the business cycle. *Journal of Monetary Economics*, 68:68–85, 2014.

L. Bretscher, A. Hsu, and A. Tamoni. The real response to uncertainty shocks: the risk premium channel. Technical report, Georgia Tech Scheller College of Business Research Paper, 2019.

M. Brunnermeier, T. Eisenbach, and Y. Sannikov. Macroeconomics with financial frictions: a survey. In E. D. D. Acemoglu, M. Arellano, editor, *Advances in Economics and Econometrics: Tenth World Congress*, pages 4–94. Cambridge Univ. Press, 2013.

C. E. Caggiano, G. and N. Groshenny. Uncertainty shocks and unemployment dynamics in u.s. recessions. *Journal of Monetary Economics*, 67:78–92, 2014.

G. Candian and M. Dmitriev. Default recovery rates and aggregate fluctuations. *Journal of Dynamics and Control*, 121:14011, 2020.

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

A. Cesa-Bianchi and E. Fernandez-Corugedo. Uncertainty, financial frictions and nominal rigidities: A quantitative investigation. *Journal of Money, Credit and Banking*, 50: 603–636, 2017.

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

L. J. Christiano, R. Motto, and M. Rostagno. Risk shocks. *American Economic Review*, 104:27–65, 2014.

K. Daniel, D. Hirshleifer, and S. Teoh. Investor psychology in capital markets: evidence and policy implications. *Journal of Monetary Economics*, 49:139–209, 2002.

J. Fernandez-Villaverde and P. Guerron-Quintana. Uncertainty shocks and business cycle research. *Review of Economic Dynamics*, 37:118–146, 2020.

J. Fernandez-Villaverde, P. Guerron-Quintana, J. Rubio-Ramirez, and M. Uribe. Risk matters: The real effects of volatility shocks. *American Economic Review*, 101:2530–2561, 2011.

J. Fernandez-Villaverde, P. Guerron-Quintana, K. Kuester, and J. Rubio-Ramirez. Fiscal volatility shocks and economic activity. *American Economic Review*, 105:3352–3384, 2015.

M. Gertler and P. Karadi. A model of unconventional monetary policy. *Journal of Monetary Economics*, 58:17–34, 2011.

M. Gertler and P. Karadi. Financial crises, bank risk exposure and government financial policy. *Journal of Monetary Economics*, 59:17–34, 2012.

S. Gilchrist, J. W. Sim, and E. Zakrajsek. Uncertainty, financial frictions, and investment dynamics. *Finance and Economics Discussion key, Board of Governors of the Federal Reserve System (U.S.),*, 69:1–58, 2014.

J. Greenwood, Z. Hercowitz, and H. G. W. Investment, capacity utilization, and the real business cycle. *American Economic Review*, 78:402–417, 1988.

Z. He and A. Krishnamurthy. Intermediary asset pricing and the financial crisis. *Annual Review of Financial Economics*, 10:173–197, 2018.

M. Iacoviello. Financial business cycles. *Review of Economic Dynamics*, 18:140–164, 2015.

N. Jaimovich and S. Rebelo. Can news about the future drive the business cycle?. *American Economic Review*, 99:1097–1118, 2009.

U. Jermann and V. Quadrini. Macroeconomic effects of financial shocks. *American Economic Review*, 102:238–271, 2012.

E. Johnson and R. Thaler. Gambling with the house money and trying to break even: The effects of prior outcomes on risky choice. *Management Science*, 36:643–660, 1990.

O. Jordà. Estimation and inference of impulse responses by local projections. *American Economic Review*, 95(1):161–182, 2005.

L. S. Jurado, K. and N. Serena. Measuring uncertainty. *American Economic Review*, 105 (3):1177–1216, 2015.

R. King and S. Rebelo. Resuscitating real business cycles. In J. B. T. . M. Woodford, editor, *Handbook of Macroeconomics*, volume 1, chapter 14, pages 927–1007. Elsevier, 1999.

R. King, C. Plosser, and S. Rebelo. Production, growth and business cycles: The basic neoclassical model. *Journal of Monetary Economics*, 21:195–232, 1988.

S. Leduc and Z. Liu. Uncertainty shocks are aggregate demand shocks. *Journal of Monetary Economics*, 82(C):20–35, 2016.

M. Plagborg-Møller and C. Wolf. Local projections and vars estimate the same impulse responses. *Econometrica*, Forthcoming.

V. Ramey and S. Zubairy. Government spending multipliers in good times and in bad: Evidence from u.s. historical data. *Journal of Political Economy*, 126:850–901, 2018.

J. J. Rotemberg. Monopolisitic price adjustment and aggregate output. *Review of Economic Studies*, 49:517–531, 1982.

H. Saijo. Redistribution and fiscal uncertainty shocks. *International Economic Review*, 61: 1073–1095, 2020.

D. Silva. The risk channel of unconventional monetary policy. Technical report, MIT Working Paper, 2020.

R. Townsend. Optimal contracts and competitive markets with costly state verification. *Journal of Economic Theory*, 21:265–293, 1979.

M. Woodford. The taylor rule and optimal monetary policy. *American Economic Review*, 91:232–237, 2001.