An Estimated Financial Accelerator Model for the Euro Area and the US Economy

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Abstract

In this paper, we analyze the importance of credit market frictions for business cycle movements in the Euro area and the US economy. To do so, we apply maximum likelihood techniques to a standard New Keynesian model, including a financial accelerator mechanism. We analyze the relative importance of different shocks using impulse responses and forecast-error variance decompositions. We find that investment-specific shocks account for most of the fluctuations in output for both economies. However, technology shocks, in particular, have contributed to output fluctuations to a much larger extent in the Euro area than in the United States.

JEL-Classification: E32, E50, E44, C54
Keywords: Business cycles, financial accelerator, FIML estimation

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1 Introduction

During past decades the monetary transmission mechanism has been subject to extensive research. Until the recent financial crises agreement had been emerging in the literature about the response of key economic variables to, for instance, monetary policy shocks (see e.g. Rotemberg & Woodford (1997), Christiano, Eichenbaum & Evans (1999), Galí (2008), Walsh (2010) and references therein). However, due to the experience that researchers and policy makers had to face in the recent financial crises, the precise channels of the transmission and their relative importance are more than ever a topic of the economic debate (see e.g. Fahr, Motto, Rostagno, Smets & Tristani (2011) and Mishkin (2011)). In particular, the discussion concentrates on whether there is an important channel of transmission besides the classical interest rate channel.

The most prominent contribution in the literature is Bernanke, Gertler & Gilchrist (1999) (BGG hereafter). There, asymmetric — or imperfect — information in credit markets makes borrowing costly, depending on borrowers' net worth. This gives rise to a "balance sheet channel" that reinforces the impact of economic shocks on real economic activity (see also Bernanke, Gertler & Gilchrist (1996), Kiyotaki & Moore (1997), and Carlstrom & Fuerst (1997)). Many researchers — see e.g. Meier & Müller (2006), Faia & Monacelli (2007), Christensen & Dib (2008), von Heideken (2009), Christiano, Motto & Rostagno (2011), Christiano, Trabandt & Walentin (2011) — have empirically analyzed the importance of such financial frictions and investigated the consequences of various shocks (e.g. monetary policy, technology, etc.) for output, inflation, and other key economic variables.

For statistical inference they use various approaches. The earlier studies rely mostly on calibration methods proposed by Kydland & Prescott (1996). Recent studies, however, use classical Maximum Likelihood techniques as well as Bayesian techniques (see e.g. Ruge-Murcia (2007) and DeJong, Ingram & Whiteman (2000)). A commonly encountered problem when estimating structural macroeconomic models with classical techniques (like full information ML) is a flat objective function, which in turn may lead to serious biases. To account for that, a growing number of researchers use Bayesian methods. Bayesian estimation techniques try to deal with this problem by incorporating prior knowledge about key economic relationships from previous macro or micro studies. However, it is largely unclear whether prior knowledge may lead to distorted estimators, when the objective function or the underlying model is already misspecified (see Canova (2009)). As a consequence, identification problems are possibly veiled. Hence, it is essential that the FIML setup is carefully analyzed for reliable statistical inference.

Using this set-up we analyze the relative importance of balance sheet transmission effects within the US economy and in the Euro area economy. We use a modern DSGE model which is similar to the ones analyzed by Christensen & Dib (2008) and von Heideken (2009). We rely on FIML instead of using Bayesian techniques (which is noteworthy, because there is essentially no contribution using classical approaches for the Euro area) and we calculate impulse responses and forecast-error variance decompositions for different horizons. In contrast to von Heideken (2009), we find that the financial accelerator mechanism is more important in the model based on US data. It turns out that in both economies investment-efficiency shocks account for the bulk of fluctuations in output. However, technology shocks, in particular, have contributed to output fluctuations to a much larger extent in the Euro area than in the United States.

In the next section, we briefly review the analyzed macroeconomic model. In Section 3 we present the FIML setup which is used to estimate the model and afterwards — in Section 4 — we present the results. Finally, highlights and concerns are expressed in the conclusion.

2 The Financial Accelerator Model

We use a DSGE model with three types of rigidities. These are sticky prices, capital adjustment costs, and credit frictions. The way the credit frictions are motivated largely follows BGG. The model distinguishes between households, entrepreneurs, capital producers, retailers, and a monetary authority. Households can choose between consumption over differentiated goods provided by retailers, and labor which they provide to entrepreneurs. Entrepreneurs hire labor and — combined with capital — they produce wholesale output in a fully competitive environment. The retail sector introduces monopolistic competition to the model. Retailers buy output from entrepreneurs and transform it to differentiated goods, which are then sold to households for consumption and to the entrepreneurs for production purposes. Prices for differentiated goods are set in the Calvo (1983) style.

The introduction of the entrepreneurial sector is crucial for the credit friction mechanism. Entrepreneurs are risk-neutral and, in contrast to households, they live finitely. Since entrepreneurs and households have different obligations and features, borrowing and lending between them is possible. The credit friction — or financial accelerating mechanism — then arises from asymmetric information in the relationship between borrowers and lenders. More precisely, lenders are assumed to face positive costs if they decide to monitor their debtors' economic performance.[1] These costs cause loans to be traded at a premium over the risk-free rate and give an important role to borrowers' balance sheet conditions. In particular, if entrepreneurial wealth is small with respect to the total amount of finance required, bankruptcy is more likely and expected default costs rise. As a consequence, borrowers must pay a higher premium to compensate lenders. This mechanism is then intended to amplify the propagation of shocks to, for instance, investment and output. In the following we formalize the outlined economy.

The Household Sector: The representative household maximizes expected utility according to:

$$\mathrm{E}\sum_{t=0}^{\infty}\beta^t\left\{\frac{\gamma e_t}{\gamma-1}\log\left[c_t^{\frac{\gamma-1}{\gamma}}+b_t^{\frac{1}{\gamma}}(\frac{M_t}{P_t})^{\frac{\gamma-1}{\gamma}}\right]+\eta\log(1-h_t)\right\}, \tag{1}$$

where c_t denotes consumption, M_t/P_t real money balances, $1-h_t$ leisure, and β, γ, and η describe the discount factor, the constant elasticity of substitution between consumption and money, and the weight on leisure in the utility function respectively.

Two structural shocks are associated with the household's utility function: the preference shock e_t and the money demand shock b_t. Both shocks follow first order autoregressive processes:

$$\log(e_t) = \rho_e\log(e_{t-1})+\varepsilon_{et}, \tag{2}$$

$$\log(b_t) = (1-\rho_b)\log(b)+\rho_b\log(b_{t-1})\varepsilon_{bt}, \tag{3}$$

[1] See Townsend (1979), Williamson (1987), and Bernanke & Gertler (1989), for a further discussion of the costly state-verification approach.

where the autoregressive coefficients are denoted by ρ_e, ρ_b, b denotes a constant which is associated with money demand, and $\varepsilon_{et}, \varepsilon_{bt}$ are zero mean and serially uncorrelated errors which are distributed normally with standard deviations σ_e and σ_b.

The household's (nominal) budget constraint is:

$$P_t c_t + M_t + D_t \leq W_t h_t + R_{t-1} D_{t-1} + M_{t-1} + T_t + \Omega_t. \tag{4}$$

In period t the representative household owns D_{t-1} units of nominal deposits, and M_{t-1} ready money. Hence, D_t pays an interest rate R_t and M_t does not. The household receives a lump-sum monetary transfer T_t, as well as dividend payments Ω_t. Furthermore, the household supplies h_t units of labor to the entrepreneurs, receiving $W_t h_t$ units of salary, where W_t denotes the nominal wage. The household uses its funds for consumption and for holding money M_t and deposits D_t (see Ireland (2004b)). In equilibrium, the representative household maximizes its expected lifetime utility (see eq. (1)) subject to the corresponding budget constraint (see eq. (4)).

The Entrepreneurial Sector: In contrast to households, entrepreneurs do not live forever. Only a fraction ν of them survive to the next period, such that $1/(1-\nu)$ denotes their expected lifetime. As a result, entrepreneurs cannot accumulate enough wealth to rely exclusively on internal finance when buying new capital. At least some part of their capital must be financed externally through loans, with a standard debt contract as described in BGG. The entrepreneur purchases capital k_{t+1} at the end of period t at a price q_t. Capital is thereby financed using net worth n_{t+1} and borrowed funds in the amount of $q_t k_{t+1} - n_{t+1}$. Thus, the demand for capital depends on the expected marginal return of capital and the expected marginal external financing cost. This can formally be translated to:

$$E_t f_{t+1} = E_t \left[\frac{z_{t+1} + (1-\delta) q_{t+1}}{q_t} \right], \tag{5}$$

such that financing costs equal the expected real interest rate on external funds. Here, δ describes the depreciation rate of capital, z_{t+1} the marginal productivity of capital at $t+1$, and $(1-\delta)q_{t+1}$ the discounted value of capital in the next period. Following BGG we assume a borrower-lender conflict which is essential for the existence of the accelerator effect. Due to this conflict, external finance is more expensive than internal finance, because lenders are facing costs for monitoring the performance of entrepreneurs. This external finance premium depends on the entrepreneurs' capital to wealth ratio (i.e. leverage). If the capital to net worth ratio is small (leverage is high) this means that the entrepreneur relies mostly on uncollateralized borrowing to fund their investments. This leads to the following equation describing the financing costs (in log-linear terms):

$$\hat{f}_{t+1} = \hat{R}_t - \hat{\pi}_{t+1} + \psi(\hat{q}_t + \hat{k}_{t+1} - \hat{n}_{t+1}), \tag{6}$$

where ψ describes the elasticity of the external finance premium with respect to a change in the leverage position of entrepreneurs, and variables with a hat denote deviations from steady-state values. Furthermore, νv_t is the equity held by entrepreneurs who are still in business at time t, and $(1-\nu)g_t$ is the equity held by new entrepreneurs entering the economy such that aggregate entrepreneurial net worth n_{t+1} is given by:

$$n_{t+1} = \nu v_t + (1-\nu) g_t, \tag{7}$$

and v_t itself evolves according to:

$$v_t = \left[f_t q_{t-1} k_t - E_{t-1} f_t (q_{t-1} k_t - n_t)\right]. \tag{8}$$

The entrepreneur maximizes utility by choosing capital in combination with hired labor to produce output according to a standard production function with constant returns to scale and an exogenous technology parameter A_t:

$$y = k_t^{\alpha} (A_t h_t)^{(1-\alpha)}, \quad \alpha \in (0,1). \tag{9}$$

The technology parameter is assumed to follow a stationary AR(1) process:

$$\log A_t = \rho_A \log(A_{t-1}) + \varepsilon_{A_t}, \tag{10}$$

where $\rho_A \in (-1,1)$, and $\varepsilon_{A_t} \sim N(0, \sigma_A^2)$.

