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in Business Cycle Fluctuations

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The International Finance Multiplier in Business Cycle Fluctuations

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Abstract

In the wake of the "Great Recession" of 2007–09, recent studies have emphasized the importance of the "international finance multiplier (IFM)" mechanism for international business cycles, using calibrated two-country models. This paper develops and estimates a two-country model with the IFM mechanism using 21 time series from the Euro Area (EA) and the US. The estimation results show that during the past quarter-century, EA shocks to the external finance premium and net worth not only had a considerable effect on the EA economy together with an EA neutral technology shock, but also were transmitted to the US through the IFM mechanism and had a great impact on the US economy together with a US marginal efficiency of investment (MEI) shock. The rate of EA neutral technological change and the US MEI shock then have strong correlations with lending attitudes of banks in the EA and the US, and thus the EA neutral technology shock and the US MEI shock are likely to represent disturbances to the banking sectors in the EA and the US. These findings therefore demonstrate that financial factors are important sources of EA and US business cycle fluctuations over the past quarter-century.

Keywords: Business cycle fluctuations; International finance multiplier mechanism; Financial accelerator mechanism
JEL classification: F3, F4

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1 Introduction

The "Great Recession" of 2007–09 highlighted the critical role of investors and financial institutions in the international propagation of shocks originating in one country. Allegedly their global investment activities generated economic interdependence among countries through financial markets and induced simultaneous economic slowdown in these countries. Krugman (2008) refers to this mechanism as the "international finance multiplier (IFM)," an idea originally proposed by Calvo (2000) in regard to the Russian crisis in the late 1990s.[1] Recent studies thus emphasize the importance of the IFM mechanism for international business cycles, using calibrated two-country models with financial frictions.[2] Devereux and Yetman (2010) show that the presence of Kiyotaki and Moore (1997)-type leverage-constrained investors, in combination with their internationally diversified portfolios, introduces a powerful financial transmission channel that results in comovement of GDP in two countries, independently of the size of international trade linkages. Dedola and Lombardo (2012), using a calibrated two-country model augmented with the financial accelerator mechanism of Bernanke, Gertler, and Gilchrist (1999), indicate that in the presence of investors who search for the same expected return across internationally traded assets, an adverse shock to the investors' net worth in one country raises external finance (EF) premiums in both countries and induces simultaneous contractions in these countries.

This paper empirically investigates the implications of the IFM mechanism for business cycle fluctuations. Specifically, a two-country model with the IFM mechanism is developed by incorporating not only the Bernanke, Gertler, and Gilchrist (1999) finan-

[1]Krugman (2008) refers to international business cycle linkages through financial markets as the *international finance multiplier* after Robinson (1952), who calls international business cycle linkages through trade of goods and services the *foreign trade multiplier*.

[2]Perri and Quadrini (2011) develop a two-country model with financial frictions and show that a credit contraction can emerge as a self-fulfilling equilibrium caused by pessimistic but fully rational expectations and that, as a consequence of such a credit contraction, countries in a financially integrated world experience large and endogenously synchronized declines in asset prices and economic activity.

cial accelerator mechanism and associated shocks to the EF premium and net worth but also the IFM mechanism modeled by Dedola and Lombardo (2012) in a variant of the two-country model of Ireland (2013). In the model, the IFM mechanism induces pressure for the equalization of EF premiums across two countries, while the financial accelerator mechanism makes variations in the EF premium amplify business cycle fluctuations in each country. Therefore, a shock that affects the EF premium in one country has an impact on business cycle fluctuations in the two countries. The model is estimated using a Bayesian likelihood approach with 21 quarterly time series from the Euro Area (EA) and the United States: GDP, consumption, investment, labor, wages, consumption prices, investment prices, monetary policy rates, loans, net worth, and the exchange rate.[3]

The estimation results show that during the past quarter-century, EA shocks to the EF premium and net worth not only had a considerable effect on EA business cycle fluctuations together with an EA neutral technology shock, but also were transmitted to the US through the IFM mechanism and had a great impact on US business cycle fluctuations together with a US marginal efficiency of investment (MEI) shock.[4] The EA shocks to the EF premium and net worth explain 69.7% and 13.6% of the variances of EA investment and GDP growth during the past quarter-century and 15.6% and 5.3% of their US counterparts, whereas US shocks to the EF premium and net worth make negligible contributions to the two economies' business cycle fluctuations relative to other shocks considered in the model. The EA neutral technology shock accounts for 3.1% and 27.4% of the variances of EA investment and GDP growth, while the US MEI shock

[3] For Bayesian estimation of two-country models (without the IFM mechanism or the financial accelerator mechanism), see, e.g., Lubik and Schorfheide (2006), Rabanal and Tuesta (2010), and Hirose (2013).

[4] As originally proposed by Greenwood, Hercowitz, and Huffman (1988), a MEI shock is a disturbance that affects the transformation of investment goods into capital goods. Justiniano, Primiceri, and Tambalotti (2010, 2011) estimate a closed-economy model with no financial frictions using US data and show that their estimated MEI shock is the main source of US business cycle fluctuations and that the time series of the shock has a strong negative correlation with that of a credit spread and thus the MEI shock is likely to represent a disturbance to the intermediation ability of the US financial sector.

explains 61.1% and 17.0% of the variances of US investment and GDP growth. Then, the time series of the rate of EA neutral technological change and the US MEI shock respectively have strong negative correlations with those of lending attitudes of banks in the EA and the US (i.e., the net tightening of credit standards by EA banks in the Euro Area Bank Lending Survey and domestic respondents' tightening standards for C&I loans in the Senior Loan Officer Opinion Survey on Bank Lending Practices).[5] Thus, the EA neutral technology shock and the US MEI shock are likely to represent disturbances to the functioning of the banking sectors in the EA and the US, respectively.[6] These findings therefore demonstrate that financial factors are important sources of EA and US business cycle fluctuations over the past quarter-century.

In the literature, this paper is closely related and complementary to Kollmann (2013). He estimates a variant of the two-country model with a global bank developed by Kollmann, Enders, and Müller (2011), using 12 quarterly time series: EA and US data on GDP, consumption, investment, labor, and loans detrended linearly in log-form and US data on commercial banks' loan rate spread and capital ratio. His estimation results show that shocks to the global bank (i.e., shocks to loan losses in the EA and the US and the required capital ratio) explain 22.6% and 4.0% of the variances of detrended investment and GDP in the EA during the past two decades and 6.1% and 3.1% of their US counterparts. Compared with this empirical finding of Kollmann, our finding puts much more emphasis on financial factors in EA and US business cycle fluctuations. Our study differs markedly from Kollmann's in that his model contains only the IFM mech-

[5] By contrast, the time series of the EA MEI shock and the rate of US neutral technological change respectively have weak correlations with those of lending attitudes of banks in the EA and the US.

[6] As a source of fluctuations in total factor productivity growth (i.e., neutral technological change), recent studies including Moll (2012) and Queralto (2013) point out financial frictions that induce misallocation of capital and reduction of R&D investment. Kaihatsu and Kurozumi (2013b) estimate a closed-economy model with a financial accelerator mechanism using Japan's data and show that their estimated adverse neutral technology shock mainly induced Japan's "Great Stagnation" in the 1990s–in line with the view of Hayashi and Prescott (2002)–and that the time series of the rate of Japan's neutral technological change has a strong correlation with that of all enterprises' financial position in the Tankan (i.e., the Short-term Economic Survey of Enterprises in Japan).

anism induced by the global bank, whereas our model incorporates not only the IFM mechanism generated by investors but also the financial accelerator mechanism through which financial factors amplify business cycle fluctuations.[7]

The remainder of the paper proceeds as follows. Section 2 describes a two-country model with the IFM mechanism. Section 3 presents strategy and data for estimating the model. Section 4 explains results of the empirical analysis. Section 5 concludes.

2 The two-country model with the international finance multiplier mechanism

In a variant of the two-country model of Ireland (2013), the present paper incorporates the financial accelerator mechanism of Bernanke, Gertler, and Gilchrist (1999) and the IFM mechanism modeled by Dedola and Lombardo (2012). The key feature of the model is the presence of investors who search for the same expected return on capital across two countries, which induces pressure for the equalization of EF premiums across the countries through the IFM mechanism and then affects both countries' business cycle fluctuations through the financial accelerator mechanism.

The model consists of home and foreign countries. In each country there are a representative household that consists of worker and investor members, financial intermediaries, intermediate-good firms, consumption-good firms, investment-good firms, capital-good firms, and a central bank. Each country has the same structure and thus the following exposition focuses on the home country. Foreign variables are denoted by an asterisk.

[7] Another key difference between Kollmann's and our studies is that his study uses the detrended data to estimate the model for stationary variables, whereas our study uses the nondetrended data to estimate the model for nonstationary variables that grow at the rates of technological changes. Our strategy of modeling and estimation is of crucial importance in examining business cycle implications, because estimates of the rates of technological changes determine those of trends in data for estimation and hence the magnitude and direction of the business cycle component of the data.

2.1 The representative household

In the representative household, there is a continuum of members. Some members are workers $m \in [0,1]$ and others are investors. It is assumed as in Andolfatto (1996) and Merz (1995) that all members pool consumption and make joint consumption–saving decisions to avoid distributional issues. The household derives utility from purchasing consumption goods $\tilde{C}_t$ and disutility from supplying differentiated labor services $\{h_t(m)\} = \{\int_0^1 h_t(m,f)df\}$ to intermediate-good firms $f \in [0,1]$. This household's preferences are then represented by the utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \exp(z_{b,t}) \left[\log\left(\tilde{C}_t - bC_{t-1}\right) - \exp(\tilde{z}_{h,t}) \int_0^1 \frac{(h_t(m))^{1+\chi}}{1+\chi} dm \right],$$

where E_t is the expectation operator conditional on information available in period t, C_t is home aggregate consumption, $\beta \in (0,1)$ is the subjective discount factor, $b \in [0,1]$ is the degree of external habit persistence in consumption preferences, $\chi > 0$ is the inverse of the elasticity of labor supply, and $z_{b,t}$ and $\tilde{z}_{h,t}$ represent an intertemporal preference shock and a labor shock, respectively. The household's budget constraint is given by

$$\begin{aligned} &P_t \tilde{C}_t + D_{H,t} + e_t^n \tilde{B}_{H,t}^* \\ &= \int_0^1 P_t W_t(m) h_t(m) dm + r_{t-1} D_{H,t-1} + e_t^n r_{t-1}^* \exp\left(-\phi_e \frac{e_{t-1}^n B_{H,t-1}^* / P_{t-1}}{Y_{t-1}} + z_{e,t-1}\right) \tilde{B}_{H,t-1}^* + T_t, \end{aligned}$$

where P_t is the price of consumption goods; $D_{H,t}$ is the sum of deposits in financial intermediaries and holdings of home currency denominated one-period bonds; their (gross) interest rates are assumed to be the same, denoted by r_t, which is also assumed to equal the home monetary policy rate; $\tilde{B}_{H,t}^*$ is holdings of foreign currency denominated one-period bonds; its (gross) interest rate is denoted by r_t^*, which is assumed to equal the foreign monetary policy rate; e_t^n is the exchange rate; $W_t(m)$ is worker m's real wage; and T_t is the sum of profits received from firms and a lump-sum public transfer. The international bond markets are incomplete. Thus, to eliminate the nonstationarity induced by this incompleteness, the present paper follows Schmitt-Grohé and Uribe (2003) and

Rabanal and Tuesta (2010) to introduce a cost of holding foreign currency denominated bonds represented by $\exp(-\phi_e(e^n_{t-1}B^*_{H,t-1}/P_{t-1})/Y_{t-1} + z_{e,t-1})$, where ϕ_e is a positive constant, $B^*_{H,t}$ is home aggregate holdings of foreign currency denominated bonds, Y_t is (real) GDP, and $z_{e,t}$ is a disturbance to the cost and represents an uncovered interest-rate parity (UIP) shock as explained later. Note that this form of foreign bond holding cost implicitly assumes balanced trade in the steady state as explained later.

The first-order conditions for optimal decisions on consumption, home deposits and bond holdings, and foreign bond holdings lead to

$$\Lambda_t = \frac{\exp(z_{b,t})}{C_t - bC_{t-1}}, \tag{1}$$

$$1 = E_t\, \beta \frac{\Lambda_{t+1}}{\Lambda_t} \frac{r_t}{\pi_{t+1}}, \tag{2}$$

$$1 = E_t\, \beta \frac{\Lambda_{t+1}}{\Lambda_t} \frac{e^n_{t+1}}{e^n_t} \frac{r^*_t}{\pi_{t+1}} \exp\left(-\phi_e \frac{e^n_t B^*_{H,t}/P_t}{Y_t} + z_{e,t}\right), \tag{3}$$

where Λ_t is the marginal utility of consumption and $\pi_t = P_t/P_{t-1}$ is the (gross) price inflation rate of home consumption goods.

2.1.1 Workers

Under monopolistic competition, intermediate-good firms' demand for worker m's labor services is given by $h_t(m) = h_t(W_t(m)/W_t)^{-(1+\lambda_w)/\lambda_w}$, where $h_t = [\int_0^1 (h_t(m))^{1/(1+\lambda_w)} dm]^{1+\lambda_w}$ is an aggregate of differentiated labor services with the substitution elasticity $(1 + \lambda_w)/\lambda_w > 1$ and

$$W_t = \left[\int_0^1 (W_t(m))^{-1/\lambda_w} dm\right]^{-\lambda_w} \tag{4}$$

is the corresponding aggregate real wage. Each wage $P_tW_t(m)$ is set on a staggered basis à la Calvo (1983). In each period, a fraction $1-\xi_w \in (0, 1)$ of wages is reoptimized, while the remaining fraction ξ_w is set by indexation to both the (gross) steady-state balanced growth rate (explained later), z, and a weighted average of past and steady-state inflation rates, $\pi^{\gamma_w}_{t-1}\pi^{1-\gamma_w}$, where $\gamma_w \in [0, 1]$ is a weight on the recent past inflation rate. Then, each wage reoptimized in period t is chosen to maximize

$$E_t \sum_{j=0}^{\infty} (\beta \xi_w)^j \left[\Lambda_{t+j} h_{t+j|t}(m) \frac{P_t W_t(m)}{P_{t+j}} \prod_{k=1}^{j} z (\pi_{t+k-1})^{\gamma_w} (\pi)^{1-\gamma_w} - \exp(z_{b,t+j}) \exp(\tilde{z}_{h,t+j}) \frac{\left(h_{t+j|t}(m)\right)^{1+\chi}}{1+\chi} \right]$$

subject to

$$h_{t+j|t}(m) = h_{t+j} \left[\frac{P_t W_t(m)}{P_{t+j} W_{t+j}} \prod_{k=1}^{j} z (\pi_{t+k-1})^{\gamma_w} (\pi)^{1-\gamma_w} \right]^{-\frac{1+\lambda_w}{\lambda_w}}.$$

The first-order condition for the reoptimized real wage $\bar{W}_t$ is given by

$$\bar{W}_t^{1+\frac{\chi(1+\lambda_w)}{\lambda_w}} = (1+\lambda_w) \frac{E_t \sum_{j=0}^{\infty} (\beta \xi_w)^j \exp(z_{b,t+j}) \exp(\tilde{z}_{h,t+j}) \left\{ \left[\frac{1}{W_{t+j}} \prod_{k=1}^{j} z \left(\frac{\pi_{t+k-1}}{\pi} \right)^{\gamma_w} \frac{\pi}{\pi_{t+k}} \right]^{-\frac{1+\lambda_w}{\lambda_w}} h_{t+j} \right\}^{1+\chi}}{E_t \sum_{j=0}^{\infty} (\beta \xi_w)^j \Lambda_{t+j} \left(\frac{1}{W_{t+j}} \right)^{-\frac{1+\lambda_w}{\lambda_w}} \left[\prod_{k=1}^{j} z \left(\frac{\pi_{t+k-1}}{\pi} \right)^{\gamma_w} \frac{\pi}{\pi_{t+k}} \right]^{-\frac{1}{\lambda_w}} h_{t+j}}. \tag{5}$$

The aggregate wage equation (4) can be reduced to

$$W_t^{-\frac{1}{\lambda_w}} = (1-\xi_w) \bar{W}_t^{-\frac{1}{\lambda_w}} + \xi_w \left[W_{t-1} z \left(\frac{\pi_{t-1}}{\pi} \right)^{\gamma_w} \frac{\pi}{\pi_t} \right]^{-\frac{1}{\lambda_w}}. \tag{6}$$

2.1.2 Investors and financial intermediaries

Investors transfer from the previous period home and foreign capital goods $K_{H,t-1}$, $K^*_{H,t-1}$, which were purchased at the end of the period from home and foreign capital-good firms at the real prices Q_{t-1}, $e_{t-1} Q^*_{t-1}$, where e_t denotes the real exchange rate given by $e_t = e^n_t P^*_t / P_t$ and P^*_t is the price of foreign consumption goods. Investors start the current period by adjusting the utilization rates u_t, u^*_t on the home and foreign capital goods to provide capital services $u_t K_{H,t-1}$, $u^*_t K^*_{H,t-1}$ for home and foreign intermediate-good firms at the real rental rates $R_{k,t}$, $e_t R^*_{k,t}$. After the production of intermediate-good firms, home and foreign capital goods are depreciated at the rates $\delta(u_t)$, $\delta_*(u^*_t)$. As in Greenwood, Hercowitz, and Huffman (1988), it is assumed that a higher utilization rate of capital leads to a higher depreciation rate of capital. Thus, the depreciation rate functions $\delta(\cdot)$, $\delta_*(\cdot)$ for home and foreign capital goods have properties of $\delta' > 0$, $\delta'' > 0$, $\delta(1) = \delta \in (0,1)$, and $\delta'(1)/\delta''(1) = \tau > 0$ and of $\delta'_* > 0$, $\delta''_* > 0$, $\delta_*(1) = \delta_* \in (0,1)$, and $\delta'_*(1)/\delta''_*(1) = \tau_* > 0$. Subsequently, investors sell the resulting home and foreign capital goods $(1-\delta(u_t))K_{H,t-1}$, $(1-\delta_*(u_t^*))K^*_{H,t-1}$ to home and foreign capital-good firms at the real prices Q_t, $e_t Q_t^*$.

The first-order conditions for optimal decisions on the capital utilization rates are given by[8]

$$R_{k,t} = Q_t \delta'(u_t), \tag{7}$$

$$R^*_{k,t} = Q_t^* \delta'_*(u_t^*). \tag{8}$$

Investors' purchase of home and foreign capital goods at the end of each period is financed by their real net worth N_t and by their real loan

$$L_t = Q_t K_{H,t} + e_t Q_t^* K^*_{H,t} - N_t \tag{9}$$

only from domestic financial intermediaries at the (gross nominal) loan rate $r_{l,t}$. The first-order conditions for optimal decisions on the purchase of home and foreign capital goods are given by

$$E_t \Lambda_{t+1} x_{t+1} = E_t \Lambda_{t+1} \frac{r_{l,t}}{\pi_{t+1}}, \tag{10}$$

$$E_t \Lambda_{t+1} \frac{e_{t+1}}{e_t} x^*_{t+1} = E_t \Lambda_{t+1} \frac{r_{l,t}}{\pi_{t+1}}, \tag{11}$$

where x_t, x_t^* are ex-post marginal returns on home and foreign capital given by

$$x_t = \frac{u_t R_{k,t} + Q_t\left(1 - \delta(u_t)\right)}{Q_{t-1}}, \tag{12}$$

$$x_t^* = \frac{u_t^* R^*_{k,t} + Q_t^*\left(1 - \delta_*(u_t^*)\right)}{Q^*_{t-1}}. \tag{13}$$

Equation (11) is the key condition for the IFM mechanism. This equation and (10) indicate that investors search for the same expected marginal return on capital across the two countries (i.e., $E_t \Lambda_{t+1} x_{t+1} = E_t \Lambda_{t+1}(e_{t+1}/e_t) x^*_{t+1}$).

[8] As the capital depreciation rate functions do not depend on whether investors are domestic or foreign, neither do the capital utilization rates.

The EF premium efp_t is defined as the difference between the loan rate $r_{l,t}$ and the deposit rate r_t and consists of the endogenous component $F(l_{H,t}+l^*_{H,t})$ and the exogenous one $z_{\mu,t}$

$$\frac{r_{l,t}}{r_t} = efp_t = F\big(l_{H,t} + l^*_{H,t}\big)\exp(z_{\mu,t}). \tag{14}$$

Here,

$$l_{H,t} = \frac{Q_t K_{H,t}}{N_t}, \quad l^*_{H,t} = \frac{e_t Q^*_t K^*_{H,t}}{N_t} \tag{15}$$

are investors' home and foreign leverage ratios. The endogenous component $F(\cdot)$ depends on investors' total leverage ratio $l_{H,t} + l^*_{H,t}$ and satisfies $F' > 0$ and $\mu = (l_H + l^*_H)F'(l_H + l^*_H)/F(l_H + l^*_H) \geq 0$ as in previous studies with open-economy financial accelerator models, such as Gilchrist (2004), Faia (2007), Gertler, Gilchrist, and Natalucci (2007), and Dedola and Lombardo (2012). The exogenous component $z_{\mu,t}$ denotes a shock to the EF premium. This shock represents a disturbance to the financial sector that boosts the EF premium beyond the level determined by investors' total leverage ratio.

After selling capital goods to capital-good firms and paying back $r_{l,t-1}L_{t-1}$ to financial intermediaries, a fraction $1 - \gamma_t \in (0, 1)$ of investors becomes workers, while the remaining fraction γ_t survives until the next period.[9] Investors' real net worth then evolves according to

$$N_t = \gamma_t \left[x_t l_{H,t-1} + \frac{e_t}{e_{t-1}} x^*_t l^*_{H,t-1} - \frac{r_{l,t-1}}{\pi_t}\big(l_{H,t-1} + l^*_{H,t-1} - 1\big)\right] N_{t-1} + (1 - \gamma_t)\, t_n Z_t, \tag{16}$$

where t_n is a positive constant and Z_t is the composite technological level explained later. The term $t_n Z_t$ denotes the transfer that surviving investors receive from investors who become workers. The probability of surviving until the next period is given by $\gamma_t = \gamma \exp(\tilde{z}_{\gamma,t})/\left(1 - \gamma + \gamma \exp(\tilde{z}_{\gamma,t})\right)$, where $\tilde{z}_{\gamma,t}$ represents a net worth shock.

[9]This assumption ensures that investors' net worth will never be sufficient to entirely finance their purchase of capital.

2.2 Intermediate-good firms

Each intermediate-good firm $f \in [0,1]$ produces output $Y_t(f)$ by choosing a combination of labor and capital inputs $\{h_t(f), K_t(f)\}$ at the real rental rates $\{W_t, R_{k,t}\}$ according to the production function

$$Y_t(f) = (A_t h_t(f))^{1-\alpha} (K_t(f))^{\alpha}. \tag{17}$$

Here, A_t represents the level of neutral technology and it is assumed as in Rabanal, Rubio-Ramírez, and Tuesta (2011) and Ireland (2013) that its growth rate follows the stochastic process

$$\log \frac{A_t}{A_{t-1}} = (1-\rho_a)\log a + \rho_a \log \frac{A_{t-1}}{A_{t-2}} + \rho_{ad} \log \frac{A^*_{t-1}}{A_{t-1}} + \varepsilon_{a,t}, \tag{18}$$

where $\rho_a \in [0,1)$ is the persistence parameter; $\rho_{ad} \geq 0$ is the error-correction parameter; $a > 1$ denotes the (gross) steady-state rate of neutral technological change, which is assumed to be the same across the two countries; and $\varepsilon_{a,t}$ represents a (nonstationary) neutral technology shock. The labor input is given by $h_t(f) = [\int_0^1 (h_t(m,f))^{1/(1+\lambda_w)} dm]^{1+\lambda_w}$. The parameter $\alpha \in (0,1)$ represents the capital elasticity of output, which is assumed to be the same across the two countries.