The Capital Producer Sector: Capital producers use a fraction of final goods i_t purchased from retailers to produce improved investment goods $x_t i_t$. Thereby, x_t is an investment-efficiency shock which follows a first-order autoregressive process:

$$\log(x_t) = \rho_x \log(x_{t-1}) + \varepsilon_{xt}, \tag{11}$$

where $\rho_x \in (-1, 1)$ describes the persistence parameter, and $\varepsilon_{xt} \sim N(0, \sigma_x^2)$. The improved goods are combined with the existing capital stock to produce new capital, k_{t+1}:

$$k_{t+1} = x_t i_t + (1 - \delta) k_t, \tag{12}$$

where δ describes the capital depreciation rate. The new capital goods replace depreciated capital and add to the capital stock. Capital producers are subject to capital adjustment costs which we specify as $\frac{\chi}{2}(\frac{i_t}{k_t} - \delta)^2 k_t$.[2] This leads to the following equation relating the price of capital to the marginal adjustment costs[3]:

$$E_t \left[q_t x_t - 1 - \chi \left(\frac{i_t}{k_t} - \delta \right) \right] = 0. \tag{13}$$

Capital adjustment make investment less responsive to shocks. This directly affects the price of capital, contributing to fluctuations of entrepreneurial net worth. Thus, there is a direct link of the adjustment costs for capital to the balance sheet conditions of entrepreneurs — i.e. to the financial accelerator mechanism.

The Retail Sector: Households and entrepreneurs are distinct from one another in order to motivate lending and borrowing. The retailers then introduce inertia in price setting. Thus — in contrast to standard New Keynesian models — we distinguish between entrepreneurs and retailers. Entrepreneurs produce whole-

[2] At this point we follow Christensen & Dib (2008) and allow for quadratic adjustment costs. This deviates from other applications of the financial accelerator model, see e.g. von Heideken (2009).

[3] See also Christensen & Dib. In contrast, von Heideken (2009) assumes that the relative price of capital is equal to 1.

sale goods in competitive markets, and then sell their output to retailers who are monopolistic competitors. Retailers buy goods from entrepreneurs, differentiate them at no cost, and resell them to households. The feature of retailers being monopolistic competitors is the source of nominal stickiness in the model. Following Calvo (1983) and Yun (1996), we assume that retailers cannot reoptimize their selling price unless they receive a random signal. The probability of receiving such a signal is $(1-\phi)$. Thus, $l = 1/(1-\phi)$ is the average length of time a price remains unchanged. This leads then to the well-known New Keynesian Phillips curve relationship:

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \frac{(1-\beta\phi)(1-\phi)}{\phi}\hat{\xi}_t, \tag{14}$$

with β describing the discount factor and ξ denoting real marginal costs (see Galí & Gertler (1999)).

The Central Bank: The monetary authority conducts monetary policy by controlling the nominal interest rate, R_t, in response to deviations of inflation, π_t, output, y_t, and the money growth rate, $\mu_t = M_t/M_{t-1}$, from their steady-state values (again, indicated with a hat). The corresponding policy rule is written as:

$$\hat{R}_t = \varrho_\pi \hat{\pi}_t + \varrho_y \hat{y}_t + \varrho_\mu \hat{\mu}_t + \varepsilon_{R_t}, \tag{15}$$

where ϱ_π, ϱ_y, and ϱ_μ are policy coefficients, which are chosen by the monetary authority in order to conduct monetary policy, and ε_{R_t} denotes the monetary policy shock with $\varepsilon_{R_t} \sim N(0, \sigma_R^2)$.

3 Empirical Set-up

Model Solution: The log-linear model represents a dynamic system of difference equations that describes the joint determination of the endogenous variables. We cast this system into the following standard form:

$$AE_tY_{t+1} = BY_t + CX_t. \tag{16}$$

Here, Y_t and X_t denote the endogenous and exogenous variables and are given by $Y_t = (y_t,\ c_t,\ i_t,\ k_t,\ n_t,\ R_t,\ \omega_t,\ m_t,\ h_t,\ \xi_t,\ z_t,\ \pi_t,\ f_t,\ \mu,\ q_t,\ \lambda_t)'$ and $X_t = (e_t,\ b_t,\ A_t,\ x_t,\ \varepsilon_{R_t})'$. The rational expectations solution is calculated using the methods provided by King & Watson (2002) and King & Kurmann (2005). The corresponding solution can be written in state space form according to:

$$\begin{aligned} Z_t &= \Pi S_t \\ S_t &= MS_{t-1} + G\upsilon_t. \end{aligned} \tag{17}$$

Here, Z_t is a 19×1 dimensional vector containing all relevant variables of the system; S_t is of dimension 8×1 and includes the predetermined variables $(m_{t-1},\ q_{t-1},\ R_{t-1})'$ and the five shocks $(e_t,\ b_t,\ A_t,\ x_t,\ \varepsilon_{R_t})'$; υ_t contains the underlying structural shocks of the economy $(\epsilon_t^e,\ \epsilon_t^b,\ \epsilon_t^A,\ \epsilon_t^x,\ \epsilon_t^R)'$. The matrices Π, M, and G are functions of the structural parameters and are obtained using the solution algorithm (see King & Watson (2002)). The complete system of log-linearized equations can be found in Appendix A.

Estimation Strategy: We use full information maximum likelihood to estimate the outlined economy. We rely on equation (17) to estimate the structural parameters via the Kalman filter (see e.g. Ireland 2003, Ireland 2004a, for a similar strategy). To avoid stochastic singularity we use as many observables as we have structural shocks in the model.[4] As observables we use output, investment, real balances, the interest rate, and the inflation rate. That is, $d_t = (y_t, i_t, m_t, R_t, \pi_t)'$ denotes our observables vector. Next, we evaluate the likelihood function $L(\{d_t\}_{t=1}^T|\Upsilon)$. The vector Υ contains the structural model parameters, given the sample of observations $\{d_t\}_{t=1}^T$. Following Christensen & Dib (2008), and due to potential identification difficulties, we only estimate a subset of the parameters denoted by
$\Upsilon' = [\varrho_\pi, \varrho_y, \varrho_\mu, \chi, \phi, \psi, \alpha, \gamma, \sigma_R, \rho_e, \sigma_e, \rho_A, \sigma_A, \rho_x, \sigma_x, \rho_b, \sigma_b]'$. The remaining model parameters β, η, θ, δ, b, π, ν, S and k/n are calibrated. This deviates from the study of von Heideken (2009) who also calibrates the α coefficient. The corresponding calibration values can be found in Table 1. The ML estimator of Υ' is obtained as

$$\hat{\Upsilon}'_{ml} = \max_{\Upsilon'} \sum_{t=1}^{T} \log L(d_t|\Upsilon'), \tag{18}$$

which implies a covariance matrix:

$$\hat{\Sigma}_{ml} = \left[\frac{\partial^2 \log L(\{d_t\}_{t=1}^T|\Upsilon'_{ml})}{\partial \Upsilon'_{ml} \partial \Upsilon''_{ml}} \right]^{-1}. \tag{19}$$

[4] Another possibility would be to add measurement errors to the observation equation (see e.g. Ireland 2004a). We opt for the first alternative and include five variables in line with Christensen & Dib (2008).

Hence, the standard errors of $\hat{\Upsilon}'_{ml}$ are given by the square root of the diagonal elements of $\hat{\Sigma}_{ml}$.[5]

Data: In order to provide a level playing field we use the same observables for the Euro area and the US economy. We use quarterly data for the United States from 1979Q3 to 2008Q3, and for the Euro area from 1980Q1 to 2009Q3. We use real GDP for output[6], changes in the GDP deflator for quarter on quarter inflation, real gross domestic investment for investment, and a three-month interest rate for the short-term interest rate. In case of the United States we use the three-month Treasury Bill rate and for the Euro area we use the three-month Euribor interest rate. Real money balances are measured by dividing M0 (for the United States) and M3 (for the Euro area) by the GDP deflator, respectively[7]. Data for the US economy are obtained from the Fed St Louis research database (FRED), whereas data for the Euro area economy are obtained from the area-wide model database (AWM), which is developed by ECB staff and is downloadable from the statistical data warehouse website. All series are seasonally adjusted and detrended using the HP-filter before estimation.

[5] For the estimation we transform our parameters so that estimation respects boundaries (see DeJong & Dave (2007). The boundaries used for estimation are specified in Table 5 in Appendix B.

[6] We exclude government expenditures for both the Euro area and for US GDP, because there is no fiscal part in our model (see Christensen & Dib (2008) for comparison).

[7] Only the monetary aggregate M3 is available in the Euro area-wide model database which dates back to 1980. So we must take M3 to use the long sample. However, when using another monetary aggregate for the United States — for instance M2 as in Ireland (2003) — the results do not change qualitatively.