Combining the first-order conditions for optimal decisions on capital and labor inputs leads to

$$\frac{u_t (K_{H,t-1} + K_{F,t-1})}{h_t} = \frac{\alpha W_t}{(1-\alpha) R_{k,t}}, \tag{19}$$

where $h_t = \int_0^1 h_t(f)df$, $u_t K_{H,t-1} = \int_0^1 K_{H,t}(f)df$, and $u_t K_{F,t-1} = \int_0^1 K_{F,t}(f)df$, and the real marginal cost is given by

$$mc_t = \left(\frac{W_t}{(1-\alpha)A_t}\right)^{1-\alpha} \left(\frac{R_{k,t}}{\alpha}\right)^{\alpha}. \tag{20}$$

Under monopolistic competition, intermediate-good firm f faces home and foreign consumption-good firms' demand $Y_{H,t}(f) = Y_{H,t}(P_{H,t}(f)/P_{H,t})^{-(1+\lambda_H)/\lambda_H}$ and $Y^*_{H,t}(f) = Y^*_{H,t}(P^*_{H,t}(f)/P^*_{H,t})^{-(1+\lambda^*_H)/\lambda^*_H}$, where $P_{H,t}(f)$ and $P^*_{H,t}(f)$ are home and foreign prices of differentiated goods produced by intermediate-good firm f, $Y_{H,t}$ and $Y_{H,t}^*$ are home and foreign aggregates of intermediate goods with the substitution elasticities $(1+\lambda_H)/\lambda_H, (1+\lambda_H^*)/\lambda_H^* > 1$, and $P_{H,t}$ and $P_{H,t}^*$ are the corresponding aggregate prices. Then, it is assumed as in Rabanal and Tuesta (2010) that intermediate-good firms adopt local currency pricing of their differentiated products on a staggered basis à la Calvo (1983). In each period, a fraction $1-\xi_H \in (0,1)$ of intermediate-good firms reoptimizes prices of their products purchased by home consumption-good firms, while the remaining fraction ξ_H indexes prices of the products to a weighted average of past and steady-state inflation rates of the aggregate price $P_{H,t}$, $(\pi_{H,t-1})^{\gamma_H}(\pi_H)^{1-\gamma_H}$, where $\pi_{H,t} = P_{H,t}/P_{H,t-1}$ and $\gamma_H \in [0,1]$. Similarly, a fraction $1-\xi_H^* \in (0,1)$ of intermediate-good firms reoptimizes prices of their products purchased by foreign consumption-good firms, while the remaining fraction ξ_H^* indexes prices of the products to a weighted average of past and steady-state inflation rates of the aggregate price $P_{H,t}^*$, $(\pi_{H,t+k-1}^*)^{\gamma_H^*}(\pi_H^*)^{1-\gamma_H^*}$, where $\pi_H^* = P_{H,t}^*/P_{H,t-1}^*$ and $\gamma_H^* \in [0,1]$. Hence, intermediate-good firms that reoptimize current-period prices of their products purchased by home consumption-good firms choose the prices to maximize

$$E_t \sum_{j=0}^{\infty} (\xi_H)^j \left(\beta^j \frac{\Lambda_{t+j}}{\Lambda_t} \right) \left[\frac{P_{H,t}(f)}{P_{t+j}} \prod_{k=1}^{j} (\pi_{H,t+k-1})^{\gamma_H} (\pi_H)^{1-\gamma_H} - mc_{t+j} \right] Y_{H,t+j|t}(f)$$

subject to

$$Y_{H,t+j|t}(f) = Y_{H,t+j} \left[\frac{P_{H,t}(f)}{P_{H,t+j}} \prod_{k=1}^{j} (\pi_{H,t+k-1})^{\gamma_H} (\pi_H)^{1-\gamma_H} \right]^{-\frac{1+\lambda_H}{\lambda_H}},$$

where $\beta^j \Lambda_{t+j}/\Lambda_t$ shows the stochastic discount factor between period t and period $t+j$. Similarly, intermediate-good firms that reoptimize current-period prices of their products purchased by foreign consumption-good firms choose the prices to maximize

$$E_t \sum_{j=0}^{\infty} (\xi_H^*)^j \left(\beta^j \frac{\Lambda_{t+j}}{\Lambda_t} \right) \left[\frac{e_{t+j}^n P_{H,t}^*(f)}{P_{t+j}} \prod_{k=1}^{j} \left(\pi_{H,t+k-1}^*\right)^{\gamma_H^*} (\pi_H^*)^{1-\gamma_H^*} - mc_{t+j} \right] Y_{H,t+j|t}^*(f)$$

subject to

$$Y^*_{H,t+j|t}(f) = Y^*_{H,t+j}\left[\frac{P^*_{H,t}(f)}{P^*_{H,t+j}}\prod_{k=1}^{j}\left(\pi^*_{H,t+k-1}\right)^{\gamma^*_H}\left(\pi^*_H\right)^{1-\gamma^*_H}\right]^{-\frac{1+\lambda^*_H}{\lambda^*_H}}.$$

The first-order conditions for reoptimized real prices $\bar{p}_{H,t}$, $\bar{p}^*_{H,t}$ are given by

$$\bar{p}_{H,t} = (1+\lambda_H)\frac{E_t\sum_{j=0}^{\infty}(\beta\xi_H)^j\Lambda_{t+j}Y_{H,t+j}mc_{t+j}\left[\prod_{k=1}^{j}\left(\frac{\pi_{H,t+k-1}}{\pi_H}\right)^{\gamma_H}\frac{\pi_H}{\pi_{H,t+k}}\right]^{-\frac{1+\lambda_H}{\lambda_H}}}{E_t\sum_{j=0}^{\infty}(\beta\xi_H)^j\Lambda_{t+j}Y_{t+j}p_{H,t+j}\left[\prod_{k=1}^{j}\left(\frac{\pi_{H,t+k-1}}{\pi_H}\right)^{\gamma_H}\frac{\pi_H}{\pi_{H,t+k}}\right]^{-\frac{1}{\lambda_H}}}, \tag{21}$$

$$\bar{p}^*_{H,t} = (1+\lambda^*_H)\frac{E_t\sum_{j=0}^{\infty}(\beta\xi^*_H)^j\Lambda_{t+j}Y^*_{H,t+j}mc_{t+j}\left[\prod_{k=1}^{j}\left(\frac{\pi^*_{H,t+k-1}}{\pi^*_H}\right)^{\gamma^*_H}\frac{\pi^*_H}{\pi^*_{H,t+k}}\right]^{-\frac{1+\lambda^*_H}{\lambda^*_H}}}{E_t\sum_{j=0}^{\infty}(\beta\xi_H)^j\Lambda_{t+j}Y^*_{t+j}p^*_{H,t+j}e_{t+j}\left[\prod_{k=1}^{j}\left(\frac{\pi^*_{H,t+k-1}}{\pi^*_H}\right)^{\gamma^*_H}\frac{\pi^*_H}{\pi^*_{H,t+k}}\right]^{-\frac{1}{\lambda^*_H}}}. \tag{22}$$

Aggregating the production functions (17) over intermediate-good firms yields the GDP equation

$$Y_t = \int_0^1 Y_t(f)df = (A_t h_t)^{1-\alpha}\left[u_t\left(K_{H,t-1}+K_{F,t-1}\right)\right]^{\alpha}. \tag{23}$$

Moreover, aggregating the intermediate-good market clearing conditions $Y_t(f) = Y_{H,t}(f) + Y^*_{H,t}(f)$ leads to

$$Y_t = Y_{H,t}d_{H,t} + Y^*_{H,t}d^*_{H,t}, \tag{24}$$

where $d_{H,t} = \int_0^1 (P_{H,t}(f)/P_{H,t})^{-(1+\lambda_H)/\lambda_H}df$ and $d^*_{H,t} = \int_0^1 (P^*_{H,t}(f)/P^*_{H,t})^{-(1+\lambda^*_H)/\lambda^*_H}df$ are price dispersion of intermediate goods purchased by home and foreign consumption-good firms. Note that the price dispersion is of second order under the staggered pricing and that its steady-state value is unity.

2.3 Consumption-good firms

Consumption-good firms produce output $Y_{c,t}$ in two steps to introduce a price markup shock. First, they produce differentiated inputs $\{Y_{c,t}(f_c)\}$ by choosing a combination of home and foreign intermediate goods $\{\{Y_{H,t}(f)\}, \{Y_{F,t}(f^*)\}\}$ at the prices $\{\{P_{H,t}(f)\}, \{P_{F,t}(f^*)\}\}$ according to the production function $Y_{c,t}(f_c) = [(\omega)^{1/\theta}(Y_{H,t})^{(\theta-1)/\theta} + (1-\omega)^{1/\theta}(Y_{F,t})^{(\theta-1)/\theta}]^{\theta/(\theta-1)}$, where $Y_{H,t} = [\int_0^1 (Y_{H,t}(f))^{1/(1+\lambda_H)} df]^{1+\lambda_H}$ and $Y_{F,t} = [\int_0^1 (Y_{F,t}(f^*))^{1/(1+\lambda_F)} df^*]^{1+\lambda_F}$ are aggregates of home and foreign intermediate goods. In the second step, they combine differentiated inputs to produce consumption goods $Y_{c,t} = [\int_0^1 (Y_{c,t}(f_c))^{1/(1+\lambda_{c,t})} df_c]^{1+\lambda_{c,t}}$. Consequently, output is given by

$$Y_{c,t} = \left[(\omega)^{\frac{1}{\theta}} (Y_{H,t})^{\frac{\theta-1}{\theta}} + (1-\omega)^{\frac{1}{\theta}} (Y_{F,t})^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}. \tag{25}$$

The first-order conditions for cost minimization yield consumption-good firms' demand for home intermediate good f and foreign intermediate good f^* given by

$$Y_{H,t}(f) = Y_{H,t} \left(\frac{P_{H,t}(f)}{P_{H,t}} \right)^{-\frac{1+\lambda_H}{\lambda_H}} = \omega \left(\frac{P_{H,t}}{MC_{c,t}} \right)^{-\theta} \left(\frac{P_{H,t}(f)}{P_{H,t}} \right)^{-\frac{1+\lambda_H}{\lambda_H}} Y_{c,t},$$

$$Y_{F,t}(f^*) = Y_{F,t} \left(\frac{P_{F,t}(f^*)}{P_{F,t}} \right)^{-\frac{1+\lambda_F}{\lambda_F}} = (1-\omega) \left(\frac{P_{F,t}}{MC_{c,t}} \right)^{-\theta} \left(\frac{P_{F,t}(f^*)}{P_{F,t}} \right)^{-\frac{1+\lambda_F}{\lambda_F}} Y_{c,t},$$

and their marginal cost given by

$$MC_{c,t} = [\omega(P_{H,t})^{1-\theta} + (1-\omega)(P_{F,t})^{1-\theta}]^{\frac{1}{1-\theta}},$$

where $P_{H,t} = [\int_0^1 (P_{H,t}(f))^{-\frac{1}{\lambda_H}} df]^{-\lambda_H}$ and $P_{F,t} = [\int_0^1 (P_{F,t}(f^*))^{-\frac{1}{\lambda_F}} df^*]^{-\lambda_F}$ are aggregate prices of home and foreign intermediate goods. These demand equations yield

$$\frac{Y_{F,t}}{Y_{H,t}} = \frac{1-\omega}{\omega} \left(\frac{p_{F,t}}{p_{H,t}} \right)^{-\theta}. \tag{26}$$

From the staggered pricing of home and foreign intermediate-good firms, the aggregate price equations for $P_{H,t}$, $P_{F,t}$ can be reduced to

$$1 = (1-\xi_H)(\bar{p}_{H,t})^{-\frac{1}{\lambda_H}} + \xi_H \left[\frac{\pi_H}{\pi_{H,t}} \left(\frac{\pi_{H,t-1}}{\pi_H} \right)^{\gamma_H} \right]^{-\frac{1}{\lambda_H}}, \tag{27}$$

$$1 = (1-\xi_F)(\bar{p}_{F,t})^{-\frac{1}{\lambda_F}} + \xi_F \left[\frac{\pi_F}{\pi_{F,t}} \left(\frac{\pi_{F,t-1}}{\pi_F} \right)^{\gamma_F} \right]^{-\frac{1}{\lambda_F}}. \tag{28}$$

The price of consumption goods is given by $P_t = (1+\lambda_{c,t})MC_{c,t}$, which can be reduced to

$$1 = (1+\lambda_{c,t}) \left[\omega (p_{H,t})^{1-\theta} + (1-\omega)(p_{F,t})^{1-\theta} \right]^{\frac{1}{1-\theta}}, \tag{29}$$

where $p_{H,t} = P_{H,t}/P_t$ and $p_{F,t} = P_{F,t}/P_t$.