Table 1: Parameter Calibration

Definition		US	Euro area
discount factor	β	0.9928	0.9928
weight on leisure in the utility function	η	1.3150	1.3150
intermediate-goods elasticity of substitution	θ	6	6
capital depreciation rate	δ	0.0250	0.0250
constant associated with money-demand shock	b	0.0700	0.0700
gross steady-state inflation rate	π	1.0079	1.0094
survival rate of entrepreneurs	ν	0.9728	0.9728
gross steady-state risk premium	S	1.0075	1.0050
steady-state ratio of capital to net worth	k/n	2.00	2.65

Notes: The table reports calibrated values which are taken from Christensen & Dib (2008) and von Heideken (2009). Values for the inflation rate and the risk premium are chosen to match the historical average of the corresponding series.

4 Estimation Results

4.1 Parameter Estimates

The FIML procedure yields the following estimation results. Table 2 presents the coefficient estimates and the corresponding standard errors for both the US economy and the Euro area. For comparison, we also report the results obtained by Christensen & Dib (2008).

We can see significant differences among the estimates of the different economies. In general, all estimates belonging to the US economy are significant and have smaller standard errors than the estimates for the Euro area economy. The parameter ψ which measures the elasticity of the external finance premium with respect to a change in the leverage position of firms is about 0.0341, which is slightly higher than the values reported in von Heideken (2009) and De Fiore & Uhlig (2005). The capital adjustment cost parameter χ is about 0.5632 and so it is very close to the estimates reported by Christensen & Dib (2008) and Meier & Müller (2006). The capital share parameter α from the production function is estimated at 0.3645 and is similar to those often reported in the literature. The estimates for the policy rule ϱ_π, ϱ_μ, and ϱ_y are found to be similar to those reported by Christensen & Dib (2008). The estimated persistence parameters ρ are quite similar and lie in a range of 0.51 to 0.64. Overall, they are somewhat smaller than the ones reported by Christensen & Dib (2008). For the estimated shocks the picture is reversed. They are slightly greater than the ones reported by Christensen & Dib (2008).

Table 2: FIML estimates

Parameter	Christensen & Dib		United States		Euro area	
	Estimate	Std. error	Estimate	Std. error	Estimate	Std. error
ϱ_π	1.4059	0.0788	1.6590	0.0267	1.8227	0.1321
ϱ_μ	0.6532	0.0783	0.6553	0.0054	0.9828	0.0906
ϱ_y	0.2947	0.0690	0.4171	0.0039	0.1610	0.0517
χ	0.5882	0.1742	0.5632	0.0065	0.9683	0.0093
ϕ	0.7418	0.0118	0.7721	0.0100	0.7510	0.0440
ψ	0.0420	0.0137	0.0341	0.0003	0.0026	0.0283
α	0.3384	0.0259	0.3645	0.0015	0.4293	0.0280
γ	0.0598	0.0039	0.0090	0.0013	0.0158	0.0392
ρ_b	0.7206	0.0242	0.5124	0.0001	0.7313	0.0141
ρ_e	0.6156	0.0194	0.6379	0.0002	0.6404	0.0002
ρ_A	0.7625	0.0262	0.6307	0.0001	0.7142	0.0005
ρ_x	0.6562	0.0194	0.6185	0.0001	0.9038	0.0002
σ_b	0.0103	0.0008	0.0088	0.0002	0.0075	0.0005
σ_e	0.0073	0.0007	0.0211	0.0002	0.0168	0.0013
σ_A	0.0096	0.0015	0.0129	0.0001	0.0151	0.0002
σ_x	0.0331	0.0039	0.0389	0.0003	0.0234	0.0003
σ_R	0.0058	0.0003	0.0099	0.0004	0.0077	0.0009

Notes: The table reports FIML estimates and corresponding standard errors for the Euro area and the US economy model as well as the estimates obtained by Christensen & Dib (2008).

For the Euro area economy there are two parameters for which the estimates are not statistically different from zero. These two are the constant elasticity of substitution between consumption and real balances, and the parameter of the financial accelerator mechanism ($\psi = 0.0026$). This corresponds to the findings by Meier & Müller (2006), who also report a lesser importance of the financial accelerator mechanism.[8] However, restricting theses parameters to zero results in a significantly lower likelihood. The value of the constrained likelihood L^c is 2753.9, whereas the value of the unconstrained likelihood L^u is 2770.8. This corresponds to a likelihood ratio test statistic of 33.8 such that the null of validity of the restriction is strongly rejected. Hence, the model fits the data better when we include both mechanisms. The capital adjustment cost parameter χ is about 0.9683 and is lower than that estimated by von Heideken (2009), implying that making investments is less expensive and more responsive to shocks. The capital share parameter α from the production function is estimated at 0.4293 and is higher than that calibrated by von Heideken (2009). In contrast to the United States, the estimate for ϱ_y is far smaller for the Euro area. As also stated by Christensen & Dib (2008) a smaller estimate for ϱ_y indicates that the financial accelerator mechanism is playing a less important role. The financial accelerator mechanism itself should lead to an amplification and propagation of the impacts of shocks on output. Thus, the central bank does not have to respond aggressively to changes in output if the financial accelerator mechanism is of secondary importance. The estimated persistence parameters are higher in the Euro area model than in the US

[8] In contrast — using Bayesian techniques — von Heideken (2009) and Lombardo & McAdam (2012) find a higher value and lower corresponding standard errors for ψ. This might indicate a lack of identification associated with the elasticity of the external finance premium which is veiled using the Bayesian approach.

model. Since the propagation mechanism is more important in the US economy, this result seems to be plausible.

4.2 Impulse Responses

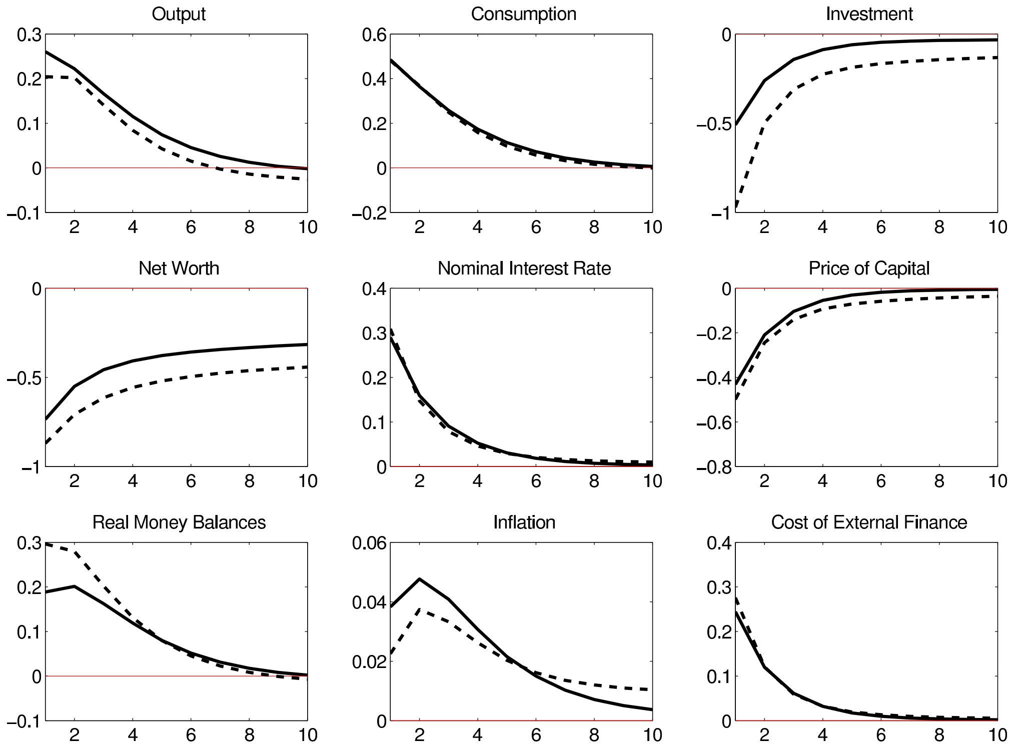
To analyze the different dynamics in the US economy and the Euro area economy we present impulse responses from both estimated models. Figures 1 to 3 display the responses of the demand side shocks (i.e. preferences, money demand, and interest rates), whereas Figures 4 and 5 report the supply side shocks (i.e. technology and investment). The impulse responses are measured as percentage deviations of the corresponding variables from their steady-state values.[9]

Figure 1 shows the impulse responses to a positive 1 per cent preference shock. Following this shock, households increase consumption and their demand for ready money. As a result, inflation rises and the monetary authority responds by raising interest rates. This will increase the real cost of debt repayment and, thus, decrease entrepreneurial net worth. This leads to higher costs for external finance because of weakened balance sheet conditions, such that this — financial accelerator — effect then amplifies the negative response of investment. Overall, there is no big difference in the (positive) output response between the two economies. However, the higher amplification effect in the US economy is especially visible for investment and net worth.

Figure 2 shows the impulse responses to a positive 1 per cent money demand shock. This shock leads to a rise in real money balances driving down consumption and savings, as well as investment and output. Due to the increased money supply, the

[9]The Figures for the individual countries — including 90 percent confidence intervals — can be found in Appendix C.