2.4 Investment-good firms

Investment-good firms use the production technology that converts one unit of consumption goods into Ψ_t units of investment goods. Thus, Ψ_t represents the level of investment-specific (IS) technology.[10] It is assumed as in Ireland (2013) that its growth rate follows the stochastic process

$$\log \frac{\Psi_t}{\Psi_{t-1}} = (1-\rho_\psi)\log\psi + \rho_\psi \log \frac{\Psi_{t-1}}{\Psi_{t-2}} + \rho_{\psi d}\log \frac{\Psi^*_{t-1}}{\Psi_{t-1}} + \varepsilon_{\psi,t}, \tag{30}$$

where $\rho_\psi \in [0,1)$ is the persistence parameter; $\rho_{\psi d} \geq 0$ is the error-correction parameter; $\psi > 1$ denotes the (gross) steady-state rate of IS technological change, which is assumed to be the same across the two countries; and $\varepsilon_{\psi,t}$ represents a (nonstationary) IS technology shock. The cost minimization of investment-good firms shows that their real marginal cost equals the inverse of the IS technological level, $1/\Psi_t$. Thus, the price of investment goods is given by

$$P_{i,t} = \frac{P_t}{\Psi_t}, \tag{31}$$

and the (gross) rate of change in the relative price of investment goods to consumption goods is given by

$$r_{i,t} = \frac{P_{i,t}/P_t}{P_{i,t-1}/P_{t-1}} = \frac{\Psi_{t-1}}{\Psi_t}. \tag{32}$$

The market clearing condition for consumption goods is now given by

$$Y_{c,t} = C_t + \frac{I_t}{\Psi_t} + Z_t \exp(z_t^g), \tag{33}$$

where the last term $Z_t \exp(z_t^g)$ denotes demand for consumption goods other than the household's consumption demand and investment-good firms' demand, z_t^g represents a shock to this exogenous consumption-good demand, and Z_t is the composite technological level given by $Z_t = A_t(\Psi_t)^{\alpha/(1-\alpha)}$. This composite technological level can be derived using the GDP equation (23). Then, the composite technological change $z_t = Z_t/Z_{t-1}$ turns

[10] The presence of IS technological change is based on the observed downward trend in the US data on the relative price of investment to consumption. Greenwood, Hercowitz, and Krusell (1997) indicate the importance of IS technological change for US economic growth.

out to be the (gross) rate of home-country balanced growth and its steady-state value is given by $z = a\psi^{\alpha/(1-\alpha)}$, which implies that the steady-state balanced growth rate is the same across the two countries.

2.5 Capital-good firms

Capital-good firms purchase capital goods $(1-\delta(u_t))K_{H,t-1}$, $(1-\delta(u_t))K_{F,t-1}$ back from home and foreign investors and make an investment I_t. This investment is subject to not only adjustment costs $S((I_t/I_{t-1})/(z\psi)) = (\zeta/2)[(I_t/I_{t-1})/(z\psi) - 1]^2$, $\zeta > 0$, as advocated by Christiano, Eichenbaum, and Evans (2005), but also the MEI shock $z_{\nu,t}$ proposed by Greenwood, Hercowitz, and Huffman (1988). This shock represents a disturbance that affects the transformation of investment goods into capital goods. The capital accumulation equation is thus given by

$$K_t = (1-\delta(u_t))K_{t-1} + \exp(z_{\nu,t})\left(1 - S\left(\frac{I_t/I_{t-1}}{z\psi}\right)\right) I_t, \tag{34}$$

where

$$K_t = K_{H,t} + K_{F,t}. \tag{35}$$

Subsequently, capital-good firms sell capital goods $K_{H,t}$, $K_{F,t}$ to home and foreign investors.

Capital-good firms' problem is to choose investment I_t and a combination of investment goods $\{I_t(f_i)\}$ to maximize profit

$$E_t \sum_{j=0}^{\infty} \beta^j \frac{\Lambda_{t+j}}{\Lambda_t} \left\{ Q_{t+j} \left[K_{t+j} - (1-\delta(u_{t+j}))K_{t+j-1} \right] - \frac{P_{i,t+j}}{P_{t+j}} I_{t+j} \right\}$$

subject to the capital accumulation equation (34). The first-order condition for optimal decisions on investment I_t is given by

$$\begin{aligned} \frac{P_{i,t}}{P_t} = {} & Q_t \exp(z_{\nu,t})\left[1 - S\left(\frac{I_t/I_{t-1}}{z\psi}\right) - S'\left(\frac{I_t/I_{t-1}}{z\psi}\right)\frac{I_t/I_{t-1}}{z\psi}\right] \\ & + E_t \beta \frac{\Lambda_{t+1}}{\Lambda_t} z\psi Q_{t+1} \exp(z_{\nu,t+1}) S'\left(\frac{I_{t+1}/I_t}{z\psi}\right)\left(\frac{I_{t+1}/I_t}{z\psi}\right)^2. \end{aligned} \tag{36}$$

2.6 Central bank

The central bank conducts monetary policy by adjusting the policy rate according to the Taylor (1993)-type rule

$$\log r_t = \phi_r \log r_{t-1} + (1-\phi_r)\left(\log r + \frac{\phi_\pi}{4}\sum_{j=0}^{3}\log\frac{\pi_{t-j}}{\pi} + \phi_y \log\frac{Y_t/Z_t}{y}\right) + \phi_{\Delta y}\log\frac{Y_t/Y_{t-1}}{z} + z_{r,t}, \tag{37}$$

where r is the (gross) steady-state monetary policy rate, y is the steady-state value of detrended GDP $y_t = Y_t/Z_t$, $\phi_r \in [0,1)$ represents the degree of policy rate smoothing, $\phi_\pi, \phi_y, \phi_{\Delta y} \geq 0$ represent the degrees of policy responses to inflation, GDP, and GDP growth, and the disturbance $z_{r,t}$ represents a monetary policy shock.

2.7 Exchange rate

The exchange rate is determined as follows. The law of motion of foreign currency denominated one-period bonds is given by

$$e_t^n B_{H,t}^* = e_t^n r_{t-1}^* \exp\left(-\phi_e \frac{e_{t-1}^n B_{H,t-1}^*/P_{t-1}}{Y_{t-1}} + z_{e,t-1}\right) B_{H,t-1}^* + e_t^n P_{H,t}^* Y_{H,t}^* - P_{F,t} Y_{F,t},$$

which can be reduced to

$$\log d_t = \log d_{t-1} \frac{e_t}{e_{t-1}} \frac{r_{t-1}^*}{\pi_t^*} \frac{Y_{t-1}}{Y_t} \exp\left(-\phi_e \log d_{t-1} + z_{e,t-1}\right) + e_t p_{H,t}^* \frac{Y_{H,t}^*}{Y_t} - p_{F,t}\frac{Y_{F,t}}{Y_t}, \tag{38}$$

where $\log d_t = (e_t^n B_{H,t}^*/P_t)/Y_t$ and $p_{H,t}^* = P_{H,t}^*/P_t^*$. Then, from (3) and the foreign counterpart to (2), the real exchange rate e_t is determined according to

$$E_t\left[\frac{1}{\pi_{t+1}^*}\left(\frac{\Lambda_{t+1}^*}{\Lambda_t^*} - \frac{\Lambda_{t+1}}{\Lambda_t}\frac{e_{t+1}}{e_t}\exp\left(-\phi_e \log d_t + z_{e,t}\right)\right)\right] = 0. \tag{39}$$

Note that this equation imposes balanced trade in the steady state.

2.8 Equilibrium conditions

In the model, the equilibrium conditions consist of three parts. First, the conditions for the home country are given by (1), (2), (5)–(16), (19)–(29), (31)–(36), and (37), together with the stochastic processes of neutral and IS technological changes, (18), (30), and those of the other eight exogenous shocks $z_{x,t}$, $x \in \{b, g, h, c, r, \nu, \mu, \gamma\}$, where $z_{h,t} = (1-\xi_w)(1-\beta\xi_w)/\{\xi_w[1+\chi(1+\lambda_w)/\lambda_w]\}\tilde{z}_{h,t}$, $z_{c,t}$ is the shock associated with the consumption-good price markup $\lambda_{c,t}$, and $z_{\gamma,t} = \gamma[r_l/(z\pi)-1]\tilde{z}_{\gamma,t}$. Each of the exogenous shocks is assumed to follow the univariate stationary first-order autoregressive process with the persistence parameter ρ_x and the standard deviation of shock innovations σ_x. Second, there are the foreign-country counterparts to these home-country conditions. Last, the exchange rate–related conditions are given by (38) and (39) together with the univariate stationary first-order autoregressive process of the UIP shock (ρ_e, σ_e).

3 The strategy and data for estimation

This section describes strategy and data for estimating the model presented in the preceding section.

3.1 The estimation strategy

The model is estimated using a Bayesian likelihood approach with 21 quarterly time series: EA and US GDP Y_t, Y_t^*; EA and US consumption C_t, C_t^*; EA and US investment I_t, I_t^*; EA and US labor h_t, h_t^*; EA and US real wages W_t, W_t^*; EA and US prices of consumption goods P_t, P_t^*; EA and US relative prices of investment goods $P_{i,t}/P_t, P_{i,t}^*/P_t^*$; EA and US monetary policy rates r_t, r_t^*; EA and US real loans L_t, L_t^*; EA and US real net worth N_t, N_t^*; and the Euro per USD real exchange rate e_t.

For estimation, the equilibrium conditions of the model are rewritten in terms of detrended variables: $y_t = Y_t/Z_t$, $y_{c,t} = Y_{c,t}/Z_t$, $c_t = C_t/Z_t$, $w_t = W_t/Z_t$, $n_t = N_t/Z_t$, $l_t = L_t/Z_t$, $\lambda_t = \Lambda_t Z_t$, $i_t = I_t/(Z_t\Psi_t)$, $k_t = K_t/(Z_t\Psi_t)$, $k_{H,t} = K_{H,t}/(Z_t\Psi_t)$, $k_{F,t} = K_{F,t}/(Z_t\Psi_t)$, $r_{k,t} = R_{k,t}\Psi_t$, $q_t = Q_t\Psi_t$, $z_t = Z_t/Z_{t-1}$, $a_t = A_t/A_{t-1}$, $\psi_t = \Psi_t/\Psi_{t-1}$, and the foreign counterparts of these variables, together with $z_t^d = Z_t/Z_t^*$, $a_t^d = A_t/A_t^*$, $\psi_t^d = \Psi_t/\Psi_t^*$. The resulting equilibrium conditions are then log-linearized around a (deterministic) steady state with home and foreign capital utilization rates of unity and home and foreign investors' portfolio shares of holdings of claims on domestic capital of $\eta, \eta^* \in [0, 1]$.[11]

Like recent studies that estimate dynamic stochastic general equilibrium models by Bayesian methods, such as Lubik and Schorfheide (2006) and Smets and Wouters (2003, 2007), the present paper uses the Kalman filter to evaluate the likelihood function for the system of log-linearized equilibrium conditions in terms of detrended variables, and applies the Metropolis–Hastings algorithm to generate 200,000 draws from the posterior distribution of model parameters. Based on the second half of the draws, our empirical analysis is conducted.[12]

3.2 The data

The data on EA and US consumption-good prices P_t, P_t^* are the Harmonised Index of Consumer Prices (HICP) and the Personal Consumption Expenditures (PCE) price index. The data on the real exchange rate e_t is then obtained from $e_t = e_t^n P_t^* / P_t$, where the data on the nominal exchange rate e_t^n is the Euro per USD exchange rate in the 10th update of the Area-Wide Model (AWM) database.[13] The other 18 time series are the same as those in Christiano, Motto, and Rostagno (2010), except that (i) the US series of consumption and investment are PCE and Fixed Private Investment (FPI) as used in Ireland (2013); and (ii) the EA and US investment-good prices and the EA and US nominal series of consumption, wages, loans, and net worth are deflated with the

[11] It is well known that steady-state portfolio choices are indeterminate. As explained in Devereux and Sutherland (2011), the second-order approximation of equilibrium conditions for asset pricing, together with the first-order approximation of other equilibrium conditions, is required to compute optimal steady-state portfolio choices. Applying such techniques in our estimation is beyond the scope of the present paper. Our paper infers steady-state portfolio choices from the data.