Figure 1: Impulse response to a preference shock



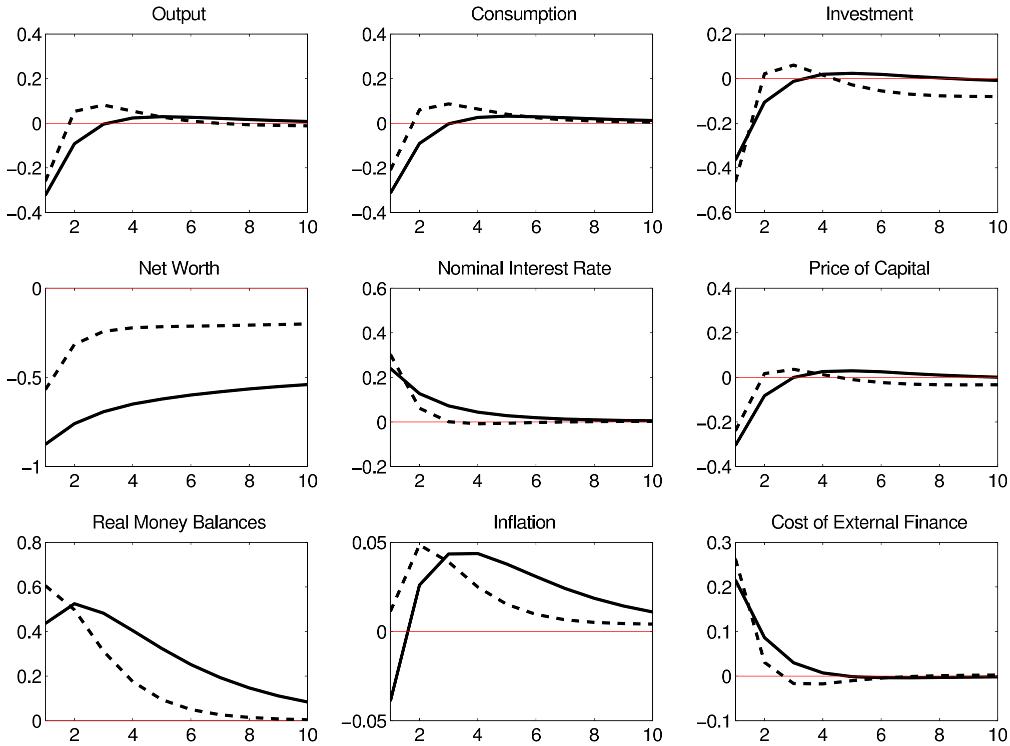
Notes: The figure displays each individual variable's responses as percentage deviations from its steady-state value. The solid line displays the responses from the Euro area model. The dashed line displays the responses from the US model. The impulse response 'cost of external finance' corresponds to $\hat{f}_{t+1}$ in eq. 6.

monetary authority increases interest rates implying higher costs for existing debt. As a consequence, net worth decreases and the probability of a default rises for entrepreneurs with high leverage. Hence, lenders increase their monitoring costs to avoid future defaults (flight to quality).[10] This extra cost is then reflected in a higher external finance premium.

Figure 3 shows the impulse responses corresponding to a tightening of monetary

[10]See e.g. Bernanke et al. (1996) and Gertler & Gilchrist (1993).

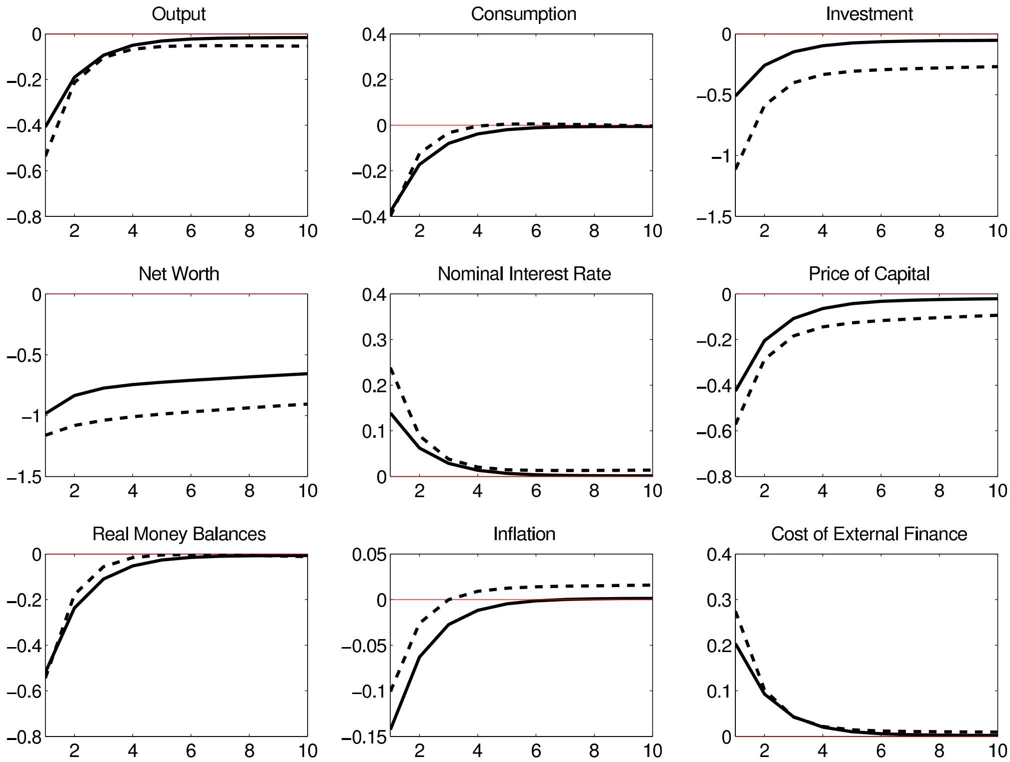
Figure 2: Impulse response to a money demand shock



Notes: The figure displays each individual variable's responses as percentage deviations from its steady-state value. The solid line displays the responses from the Euro area model. The dashed line displays the responses from the US model. The impulse response 'cost of external finance' corresponds to $\hat{f}_{t+1}$ in eq. 6.

policy (i.e. a positive 1 per cent monetary policy shock). Higher interest rates lead to a sharp decrease in net worth implying a higher risk premium for external finance. Since the financial accelerator effect is more pronounced in the US economy, we see a sharper decline in investment and output there than in the Euro area. Inflation and real money holdings also decrease in response to monetary tightening. These responses are of the same magnitude and are not driven by any accelerating effects. For both economies we see that the decrease in net worth

Figure 3: Impulse response to a monetary policy shock

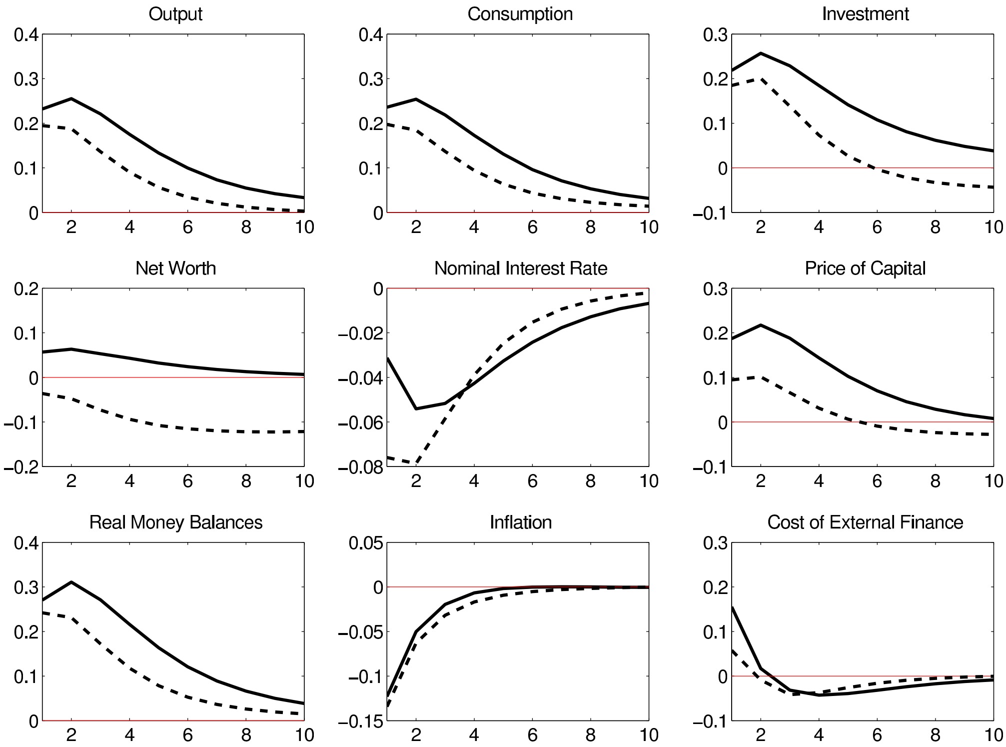


Notes: The figure displays each individual variable's responses as percentage deviations from its steady-state value. The solid line displays the responses from the Euro area model. The dashed line displays the responses from the US model. The impulse response 'cost of external finance' corresponds to $\hat{f}_{t+1}$ in eq. 6.

is considerably higher than the fall in inflation (a debt deflation effect; see also Christensen & Dib (2008)).

Figure 4 shows the impulse responses to a positive 1 per cent technology shock. In line with Ireland (2004b) — after a technology shock — output growth increases and the rate of inflation declines. The reaction of output is also reflected in the positive investment response, leading to an increasing price of capital and a higher demand for external finance; this in turn increases the external finance premium.