[12] Our estimation is done using DYNARE (Adjemian et al., 2011). The scale factor for the jumping distribution in the Metropolis–Hastings algorithm was adjusted so that an acceptance rate of around 24% was obtained.

[13] For details of the AWM database, see Fagan, Henry, and Mestre (2001).

HICP and the PCE price index to obtain their relative prices and their real series.[14] The sample period is from 1985:1Q to 2009:4Q. The end of the sample period is set to be 2009:4Q because this paper aims to investigate the business cycle implications of the IFM mechanism during the period including the Great Recession of 2007–09 and because the effect of the nonlinearity of the model stemming from zero lower bounds on monetary policy rates on the estimation strategy employed here is considered not to be severe so long as the sample period ends in 2009:4Q. The corresponding observation equations are

$$\begin{bmatrix} 100\Delta\log Y_t \\ 100\Delta\log C_t \\ 100\Delta\log I_t \\ 100\log h_t \\ 100\Delta\log W_t \\ 100\Delta\log P_t \\ 100\Delta\log(P_{i,t}/P_t) \\ 100\log r_t \\ 100\Delta\log L_t \\ 100\Delta\log N_t \\ 100\Delta\log Y_t^* \\ 100\Delta\log C_t^* \\ 100\Delta\log I_t^* \\ 100\log h_t^* \\ 100\Delta\log W_t^* \\ 100\Delta\log P_t^* \\ 100\Delta\log(P_{i,t}^*/P_t^*) \\ 100\log r_t^* \\ 100\Delta\log L_t^* \\ 100\Delta\log N_t^* \\ 100\Delta\log e_t \end{bmatrix} = \begin{bmatrix} \bar{z} \\ \bar{z} \\ \bar{z}+\bar{\psi} \\ \bar{h} \\ \bar{z} \\ \bar{\pi} \\ -\bar{\psi} \\ \bar{r} \\ \bar{z} \\ \bar{z} \\ \bar{z} \\ \bar{z} \\ \bar{z}+\bar{\psi} \\ \bar{h}^* \\ \bar{z} \\ \bar{\pi} \\ -\bar{\psi} \\ \bar{r} \\ \bar{z} \\ \bar{z} \\ 0 \end{bmatrix} + \begin{bmatrix} \hat{z}_t+\hat{y}_t-\hat{y}_{t-1} \\ \hat{z}_t+\hat{c}_t-\hat{c}_{t-1} \\ \hat{z}_t+\hat{\psi}_t+\hat{\imath}_t-\hat{\imath}_{t-1} \\ \hat{h}_t \\ \hat{z}_t+\hat{w}_t-\hat{w}_{t-1} \\ \hat{\pi}_t \\ -\hat{\psi}_t \\ \hat{r}_t \\ \hat{z}_t+\hat{l}_t-\hat{l}_{t-1} \\ \hat{z}_t+\hat{n}_t-\hat{n}_{t-1} \\ \hat{z}_t^*+\hat{y}_t^*-\hat{y}_{t-1}^* \\ \hat{z}_t^*+\hat{c}_t^*-\hat{c}_{t-1}^* \\ \hat{z}_t^*+\hat{\psi}_t^*+\hat{\imath}_t^*-\hat{\imath}_{t-1}^* \\ \hat{h}_t^* \\ \hat{z}_t^*+\hat{w}_t^*-\hat{w}_{t-1}^* \\ \hat{\pi}_t^* \\ -\hat{\psi}_t^* \\ \hat{r}_t^* \\ \hat{z}_t^*+\hat{l}_t^*-\hat{l}_{t-1}^* \\ \hat{z}_t^*+\hat{n}_t^*-\hat{n}_{t-1}^* \\ \hat{e}_t-\hat{e}_{t-1} \end{bmatrix},$$

[14] All the data on quantity variables are expressed in per-capita terms. As for the EA, the data on GDP, consumption, investment, the HICP, investment deflator, and wages come from the AWM database; the data on the monetary policy rate is the three-month Euribor; the net worth data is the Dow Jones EUROSTOXX; and the loan data is loans to the private sector. See Christiano, Motto, and Rostagno (2010) for details of the construction of the EA data on labor. As for the US, the data on GDP, consumption, investment, labor, the PCE price index, investment deflator, and wages come from the Bureau of Economic Analysis and the Bureau of Labor Statistics; the data on the monetary policy rate is the three-month average of the daily effective federal funds rate; the net worth data is the Dow Jones Wilshire 5000 index; and the loan data is credit market instruments liabilities of nonfarm nonfinancial corporate business plus credit market instruments liabilities of nonfarm noncorporate business in the US Flow of Funds Statistics.

where $\bar{z} = 100(z-1)$, $\bar{\psi} = 100(\psi-1)$, $\bar{\pi} = 100(\pi-1)$, $\bar{r} = 100(r-1)$, $\bar{h}$ and $\bar{h}^*$ are normalized to be equal to zero as in Smets and Wouters (2007), and hatted variables represent log-deviations from steady-state values.

3.3 Fixed parameters and prior distributions

Most of the model parameters are estimated, while some are fixed to avoid identification issues. The steady-state depreciation rate and the wage markup are chosen from Christiano, Motto, and Rostagno (2010) (i.e., EA: $\delta = 0.02$, $\lambda_w = 0.05$; US: $\delta^* = 0.025$, $\lambda_w^* = 0.05$). The price markup of intermediate goods and that of consumption goods at the steady state are set at 0.2 (i.e., $\lambda_x = \lambda_x^* = 0.2$; $x = H, F, c$). The share parameters ω, ω^* are chosen from Rabanal, Rubio-Ramírez, and Tuesta (2011) and Ireland (2013) (i.e., $\omega = \omega^* = 0.9$). The parameters regarding each intermediate-good firm's pricing are assumed to be the same across the two economies (i.e., $\xi_H = \xi_H^*$, $\gamma_H = \gamma_H^*$, $\xi_F^* = \xi_F$, $\gamma_F^* = \gamma_F$).

The prior distributions of parameters are shown in the third to fifth columns of Tables 1 and 2. Those of the steady-state rates of balanced growth, IS technological change, consumption price inflation, and monetary policy (i.e., $\bar{z}$, $\bar{\psi}$, $\bar{\pi}$, $\bar{r}$) are set to be the Gamma distributions with the standard deviation of 0.1 and the mean given by the EA–US sample mean of the rates of GDP growth, decline in the relative price of investment, consumption price inflation, and monetary policy, respectively. That of the steady-state EF premium (i.e., efp) is set to be the Gamma distribution with the standard deviation of 0.1 and the mean of 0.5 (i.e., 200bps. at an annualized rate), which is chosen in Bernanke, Gertler, and Gilchrist (1999). Those of the normalized steady-state labor $\bar{h}$, $\bar{h}^*$ are the same as the one in Smets and Wouters (2007). Those of the elasticity of cost of foreign bond holdings ϕ_e and the EA and US elasticities of substitution between EA and US intermediate goods θ, θ^* are the same as those in Rabanal and Tuesta (2010). Those of investors' steady-state portfolio shares of holdings of claims on domestic capital η, η^* are set to be the Beta distributions with the mean of 0.75 and the standard deviation of 0.1, taking into account a home bias. For the structural parameters that also appear in the model of Smets and Wouters (2007) (i.e., α, b, b^*, χ, χ^*, ζ, ζ^*, γ_w, γ_w^*, ξ_w, ξ_w^*, γ_H, ξ_H, γ_F^*, ξ_F^*, ϕ_r, ϕ_r^*, ϕ_π, ϕ_π^*, ϕ_y, ϕ_y^*, $\phi_{\Delta y}$, $\phi_{\Delta y}^*$), the same prior mean and the same prior standard deviations as theirs are used.[15] The prior distribution for the inverse of the elasticity of the adjustment cost of the capital utilization rate τ is set to be the Gamma distribution with the mean of 0.22 and the standard deviation of 0.1, based on Khan and Tsoukalas (2011). As for the parameters related to the financial accelerator mechanism, the prior distributions of the steady-state survival probability γ, γ^*, the steady-state liability share of net worth $n_l(= n/(n + l))$, $n_l^*(= n^*/(n^* + l^*))$, and the elasticity of the EF premium μ, μ^* are the same as those in Kaihatsu and Kurozumi (2013a). For the parameters of shocks, the present paper chooses the Beta distribution with the mean of 0.5 and the standard deviation of 0.2 for the persistence of each shock (i.e., ρ_e, ρ_x, ρ_x^*, $x \in \{b, g, h, c, r, a, \psi, \nu, \mu, \gamma\}$), the Gamma distribution with the mean of 0.2 and the standard deviation of 0.1 for the error correction in the process of each technological change (i.e., ρ_x, ρ_x^*, $x \in \{ad, \psi d\}$), and the Inverse Gamma distribution with the mean of 0.5 and the standard deviation of infinity for the standard deviation of each shock innovation (i.e., σ_e, σ_x, σ_x^*, $x \in \{b, g, h, c, r, a, \psi, \nu, \mu, \gamma\}$).

4 Results of the empirical analysis

This section presents the results of the empirical analysis. First, the estimates of model parameters are explained. Then, the implications of the IFM mechanism in the estimated model is examined using impulse responses to shocks to the EF premiums and net worth in the EA and the US. Last, variance and historical decompositions of EA and US business cycle fluctuations are analyzed.

[15] For the parameters χ, χ^*, ζ, ζ^*, ϕ_π, ϕ_π^*, ϕ_y, ϕ_y^*, $\phi_{\Delta y}$, and $\phi_{\Delta y}^*$, our study employs the Gamma distributions instead of the Normal distributions used in Smets and Wouters (2007), because these parameters are assumed to be positive.

4.1 Parameter estimates

Each parameter's posterior mean and 90% posterior interval are reported in the last two columns of Tables 1 and 2. We begin by comparing our estimates with Ireland (2013)'s. Our estimates of the EA and US elasticities of substitution between EA and US intermediate goods of $\theta = 0.425$ and $\theta^* = 0.810$ are smaller than his 1.571 but are comparable to Lubik and Schorfheide (2006)'s 0.43 and Rabanal Tuesta (2010)'s 0.94. As indicated by Ireland, this difference arises from the fact that his study estimates a real business cycle model using data on real variables, whereas the other three studies including ours estimate models with nominal rigidities using data on nominal as well as real variables. Regarding the persistence and error-correction parameters in the processes of neutral and IS technological changes, our estimates of the US processes of $\rho_a^* = 0.222$, $\rho_{ad}^* = 0.042$, $\rho_\psi^* = 0.627$, and $\rho_{\psi d}^* = 0.006$ are comparable to Ireland's $\rho_z^H = 0.175$, $\kappa_z^H = 0.002$, $\rho_\nu^H = 0.158$, and $\kappa_\nu^H = 0.009$, but those of the EA processes of $\rho_a = 0.366$, $\rho_{ad} = 0.039$, $\rho_\psi = 0.397$, and $\rho_{\psi d} = 0.004$ differ from his $\rho_z^F = 0.360$, $\kappa_z^F = 0.000$, $\rho_\nu^F = 0.983$, and $\kappa_\nu^F = 0.000$. This implies that in Ireland's estimated model neutral and IS technology shocks originating in the US diffuse to affect the other economy but those in the EA do not, whereas in our estimated model those originating in the EA diffuse to affect the other economy as well.

Regarding the IFM mechanism, three points are worth mentioning. First, both the EA and US estimates of investors' steady-state portfolio share of holdings of claims on domestic capital ($\eta = 0.821$, $\eta^* = 0.867$) are less than unity. This suggests that the IFM mechanism is effective in that each economy's investors hold claims on both domestic and foreign capital. Second, the EA estimate of the elasticity of the EF premium ($\mu = 0.035$) is much smaller than that in the US ($\mu^* = 0.150$). Last, the estimate of the elasticity of the foreign bond holding cost ($\phi_e = 0.004$) is close to zero. As shown in the following subsections, these parameter estimates yield a powerful propagation channel through which shocks affecting the EF premium in the EA are transmitted to the US and have a great impact on both EA and US business cycle fluctuations.