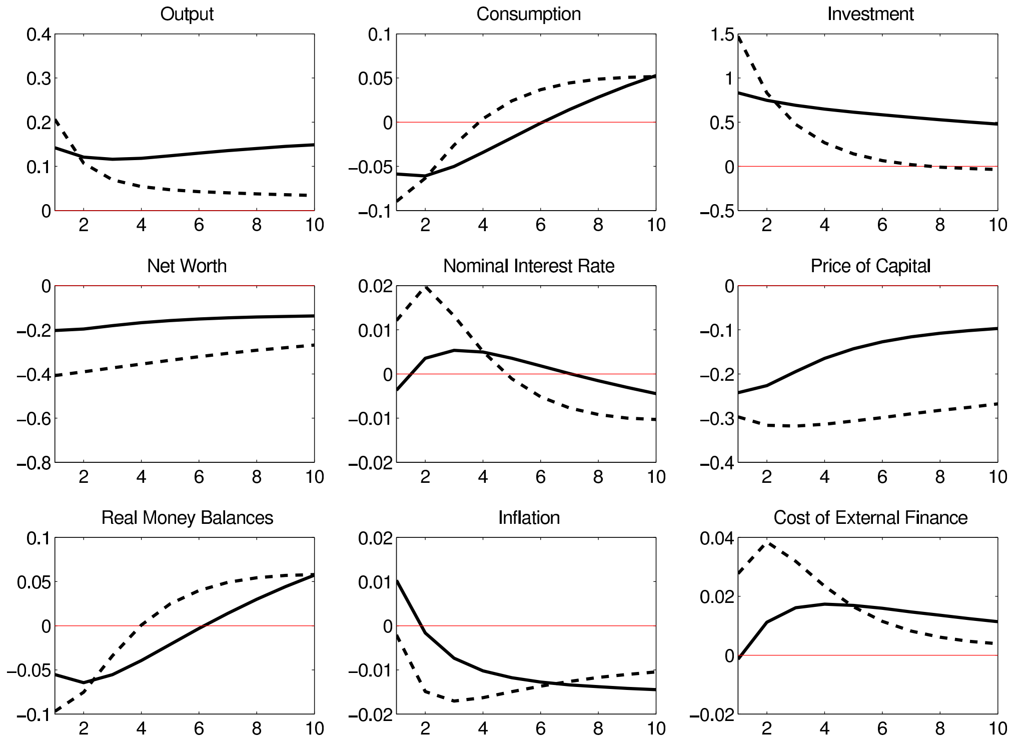
Figure 4: Impulse response to a technology shock



Notes: The figure displays each individual variable's responses as percentage deviations from its steady-state value. The solid line displays the responses from the Euro area model. The dashed line displays the responses from the US model. The impulse response 'cost of external finance' corresponds to $\hat{f}_{t+1}$ in eq. 6.

Since the steady-state capital to net worth ratio is higher in the Euro area, an increasing price of capital leads to increased net worth; the sharp rise in the cost of external finance is not so severe for Euro area entrepreneurial net worth. For the United States, however, the steady-state capital to net worth ratio is lower than in the Euro area, implying that the rise in the external finance premium is more severe. Overall, the Euro area model is far more responsive to a technology shock than the US model is, especially for output. All real variables are affected

Figure 5: Impulse response to an investment shock



Notes: The figure displays each individual variable's responses as percentage deviations from its steady-state value. The solid line displays the responses from the Euro area model. The dashed line displays the responses from the US model. The impulse response 'cost of external finance' corresponds to $\hat{f}_{t+1}$ in eq. 6.

to a much higher extent. The effects on inflation are, however, about the same magnitude for both models.

Figure 5 shows the impulse responses to a positive 1 per cent investment-specific shock. Following this shock the price of capital decreases sharply, because producing new capital is more efficient and less costly. Output and investment increase and gradually return to their steady-state values. Purchases are shifted to investment, such that consumption and savings decrease. The monetary authority responds with higher interest rates, which leads to a fall in net worth and a higher risk premium. Since we estimated a higher persistence parameter for the investment-specific shock in the Euro area, we see much more persistent effects there (especially for output and investment).

Overall, the impulse responses of the US economy are more severe for supply-side shocks. This is in line with the studies by Bernanke et al. (1999), Iacoviello (2005), and Christensen & Dib (2008) who showed that, in particular, supply-side shocks affect output fluctuations significantly. Since the FIML estimates of the financial accelerator model showed a greater importance of such a mechanism for the US economy than for the Euro area economy these results seem to be reasonable.

4.3 Variance Decompositions

To pursue the analysis of the effects of the individual structural economic shocks we present forecast-error variance decompositions from both estimated models. Table 3 displays the one-quarter-ahead forecast-error variance decompositions and Table 4 reports the two-year-ahead forecast-error variance decompositions, respectively. The tables show the percentages which are attributed to each of the five shocks. We look at exactly the same set of variables that are analyzed in Christensen & Dib (2008).

Overall, the forecast-error variance decompositions of the US model and the Euro area model show a similar pattern for consumption, nominal interest rates, and inflation. For consumption, the main drivers are preference shocks, but policy shocks also play a role at the two-year horizon. The same is true for the nominal interest rate. Inflation fluctuations are mainly driven by technology and money supply shocks.

However, for fluctuations in output, the results look different. The dominant shock in the United States is the investment-efficiency shock followed by money supply shocks. This corresponds to the results obtained by Christensen & Dib (2008), since in models where the accelerator mechanism is active (which is the especially the case for the United States), monetary policy shocks account for a slightly greater share of the output variance.

For the Euro area model it is the technology shock that contributes most to fluctuations in output. Also, preference shocks play an important role, especially in the short run. Hence, also the demand side shocks contribute to movements in output in a noteworthy way.

Table 3: One-quarter-ahead forecast-error variance decomposition

Variable / Shock	Preference	Mon. Demand	Mon. Supply	Technology	Investment
US economy					
y_t	14.02	5.82	26.84	6.55	46.77
c_t	74.10	2.87	10.46	5.73	6.84
i_t	16.24	0.66	4.41	0.11	78.58
m_t	32.96	25.09	22.60	9.78	9.58
R_t	73.98	13.58	10.03	1.91	0.51
π_t	2.17	0.18	20.21	77.31	0.13
Euro area economy					
y_t	33.27	11.12	13.70	25.08	16.83
c_t	67.36	6.67	7.76	16.30	1.92
i_t	15.60	1.46	2.16	2.43	78.35
m_t	15.12	20.63	25.34	35.88	3.03
R_t	83.60	12.45	3.18	0.75	0.01
π_t	4.79	2.32	21.42	70.30	1.18

Notes: Values are reported as percentages owing to the different shocks.

Table 4: Eight-quarter-ahead forecast-error variance decomposition

Variable / Shock	Preference	Mon. Demand	Mon. Supply	Technology	Investment
US economy					
y_t	24.02	3.79	20.34	11.52	40.23
c_t	76.06	1.85	5.31	8.19	8.59
i_t	19.82	0.52	6.19	0.26	73.21
m_t	40.88	24.05	10.71	13.14	11.23
R_t	74.63	10.26	8.60	4.72	1.78
π_t	21.99	4.70	11.05	47.15	15.11
Euro area economy					
y_t	23.10	3.57	5.10	33.87	34.37
c_t	58.84	3.15	4.16	30.96	2.88
i_t	5.30	0.37	0.70	3.14	90.49
m_t	13.92	27.52	8.14	47.04	3.38
R_t	80.00	11.14	2.55	6.17	0.14
π_t	18.97	6.45	16.28	51.86	6.43

Notes: Values are reported as percentages owing to the different shocks.

5 Conclusion

This paper analyzes the relative importance of credit market frictions for business cycle movements for the Euro area and the US economy. We apply maximum likelihood techniques to a standard New Keynesian model, including a BGG-type financial accelerator mechanism and we analyze the relative importance of different shocks for business cycle fluctuations for the two economies. In contrast to most other studies for the Euro area, we rely on non Bayesian techniques for the estimation of our model, which is new in the literature so far. Thus, we substantially extend the analysis of von Heideken (2009) and analyze the relative importance of the different structural shocks for business cycle fluctuations in much more detail. We provide an impulse response analysis and forecast-error variance decompositions for different horizons.

In contrast to von Heideken (2009), it turns out that the financial accelerator mechanism is more important in the model based on US data. The impulse responses of the US economy are more severe for supply-side shocks, which is in line with the studies by Bernanke et al. (1999), Iacoviello (2005), and Christensen & Dib (2008) who showed that, in particular, supply-side shocks affect output fluctuations in the presence of an accelerator mechanism.

The results of the forecast-error variance decomposition suggest that investment-specific shocks account for the bulk of fluctuations in output for both economies, especially, in the long run. However, technology shocks in particular have contributed to output fluctuations to a much larger extent in the Euro area than in the United States.

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A The Log-linearized System

Below is the complete log-linearized version of the model outlined in Section 2. It corresponds exactly to the model outlined in Appendix C of Christensen & Dib (2008).

$$\beta\hat{\pi}_{t+1} = \hat{\pi}_t - [(1-\beta\phi)/(1-\phi)]/\phi\hat{\xi}_t \tag{20}$$

$$\hat{\lambda}_{t+1} - \hat{\pi}_{t+1} = \hat{\lambda}_t - \hat{R}_t \tag{21}$$

$$\hat{k}_{t+1} = \delta\hat{i}_t + \delta\hat{x}_t + (1-\delta)\hat{k}_t \tag{22}$$

$$\hat{f}_{t+1} + \hat{\pi}_{t+1} - \psi\hat{k}_{t+1} + \psi\hat{n}_{t+1} = \hat{R}_t + \psi\hat{q}_t \tag{23}$$

$$(\hat{n}_{t+1}/(\nu f)) = (k/n)\hat{f}_t - (k/n-1)(\hat{R}_{t-1} - \hat{\pi}_t) - \psi(k/n-1)(\hat{k}_t) - \psi(k/n-1)\hat{q}_{t-1} + (\psi(k/n-1)+1)\hat{n}_t \tag{24}$$

$$0 = \gamma\hat{\lambda}_t + ((\lambda m(R-1))/R)(\hat{b}_t + (\gamma-1)\hat{m}_t) - \gamma\hat{e}_t - ((1-\gamma)\lambda c - 1)\hat{c}_t \tag{25}$$

$$0 = -(\gamma\hat{R}_t)/(R-1) + \hat{b}_t + \hat{c}_t - \hat{m}_t \tag{26}$$

$$0 = -h\hat{h}_t + (1-h)(\hat{w}_t + \hat{\lambda}_t) \tag{27}$$

$$0 = -\hat{y}_t + \alpha\hat{k}_t + (1-\alpha)\hat{h}_t + (1-\alpha)\hat{A}_t \tag{28}$$