4.2 Empirical implications of the international finance multiplier mechanism

The estimates of model parameters have shown that the IFM mechanism is effective in that EA and US investors who search for the same expected marginal return on capital across the two economies hold claims on both domestic and foreign capital. This subsection investigates the implications of the IFM mechanism in the estimated model.

Combining the log-linearization of the real exchange rate equation (39), the home representative household's consumption Euler equation (2), and its foreign counterpart leads to the UIP condition with the premium $(-\phi_e \hat{d}_t + z_{e,t})$,

$$\hat{r}_t - E_t \hat{\pi}_{t+1} = \hat{r}_t^* - E_t \hat{\pi}_{t+1}^* + E_t \hat{e}_{t+1} - \hat{e}_t - \phi_e \hat{d}_t + z_{e,t}, \tag{40}$$

where we can see that $z_{e,t}$ acts as a UIP shock. Moreover, combining the log-linearization of the first-order conditions for home and foreign investors' optimal decisions on the purchase of capital (i.e., (10) and its foreign counterpart) yields the loan rate version of the UIP condition

$$\hat{r}_{l,t} - E_t \hat{\pi}_{t+1} = E_t \hat{x}_{t+1} = \hat{r}_{l,t}^* - E_t \hat{\pi}_{t+1}^* + E_t \hat{e}_{t+1} - \hat{e}_t. \tag{41}$$

These two UIP conditions (40) and (41) then imply

$$\widehat{efp}_t = \hat{r}_{l,t} - \hat{r}_t = \hat{r}_{l,t}^* - \hat{r}_t^* + \phi_e \hat{d}_t - z_{e,t} = \widehat{efp}_t^* + \phi_e \hat{d}_t - z_{e,t}, \tag{42}$$

which suggests that there is pressure for the equalization of the EF premiums across home and foreign economies as long as the premium on the UIP condition $(\phi_e \hat{d}_t - z_{e,t})$ is small.

As variations in the EF premium amplify investment and GDP growth fluctuations through the financial accelerator mechanism, a shock that affects the EF premium in one economy has an impact on the economy's investment and GDP growth and simultaneously has a similar effect on the other economy's investment and GDP growth through the IFM mechanism. That is, the equalization pressure for the EF premiums across the two economies can generate international comovement of investment and GDP growth.

To see the implications of the IFM mechanism in the estimated model, impulse responses to shocks to the EF premiums and net worth in the EA and the US are examined. Figure 1 illustrates how the EF premiums and the growth rates of investment and GDP respond to a positive one-standard-deviation innovation to the EF premium shocks in the EA and the US. This figure shows that the positive EF premium shock originating in the EA raises the EF premiums in both the EA and the US and dampens investment and GDP growth in these economies, whereas the one originating in the US generates negligible responses of the EF premiums and the growth rates of investment and GDP because such a positive shock to the US EF premium is offset by a decrease in US investors' total leverage ratio together with the relatively large estimate of the US elasticity of the EF premium with respect to the leverage ratio. As for the net worth shocks in the EA and the US, the impulse responses to a positive one-standard-deviation innovation to them are illustrated in Figure 2. The positive net worth shock originating in the EA lowers the EF premiums in both the EA and the US and boosts investment and GDP growth in the two economies, while the one originating in the US induces tiny responses of the EF premiums and the growth rates of investment and GDP, as is similar to the impulse responses to the EF premium shocks. These results thus demonstrate that through the IFM mechanism, shocks to the EF premium and net worth in the EA were transmitted to the US and had an impact on both the EA and US economies during the past quarter-century but those in the US had a negligible effect on them.

4.3 Variance decompositions

The impulse responses have shown that EA shocks to the EF premium and net worth were transmitted to the US through the IFM mechanism and had an impact on both the EA and US economies during the past quarter-century, whereas US ones had a negligible effect on them. This subsection examines to what extent these shocks contribute to EA and US business cycle fluctuations, using variance decompositions.

Table 3 reports the relative contribution of each shock to the variances of GDP growth ($\Delta \log Y_t, \Delta \log Y_t^*$), investment growth ($\Delta \log I_t, \Delta \log I_t^*$), consumption growth ($\Delta \log C_t, \Delta \log C_t^*$), and labor ($\log h_t, \log h_t^*$) in the EA and the US at the business cycle frequency of 8–32 quarters, evaluated at the posterior mean estimates of model parameters. As is consistent with the impulse responses illustrated above, the US EF premium shock e_μ^* and the US net worth shock e_γ^* made negligible relative contributions to EA and US business cycle fluctuations during the past quarter-century, while the EA EF premium shock e_μ and the EA net worth shock e_γ made considerable contributions to them. The EA EF premium and net worth shocks explain 13.6%, 69.7%, 3.3%, and 20.8% of the variances of GDP growth, investment growth, consumption growth, and labor in the EA during the past quarter-century and 5.3%, 15.6%, 0.4%, and 7.7% of the US counterparts.

Regarding the sources of EA business cycle fluctuations, their key drivers are the four shocks: the EA preference shock e_b, the EA monetary policy shock e_r, the EA neutral technology shock e_a, and the EA EF premium shock e_μ. The EA preference shock explains 22.2%, 0.2%, 60.8%, and 23.8% of the variances of GDP growth, investment growth, consumption growth, and labor in the EA during the past quarter-century; the EA monetary policy shock explains 21.7%, 16.3%, 15.0%, and 27.7% of them; the EA neutral technology shock explains 27.4%, 3.1%, 5.4%, and 12.6% of them; and the EA EF premium shock explains 12.7%, 65.2%, 3.1%, and 19.5% of them. Therefore, these four shocks account for most of the EA business cycle fluctuations during the past quarter-century. Then, as shown in Figure 3, the time series of the estimated rate of the EA neutral technological change has a strong negative correlation with that of the net tightening of credit standards by EA banks on loans to enterprises in the Euro Area Bank Lending Survey (the value of the correlation coefficient is -0.71). Thus, the EA neutral technology shock is likely to represent a disturbance to the functioning of the banking sector in the EA. In this respect, recent studies including Moll (2012) and Queralto (2013) indicate that a source of fluctuations in total factor productivity (TFP) growth (i.e., neutral technological change) is a financial friction that induces misallocation of capital or reduction of R&D investment.[16]

Regarding US business cycle fluctuations, their key sources are the five shocks: the US preference shock e_b^*, the US monetary policy shock e_r^*, the US neutral technology shock e_a^*, and the US MEI shock e_ν^*, in addition to the EA EF premium shock e_μ. The US preference shock explains 27.5%, 1.2%, 70.4%, and 28.0% of the variances of GDP growth, investment growth, consumption growth, and labor in the US during the past quarter-century; the US monetary policy shock explains 15.3%, 5.7%, 10.7%, and 18.9% of them; the US neutral technology shock explains 16.0%, 1.9%, 2.7%, and 12.6% of them; the US MEI shock explains 17.0%, 61.1%, 1.3%, and 14.0% of them; and the EA EF premium shock explains 5.0%, 14.6%, 0.4%, and 7.2% of them. Therefore, these five shocks account for most of the US business cycle fluctuations during the past quarter-century. Then, as shown in Figure 4, the time series of the estimated US MEI shock has a strong negative correlation with that of domestic respondents' tightening standards for C&I loans in the Senior Loan Officer Opinion Survey on Bank Lending Practices (the value of the correlation coefficient is -0.83). The US MEI shock is thus likely to represent a disturbance to the functioning of the banking sector in the US. In this

[16] As for Japan's "Great Stagnation" in the 1990s, Hayashi and Prescott (2002) argue that its main cause is a fall in TFP growth. Behind the background of the TFP slowdown, there is the so-called "evergreening" behavior of troubled Japanese banks of that time as pointed out by Peek and Rosengren (2005), who show that these banks had an incentive to allocate credit to severely impaired borrowers so as to avoid the realization of losses on their own balance sheets and this induced the misallocation of credit in the 1990s. For bank lending to insolvent borrowers called "zombies," see also Caballero, Hoshi, and Kashyap (2008). Kaihatsu and Kurozumi (2013b) estimate a closed-economy model with a financial accelerator mechanism using Japan's data and show that their estimated adverse neutral technology shock mainly induced Japan's Great Stagnation in the 1990s and that the time series of the estimated rate of Japan's neutral technological change has a strong correlation with that of all enterprises' financial position in the Tankan (i.e., the Short-term Economic Survey of Enterprises in Japan), thus concluding that the adverse neutral technology shock, which is likely to represent a tightening of firms' financing that induced misallocation of capital and reduction of R&D investment, caused the Great Stagnation.

respect, Justiniano, Primiceri, and Tambalotti (2010, 2011) estimate a closed-economy model with no financial frictions using US data and show that their estimated MEI shock is the main source of US business cycle fluctuations and that the shock is highly correlated with a credit spread and is thus likely to represent a disturbance to the intermediation ability of the US financial sector.

The above results demonstrate that during the past quarter-century, the EA shocks to the EF premium and net worth not only had a considerable effect on EA business cycle fluctuations together with the EA neutral technology shock, which is likely to represent a disturbance to the EA banking sector, but also were transmitted to the US through the IFM mechanism and had a great impact on US business cycle fluctuations together with the US MEI shock, which is likely to represent a disturbance to the US banking sector. This paper therefore concludes that financial factors are important sources of EA and US business cycle fluctuations.

4.4 Historical decompositions

The variance decompositions have shown that during the past quarter-century, the EA shocks to the EF premium and net worth not only had a considerable effect on EA business cycle fluctuations together with the EA neutral technology shock, but also were transmitted to the US through the IFM mechanism and had a great impact on US business cycle fluctuations together with the US MEI shock, whereas the US shocks to the EF premium and net worth made negligible relative contributions to EA and US business cycle fluctuations. In the present subsection, this result, particularly that for investment and GDP growth in the EA and the US, is investigated from a historical perspective.

First, the historical decompositions of EA investment and GDP growth are investigated. Figures 5 and 6 illustrate the contributions of the four main shocks–the EA preference shock, the EA monetary policy shock, the EA neutral technology shock, and the EA EF premium shock–to the EA investment and GDP growth rates in each period. These figures show, in line with the result of the variance decompositions, that the EA EF premium shock made a considerable contribution to fluctuations in EA investment growth and the EA neutral technology shock made a sizable contribution to fluctuations in EA GDP growth.

Next, the historical decompositions of US investment and GDP growth are examined. Figures 7 and 8 show the contributions of the five main shocks–the US preference shock, the US monetary policy shock, the US neutral technology shock, the US MEI shock, and the EA EF premium shock–to the US investment and GDP growth rates in each period. These figures demonstrate, in line with the result of the variance decompositions, that the US MEI shock and the EA EF premium shock–which was transmitted to the US through the IFM mechanism–made considerable contributions to fluctuations in US investment growth and had an impact on fluctuations in US GDP growth.

5 Concluding remarks

This paper has empirically investigated the implications of the IFM mechanism for business cycle fluctuations. To this end, the paper has developed a two-country model with the IFM mechanism by incorporating the financial accelerator mechanism of Bernanke, Gertler, and Gilchrist (1999) and the IFM mechanism modeled by Dedola and Lombardo (2012) in a variant of the two-country model of Ireland (2013). The model has been estimated using a Bayesian likelihood approach with 21 time series from the EA and the US. The estimation results have shown that during the past quarter-century, the EA shocks to the EF premium and net worth not only had a considerable effect on EA business cycle fluctuations together with the EA neutral technology shock, which is likely to represent a disturbance to the EA banking sector, but also were transmitted to the US through the IFM mechanism and had a great impact on US business cycle fluctuations together with the US MEI shock, which is likely to represent a disturbance to the US banking sector. This therefore demonstrates that financial factors are important sources of EA and US business cycle fluctuations over the past quarter-century.

Our paper has estimated investors' steady-state portfolio choices directly from the data. Devereux and Sutherland (2011) present a computational method for optimal steady-state portfolio choices. Thus, one direction of future research would be to introduce this computational method in the estimation of our model. More generally, another paper of theirs (Devereux and Sutherland, 2010) provides a computational method for the first-order approximation of optimal portfolio choices. Applying this method to our model and estimation would be of great interest.

Another research direction is found in recent studies, such as Hirakata, Sudo, and Ueda (2011) and Ueda (2012), which introduce the financial accelerator mechanism in both the demand and supply sides of loans (i.e., investors and banks). Thus, developing a two-country model with the IFM mechanism along the lines of these previous studies and estimating the model would be a fruitful extension of the present analysis. We will investigate these topics in future work.

References

[1] Adjemian, Stéphane, Houtan Bastani, Michel Juillard, Ferhat Mihoubi, George Perendia, Marco Ratto, and Sébastien Villemot, 2011. "Dynare: Reference Manual Version 4." CEPREMAP, Dynare Working Papers 1.

[2] Andolfatto, David, 1996. "Business Cycles and Labor-Market Search." American Economic Review, 86(1), 112–132.

[3] Bernanke, Ben S., Mark Gertler, and Simon Gilchrist, 1999. "The Financial Accelerator in a Quantitative Business Cycle Framework." In: John B. Taylor and Michael Woodford, eds., Handbook of Macroeconomics, Volume 1C, Elsevier Science, North-Holland, Amsterdam, pp. 1341–1393.

[4] Caballero, Ricardo J., Takeo Hoshi, and Anil K Kashyap, 2008. "Zombie Lending and Depressed Restructuring in Japan." American Economic Review, 98(5), 1943–1977.

[5] Calvo, Guillermo A., 1983. "Staggered Prices in a Utility-Maximizing Framework." Journal of Monetary Economics, 12(3), 383–398.

[6] Calvo, Guillermo A., 2000. "Capital Market Contagion and Recession: An Explanation of the Russian Virus." In: Eduardo Fernández-Arias and Ricardo Hausmann, eds., Wanted: World Financial Stability, Johns Hopkins University Press, Baltimore, pp. 49–52.

[7] Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans, 2005. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." Journal of Political Economy, 113(1), 1–45.

[8] Christiano, Lawrence J., Roberto Motto, and Massimo V. Rostagno, 2010. "Financial Factors in Economic Fluctuations." European Central Bank, ECB Working Paper 1192.

[9] Dedola, Luca, and Giovanni Lombardo, 2012. "Financial Frictions, Financial Integration and the International Propagation of Shocks." Economic Policy, 27(70), 319–359.

[10] Devereux, Michael B., and Alan J. Sutherland, 2010. "Country Portfolio Dynamics." Journal of Economic Dynamics and Control, 34(7), 1325–1342.

[11] Devereux, Michael B., and Alan J. Sutherland, 2011. "Country Portfolios in Open Economy Macro Models." Journal of the European Economic Association, 9(2), 337–369.

[12] Devereux, Michael B., and James Yetman, 2010. "Leverage Constraints and the International Transmission of Shocks." Journal of Money, Credit and Banking, 42(6 Supplement), 71–105.

[13] Fagan, Gabriel, Jerome Henry, and Ricardo Mestre, 2001. "An Area-Wide Model (AWM) for the Euro Area." European Central Bank, ECB Working Paper 42.

[14] Faia, Ester, 2007. "Finance and International Business Cycles." Journal of Monetary Economics, 54(4), 1018–1034.

[15] Gertler, Mark, Simon Gilchrist, and Fabio M. Natalucci, 2007. "External Constraints on Monetary Policy." Journal of Money, Credit and Banking, 39(2-3), 295–330.

[16] Gilchrist, Simon, 2004. "Financial Markets and Financial Leverage in a Two-Country World Economy." In: Luis Antonio Ahumada and J. Rodrigo Fuentes,

eds., Banking Market Structure and Monetary Policy, Central Bank of Chile, pp. 27–57.

[17] Greenwood, Jeremy, Zvi Hercowitz, and Gregory W. Huffman, 1988. "Investment, Capacity Utilization, and the Real Business Cycle." American Economic Review, 78(3), 402–417.

[18] Greenwood, Jeremy, Zvi Hercowitz, and Per Krusell, 1997. "Long-Run Implications of Investment-Specific Technological Change." American Economic Review, 87(3), 342–362.

[19] Hayashi, Fumio, and Edward Prescott, 2002. "The 1990s in Japan: The Lost Decade." Review of Economic Dynamics, 5(1), 206–235.

[20] Hirakata, Naohisa, Nao Sudo, and Kozo Ueda, 2011. "Do Banking Shocks Matter for the U.S. Economy?" Journal of Economic Dynamics and Control, 35(12), 2042–2063.

[21] Hirose, Yasuo, 2013. "Monetary Policy and Sunspot Fluctuations in the United States and the Euro Area." Macroeconomic Dynamics, 17(1), 1–28.

[22] Ireland, Peter N., 2013. "Stochastic Growth in the United States and Euro Area." Journal of the European Economic Association, 11(1), 1–24.

[23] Justiniano, Alejandro, Giorgio E. Primiceri, and Andrea Tambalotti, 2010. "Investment Shocks and Business Cycles." Journal of Monetary Economics, 57(2), 132–145.

[24] Justiniano, Alejandro, Giorgio E. Primiceri, and Andrea Tambalotti, 2011. "Investment Shocks and the Relative Price of Investment." Review of Economic Dynamics, 14(1), 102–121.

[25] Kaihatsu, Sohei, and Takushi Kurozumi, 2013a. "Sources of Business Fluctuations: Financial or Technology Shocks?" Review of Economic Dynamics, forthcoming.

[26] Kaihatsu, Sohei, and Takushi Kurozumi, 2013b. "What Caused Japan's Great Stagnation in the 1990s?" Mimeo.

[27] Khan, Hashmat, and John Tsoukalas, 2011. "Investment Shocks and the Comovement Problem." Journal of Economic Dynamics and Control, 35(1), 115–130.

[28] Kiyotaki, Nobuhiro, and John Moore, 1997. "Credit Cycles." Journal of Political Economy, 105(2), 211–248.

[29] Kollmann, Robert, 2013. "Global Banks, Financial Shocks and International Business Cycles: Evidence from an Estimated Model." Journal of Money, Credit and Banking, forthcoming.

[30] Kollmann, Robert, Zeno Enders, and Gernot J. Müller, 2011. "Global Banking and International Business Cycles." European Economic Review, 55(3), 407–426.

[31] Krugman, Paul, 2008. "The International Finance Multiplier." Mimeo.

[32] Lubik, Thomas, and Frank Schorfheide, 2006. "A Bayesian Look at New Open Economy Macroeconomics." In: Mark Gertler and Kenneth Rogoff, eds., NBER Macroeconomics Annual 2005, Volume 20, The MIT Press, Cambridge, MA, pp. 313–366.

[33] Merz, Monika, 1995. "Search in the Labor Market and the Real Business Cycle." Journal of Monetary Economics, 36(2), 269–300.

[34] Moll, Benjamin, 2012. "Productivity Losses from Financial Frictions: Can Self-Financing Undo Capital Misallocation?" Mimeo.

[35] Queralto, Albert, 2013. "A Model of Slow Recoveries from Financial Crises." Mimeo.

[36] Peek, Joe, and Eric S. Rosengren, 2005. "Unnatural Selection: Perverse Incentives and the Misallocation of Credit in Japan." American Economic Review, 95(4), 1144–1166.

[37] Perri, Fabrizio, and Vincenzo Quadrini, 2011. "International Recessions." Institute for Monetary and Economic Studies, Bank of Japan, IMES Discussion Paper Series 2011-E-26.

[38] Rabanal, Pau, Juan F. Rubio-Ramírez, and Vicente Tuesta, 2011. "Cointegrated TFP Process and International Business Cycles." Journal of Monetary Economics, 58(1), 156–171.

[39] Rabanal, Pau, and Vicente Tuesta, 2010. "Euro-Dollar Real Exchange Rate Dynamics in an Estimated Two-Country Model: An Assessment." Journal of Economic Dynamics and Control, 34(4), 780–797.

[40] Robinson, Romney, 1952. "A Graphical Analysis of the Foreign Trade Multiplier." Economic Journal, 62(247), 546–564.

[41] Schmitt-Grohé, Stephanie, and Martin Uribe, 2003. "Closing Small Open Economy Models." Journal of International Economics, 61(1), 163–185.

[42] Smets, Frank, and Raf Wouters, 2003. "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area." Journal of the European Economic Association, 1(5), 1123–1175.

[43] Smets, Frank, and Raf Wouters, 2007. "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach." American Economic Review, 97(3), 586–606.

[44] Taylor, John B., 1993. "Discretion Versus Policy Rules in Practice." Carnegie-Rochester Conference Series on Public Policy, 39(1), 195–214.

[45] Ueda, Kozo, 2012. "Banking Globalization and International Business Cycles." Journal of International Economics, 86(1), 1–16.

Table 1: Prior and posterior distributions of structural parameters.

Parameter		Prior			Posterior	
		Type	Mean	S.D.	Mean	90% interval
ϕ_e	Elasticity of foreign bond holding cost	G	0.020	0.014	0.004	[0.001, 0.007]
α	Capital elasticity of output	B	0.300	0.050	0.255	[0.242, 0.267]
$\bar{z}$	Steady-state rate of balanced growth	G	0.410	0.100	0.290	[0.261, 0.319]
$\bar{\psi}$	Steady-state rate of IS technological change	G	0.160	0.100	0.065	[0.026, 0.107]
$\bar{\pi}$	Steady-state consumption price inflation rate	G	0.620	0.100	0.665	[0.612, 0.720]
$\bar{r}$	Steady-state monetary policy rate	G	1.330	0.100	1.179	[1.138, 1.227]
efp	Steady-state EF premium	G	0.500	0.100	0.368	[0.328, 0.406]
η	EA steady-state portfolio share of domestic capital	B	0.750	0.100	0.821	[0.798, 0.846]
b	EA habit persistence	B	0.700	0.100	0.744	[0.712, 0.782]
χ	EA inverse elasticity of labor supply	G	2.000	0.750	4.206	[3.802, 4.637]
ζ	EA elasticity of investment adjustment cost	G	4.000	1.500	4.182	[3.442, 4.716]
τ	EA inverse elasticity of utilization adjustment cost	G	0.220	0.100	0.097	[0.057, 0.135]
γ_w	EA wage indexation	B	0.500	0.150	0.458	[0.361, 0.566]
ξ_w	EA wage stickiness	B	0.500	0.100	0.678	[0.615, 0.728]
γ_H	EA intermediate-good price indexation	B	0.500	0.150	0.174	[0.090, 0.246]
ξ_H	EA intermediate-good price stickiness	B	0.500	0.100	0.926	[0.907, 0.944]
θ	EA substitution elasticity of intermediate goods	G	1.500	0.250	0.425	[0.409, 0.445]
ϕ_r	EA monetary policy rate smoothing	B	0.750	0.100	0.726	[0.688, 0.764]
ϕ_π	EA monetary policy response to inflation	G	1.500	0.250	2.026	[1.956, 2.112]
ϕ_y	EA monetary policy response to GDP	G	0.125	0.050	0.030	[0.018, 0.041]
$\phi_{\Delta y}$	EA monetary policy response to GDP growth	G	0.125	0.050	0.160	[0.144, 0.176]
$\bar{h}$	EA normalized steady-state labor	N	0.000	2.000	-0.006	[-1.673, 1.670]
μ	EA elasticity of EF premium	G	0.070	0.020	0.035	[0.027, 0.044]
γ	EA investor survival probability	B	0.973	0.020	0.959	[0.950, 0.965]
n_l	EA steady-state liability share of net worth	B	0.500	0.070	0.482	[0.442, 0.526]
η^*	US steady-state portfolio share of domestic capital	B	0.750	0.100	0.867	[0.805, 0.934]
b^*	US habit persistence	B	0.700	0.100	0.866	[0.827, 0.895]
χ^*	US inverse elasticity of labor supply	G	2.000	0.750	0.811	[0.368, 1.204]
ζ^*	US elasticity of investment adjustment cost	G	4.000	1.500	7.843	[7.313, 8.450]
τ^*	US inverse elasticity of utilization adjustment cost	G	0.220	0.100	0.083	[0.035, 0.131]
γ_w^*	US wage indexation	B	0.500	0.150	0.435	[0.376, 0.487]
ξ_w^*	US wage stickiness	B	0.500	0.100	0.756	[0.720, 0.796]
γ_F^*	US intermediate-good price indexation	B	0.500	0.150	0.406	[0.338, 0.481]
ξ_F^*	US intermediate-good price stickiness	B	0.500	0.100	0.861	[0.820, 0.896]
θ^*	US substitution elasticity of intermediate goods	G	1.500	0.250	0.810	[0.749, 0.871]
ϕ_r^*	US monetary policy rate smoothing	B	0.750	0.100	0.834	[0.797, 0.870]
ϕ_π^*	US monetary policy response to inflation	G	1.500	0.250	1.308	[1.231, 1.378]
ϕ_y^*	US monetary policy response to GDP	G	0.125	0.050	0.056	[0.037, 0.076]
$\phi_{\Delta y}^*$	US monetary policy response to GDP growth	G	0.125	0.050	0.060	[0.039, 0.075]
$\bar{h}^*$	US normalized steady-state labor	N	0.000	2.000	-0.440	[-1.522, 0.707]
μ^*	US elasticity of EF premium	G	0.070	0.020	0.150	[0.141, 0.165]
γ^*	US investor survival probability	B	0.973	0.020	0.947	[0.936, 0.958]
n_l^*	US steady-state liability share of net worth	B	0.500	0.070	0.562	[0.523, 0.601]

Note: Regarding the type of prior distributions, B, G, IG, and N stand for Beta, Gamma, Inverse Gamma, and Normal distributions, respectively.