$$0 = -y\hat{y}_t + c\hat{c}_t + i\hat{i}_t \tag{29}$$

$$0 = -\hat{w}_t + \hat{y}_t + \hat{\xi}_t - \hat{h}_t \tag{30}$$

$$0 = -\hat{z}_t + \hat{y}_t + \hat{\xi}_t - \hat{k}_t \tag{31}$$

$$0 = -\hat{mu}_t + \hat{m}_t - \hat{m}_(t-1) + \hat{\pi}_t \tag{32}$$

$$0 = -\hat{R}_t + \varrho_\pi\hat{\pi}_t + \varrho_\mu\hat{\mu}_t + \varrho_y\hat{y}_t + \varepsilon_{Rt} \tag{33}$$

$$0 = -\hat{f}_t + ((z)/(f))\hat{z}_t + ((1-\delta)/(f))\hat{q}_t - \hat{q}_{t-1} \tag{34}$$

$$0 = -\hat{q}_t + \chi(\hat{i}_t - \hat{k}_t) - \hat{x}_t. \tag{35}$$

B Parameter Boundaries

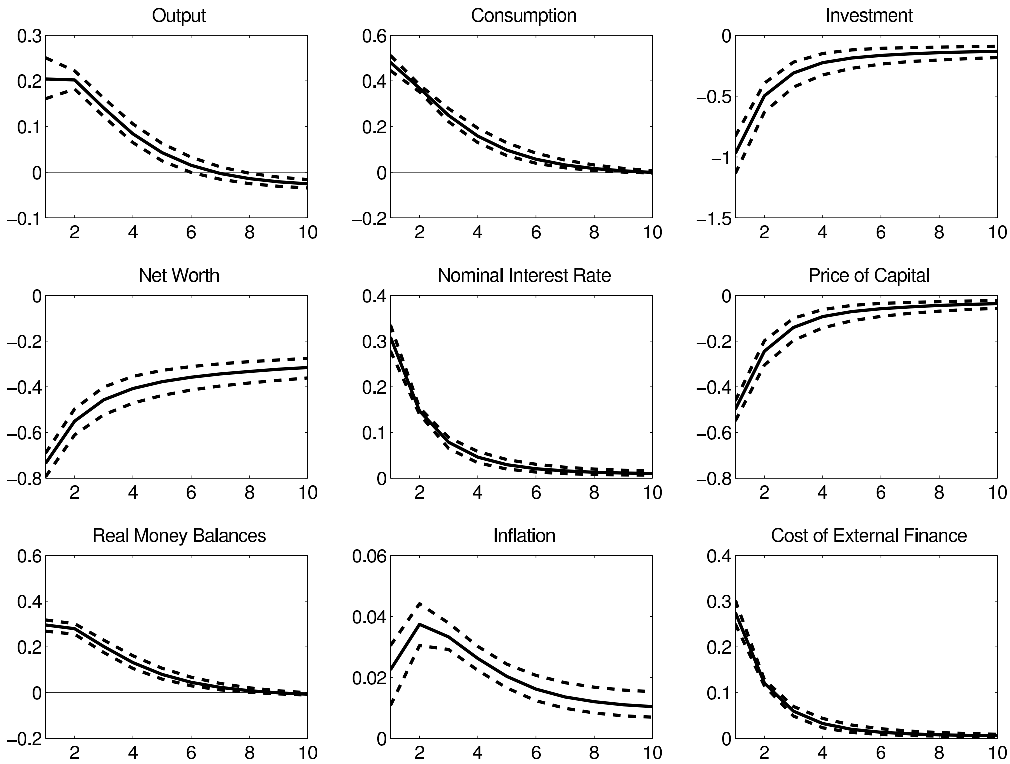
Parameters representing discount factors, the share of capital in output, the calvo parameter, autoregressive coefficients, etc., are all restricted to lie the interval between zero and one. Variances are restricted to be positive. The imposition of restrictions is done following DeJong & Dave (2007), chapter 8.4.2. Below is the complete set of parameter boundaries used for estimation.

Table 5: Parameter boundaries

parameter	upper bound	lower bound
ϱ_π	0	2.000
ϱ_μ	0	1.000
ϱ_y	0	0.999
χ	0	2.000
ϕ	0	0.999
ψ	0	0.999
α	0	0.999
γ	0	0.999
ρ_b	0	0.999
ρ_e	0	0.999
ρ_a	0	0.999
ρ_x	0	0.999
ρ_r	0	0.999
σ_g		positive
σ_g		positive
σ_g		positive
σ_g		positive
σ_g		positive

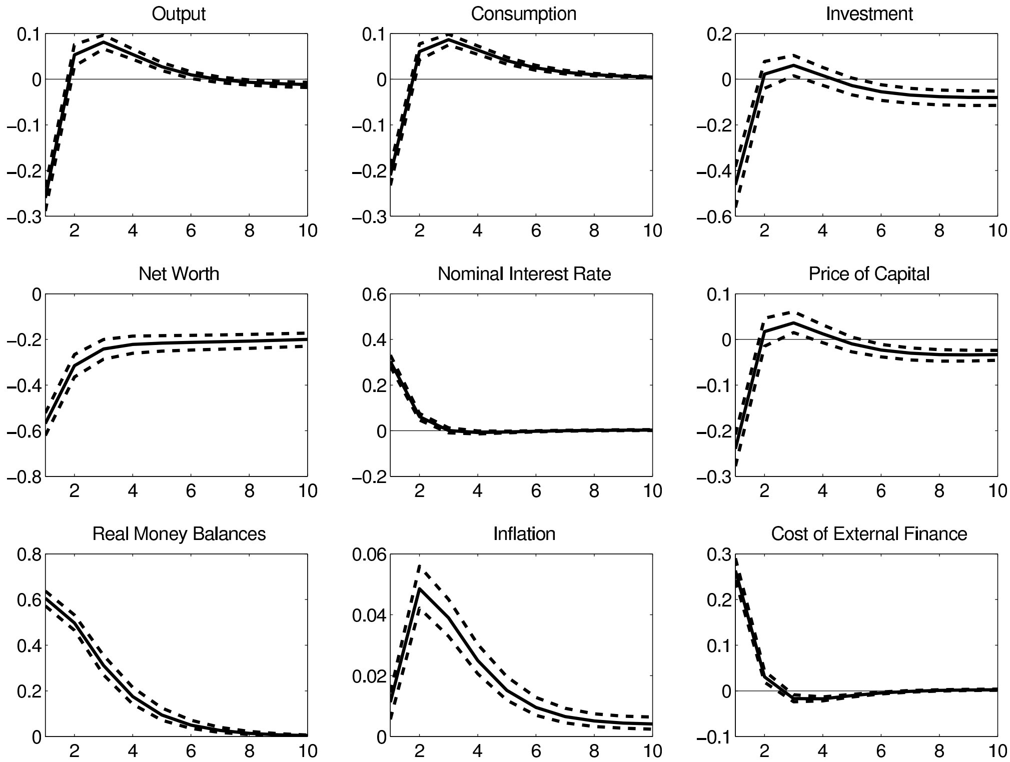
C Additional Figures

Figure 6: Impulse response to a preference shock - US



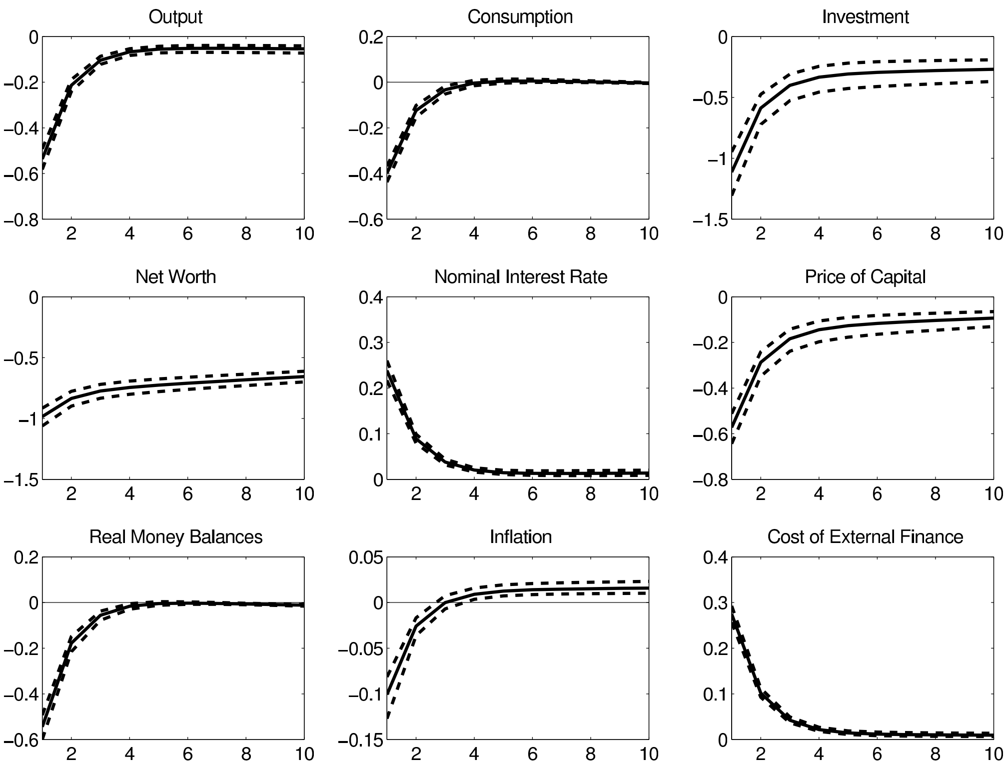
Notes: The figure displays each individual variable's responses as percentage deviations from its steady-state value. The solid line displays the median response and the dashed lines represent the 90th percentage confidence interval.

Figure 7: Impulse response to a money demand shock - US



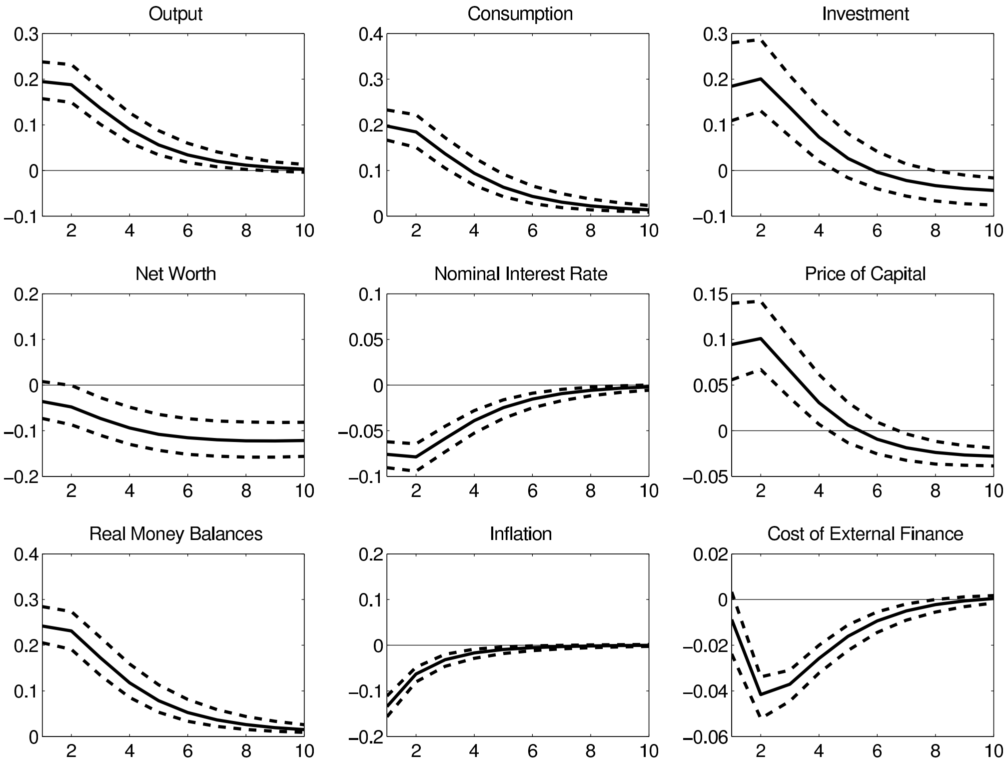
Notes: The figure displays each individual variable's responses as percentage deviations from its steady-state value. The solid line displays the median response and the dashed lines represent the 90th percentage confidence interval.

Figure 8: Impulse response to a monetary policy shock - US



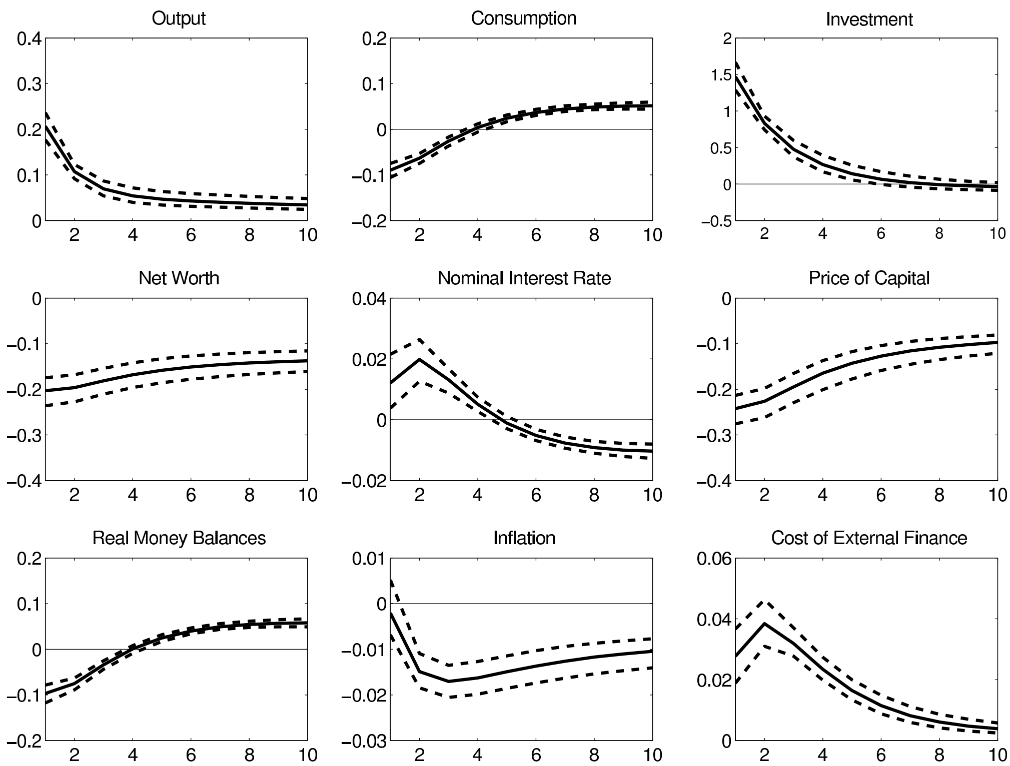
Notes: TThe figure displays each individual variable's responses as percentage deviations from its steady-state value. The solid line displays the median response and the dashed lines represent the 90th percentage confidence interval.

Figure 9: Impulse response to a technology shock - US



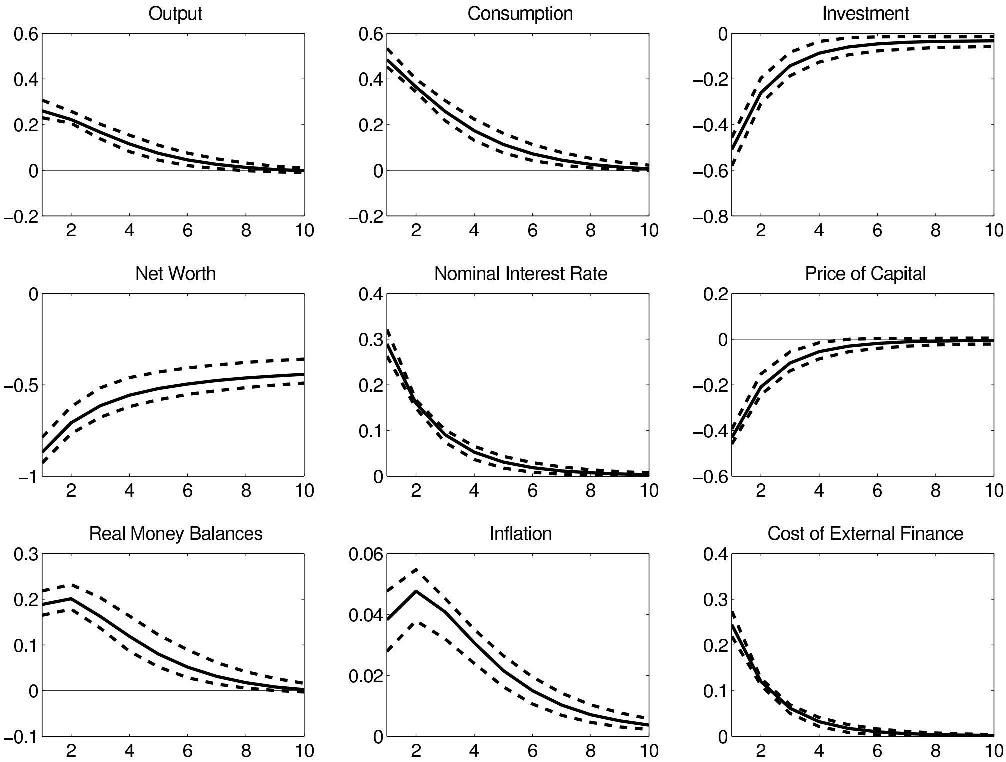
Notes: The figure displays each individual variable's responses as percentage deviations from its steady-state value. The solid line displays the median response and the dashed lines represent the 90th percentage confidence interval.

Figure 10: Impulse response to an investment shock - US



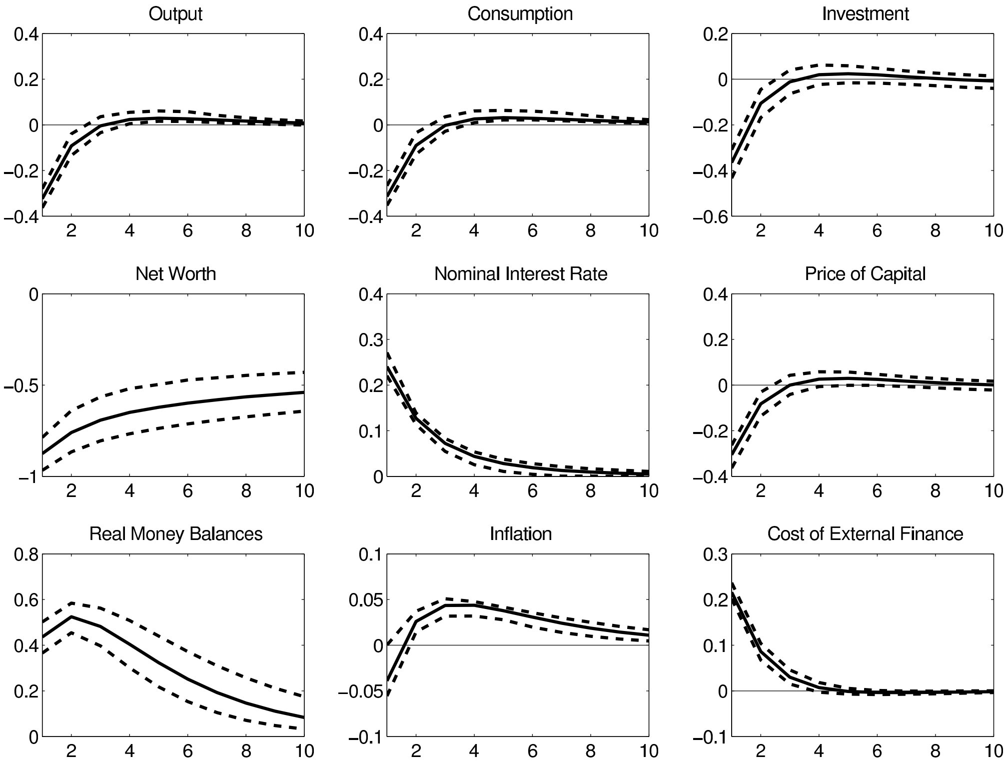
Notes: The figure displays each individual variable's responses as percentage deviations from its steady-state value. The solid line displays the median response and the dashed lines represent the 90th percentage confidence interval.

Figure 11: Impulse response to a preference shock - EA



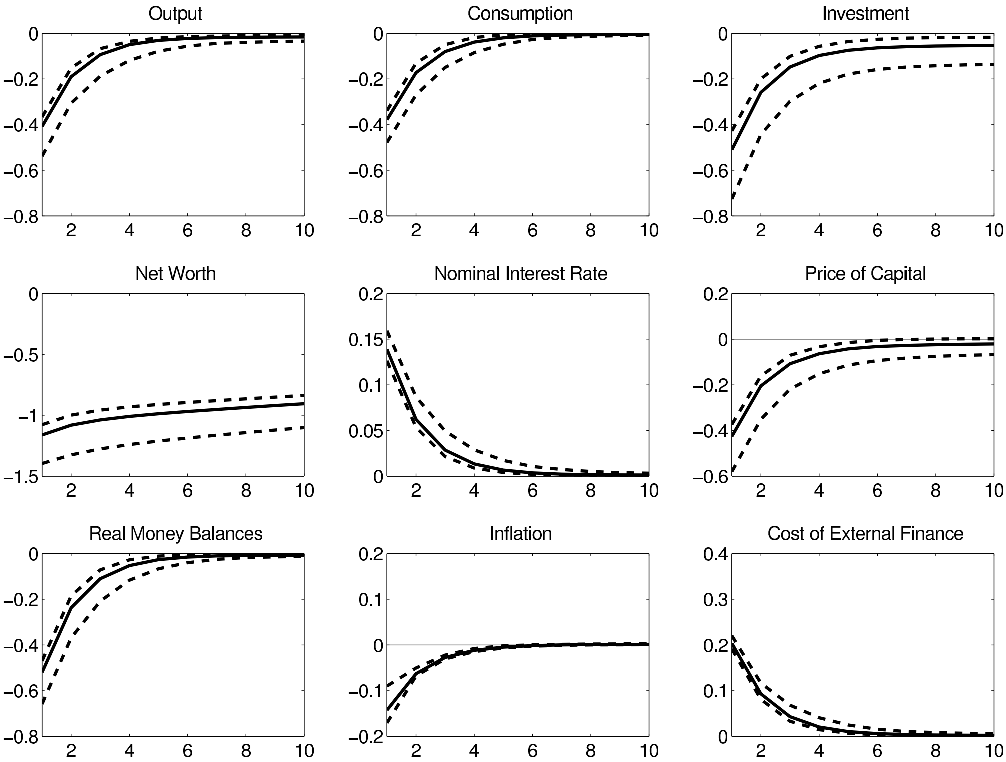
Notes: The figure displays each individual variable's responses as percentage deviations from its steady-state value. The solid line displays the median response and the dashed lines represent the 90th percentage confidence interval.

Figure 12: Impulse response to a money demand shock - EA



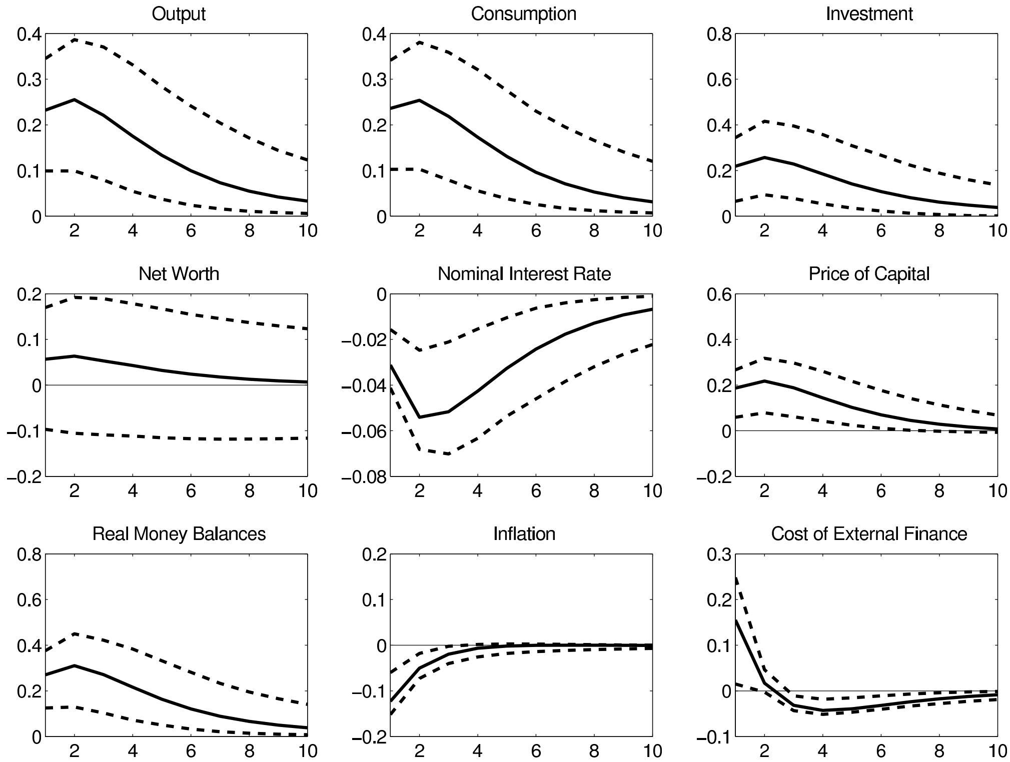
Notes: The figure displays each individual variable's responses as percentage deviations from its steady-state value. The solid line displays the median response and the dashed lines represent the 90th percentage confidence interval.

Figure 13: Impulse response to a monetary policy shock - EA



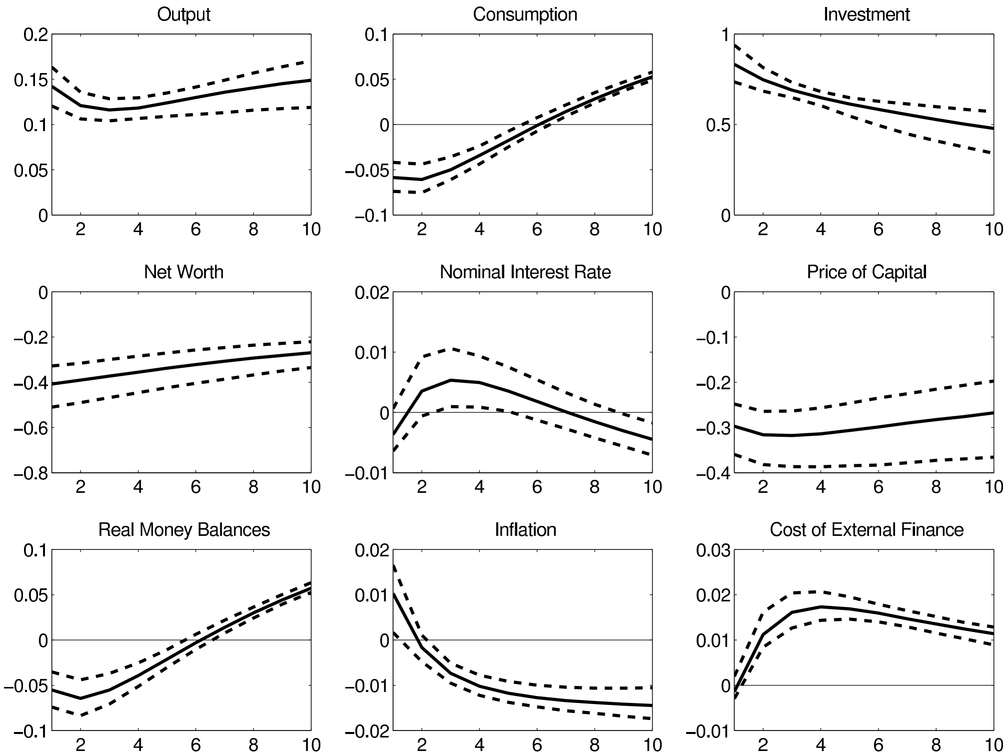
Notes: The figure displays each individual variable's responses as percentage deviations from its steady-state value. The solid line displays the median response and the dashed lines represent the 90th percentage confidence interval.

Figure 14: Impulse response to a technology shock - EA



Notes: The figure displays each individual variable's responses as percentage deviations from its steady-state value. The solid line displays the median response and the dashed lines represent the 90th percentage confidence interval.

Figure 15: Impulse response to an investment shock - EA



Notes: The figure displays each individual variable's responses as percentage deviations from its steady-state value. The solid line displays the median response and the dashed lines represent the 90th percentage confidence interval.