Table 2: Prior and posterior distributions of shock parameters.

Parameter		Prior			Posterior	
		Type	Mean	S.D.	Mean	90% interval
ρ_e	UIP shock persistence	B	0.500	0.200	0.990	[0.985, 0.994]
ρ_b	EA preference shock persistence	B	0.500	0.200	0.788	[0.703, 0.867]
ρ_g	EA exogenous demand shock persistence	B	0.500	0.200	0.985	[0.973, 0.997]
ρ_h	EA labor shock persistence	B	0.500	0.200	0.241	[0.172, 0.312]
ρ_c	EA consumption price markup shock persistence	B	0.500	0.200	0.927	[0.885, 0.970]
ρ_r	EA monetary policy shock persistence	B	0.500	0.200	0.567	[0.493, 0.642]
ρ_a	EA neutral technology shock persistence	B	0.500	0.200	0.366	[0.219, 0.544]
ρ_{ad}	EA neutral technological change error-correction	G	0.200	0.100	0.039	[0.016, 0.064]
ρ_ψ	EA IS technology shock persistence	B	0.500	0.200	0.397	[0.331, 0.461]
$\rho_{\psi d}$	EA IS technological change error-correction	G	0.200	0.100	0.004	[0.001, 0.007]
ρ_ν	EA MEI shock persistence	B	0.500	0.200	0.998	[0.997, 1.000]
ρ_μ	EA EF premium shock persistence	B	0.500	0.200	0.964	[0.948, 0.981]
ρ_γ	EA net worth shock persistence	B	0.500	0.200	0.584	[0.510, 0.663]
ρ_b^*	US preference shock persistence	B	0.500	0.200	0.894	[0.856, 0.932]
ρ_g^*	US exogenous demand shock persistence	B	0.500	0.200	0.937	[0.898, 0.978]
ρ_h^*	US labor shock persistence	B	0.500	0.200	0.331	[0.218, 0.469]
ρ_c^*	US consumption price markup shock persistence	B	0.500	0.200	0.995	[0.991, 0.999]
ρ_r^*	US monetary policy shock persistence	B	0.500	0.200	0.679	[0.577, 0.775]
ρ_a^*	US neutral technology shock persistence	B	0.500	0.200	0.222	[0.138, 0.297]
ρ_{ad}^*	US neutral technological change error-correction	G	0.200	0.100	0.042	[0.020, 0.063]
ρ_ψ^*	US IS technology shock persistence	B	0.500	0.200	0.627	[0.528, 0.739]
$\rho_{\psi d}^*$	US IS technological change error-correction	G	0.200	0.100	0.006	[0.002, 0.010]
ρ_ν^*	US MEI shock persistence	B	0.500	0.200	0.897	[0.869, 0.925]
ρ_μ^*	US EF premium shock persistence	B	0.500	0.200	0.895	[0.840, 0.950]
ρ_γ^*	US net worth shock persistence	B	0.500	0.200	0.070	[0.015, 0.123]
σ_e	UIP shock innovation S.D.	IG	0.500	Inf	0.117	[0.090, 0.142]
σ_b	EA preference shock innovation S.D.	IG	0.500	Inf	2.323	[1.952, 2.703]
σ_g	EA exogenous demand shock innovation S.D.	IG	0.500	Inf	0.268	[0.236, 0.301]
σ_h	EA labor shock innovation S.D.	IG	0.500	Inf	0.422	[0.368, 0.478]
σ_c	EA consumption price markup shock innovation S.D.	IG	0.500	Inf	0.285	[0.249, 0.318]
σ_r	EA monetary policy shock innovation S.D.	IG	0.500	Inf	0.135	[0.118, 0.152]
σ_a	EA neutral technology shock innovation S.D.	IG	0.500	Inf	0.678	[0.591, 0.762]
σ_ψ	EA IS technology shock innovation S.D.	IG	0.500	Inf	0.306	[0.270, 0.341]
σ_ν	EA MEI shock innovation S.D.	IG	0.500	Inf	5.009	[4.424, 5.580]
σ_μ	EA EF premium shock innovation S.D.	IG	0.500	Inf	0.172	[0.139, 0.202]
σ_γ	EA net worth shock innovation S.D.	IG	0.500	Inf	0.543	[0.427, 0.651]
σ_b^*	US preference shock innovation S.D.	IG	0.500	Inf	4.917	[3.410, 6.072]
σ_g^*	US exogenous demand shock innovation S.D.	IG	0.500	Inf	0.397	[0.348, 0.441]
σ_h^*	US labor shock innovation S.D.	IG	0.500	Inf	0.520	[0.433, 0.600]
σ_c^*	US consumption price markup shock innovation S.D.	IG	0.500	Inf	0.363	[0.317, 0.406]
σ_r^*	US monetary policy shock innovation S.D.	IG	0.500	Inf	0.100	[0.088, 0.112]
σ_a^*	US neutral technology shock innovation S.D.	IG	0.500	Inf	0.775	[0.682, 0.874]
σ_ψ^*	US IS technology shock innovation S.D.	IG	0.500	Inf	0.515	[0.454, 0.575]
σ_ν^*	US MEI shock innovation S.D.	IG	0.500	Inf	5.369	[4.811, 5.897]
σ_μ^*	US EF premium shock innovation S.D.	IG	0.500	Inf	0.616	[0.536, 0.688]
σ_γ^*	US net worth shock innovation S.D.	IG	0.500	Inf	10.574	[9.664, 11.587]

Note: Regarding the type of prior distributions, B, G, IG, and N stand for Beta, Gamma, Inverse Gamma, and Normal distributions, respectively.

Table 3: Variance decomposition.

Shock		$\Delta \log Y_t$	$\Delta \log Y_t^*$	$\Delta \log I_t$	$\Delta \log I_t^*$	$\Delta \log C_t$	$\Delta \log C_t^*$	$\log h_t$	$\log h_t^*$
e_e	UIP	0.5	1.7	0.1	4.8	4.1	8.9	0.8	2.3
e_b	EA preference	22.2	0.4	0.2	0.0	60.8	0.0	23.8	0.3
e_g	EA exogenous demand	3.7	0.1	0.0	0.0	2.7	0.0	2.8	0.0
e_h	EA labor	1.5	0.0	0.3	0.0	1.9	0.0	2.8	0.0
e_c	EA consumption price markup	6.0	0.1	3.6	0.0	5.0	0.0	7.2	0.1
e_r	EA monetary policy	21.7	0.4	16.3	0.1	15.0	0.0	27.7	0.5
e_a	EA neutral technology	27.4	1.5	3.1	0.1	5.4	0.5	12.6	0.5
e_ψ	EA IS technology	0.1	0.0	0.7	0.1	0.2	0.0	0.1	0.0
e_ν	EA MEI	2.0	0.4	4.6	3.3	0.1	3.3	0.9	0.5
e_μ	EA EF premium	12.7	5.0	65.2	14.6	3.1	0.4	19.5	7.2
e_γ	EA net worth	0.9	0.3	4.5	1.0	0.2	0.0	1.3	0.5
e_b^*	US preference	0.0	27.5	0.0	1.2	0.4	70.4	0.0	28.0
e_g^*	US exogenous demand	0.0	8.8	0.0	0.0	0.0	0.3	0.0	6.3
e_h^*	US labor	0.0	2.5	0.0	0.6	0.1	0.9	0.0	4.1
e_c^*	US consumption price markup	0.0	1.6	0.0	0.8	0.0	0.5	0.0	2.0
e_r^*	US monetary policy	0.0	15.3	0.0	5.7	0.0	10.7	0.0	18.9
e_a^*	US neutral technology	1.1	16.0	0.1	1.9	0.8	2.7	0.1	12.6
e_ψ^*	US IS technology	0.1	1.6	0.4	4.6	0.0	0.0	0.2	2.2
e_ν^*	US MEI	0.0	17.0	0.7	61.1	0.2	1.3	0.0	14.0
e_μ^*	US EF premium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
e_γ^*	US net worth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: This table shows the variance decomposition of EA and US GDP growth ($\Delta \log Y_t$, $\Delta \log Y_t^*$), EA and US investment growth ($\Delta \log I_t$, $\Delta \log I_t^*$), EA and US consumption growth ($\Delta \log C_t$, $\Delta \log C_t^*$), and EA and US labor ($\log h_t$, $\log h_t^*$) corresponding to periodic components with frequency between 8 and 32 quarters, evaluated at the posterior mean estimates of parameters.

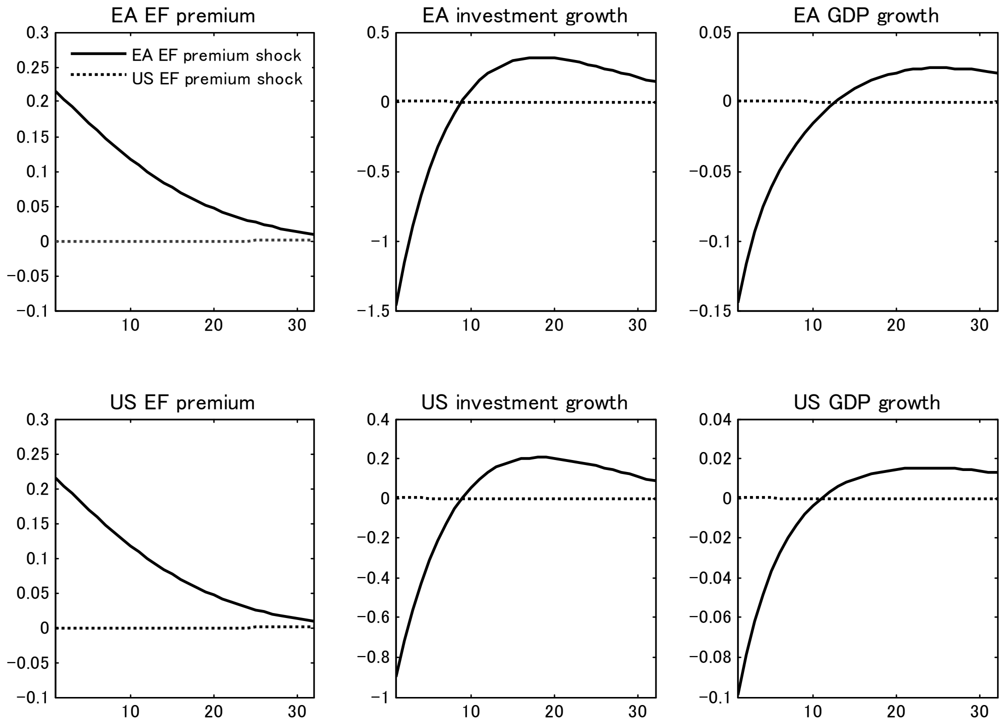

Figure 1: Impulse responses to the external finance premium shocks in the Euro Area and the United States.

Note: The figure shows the impulse responses to a positive one-standard-deviation innovation to the EF premium shocks in the EA and the US, based on the posterior mean estimates of parameters.

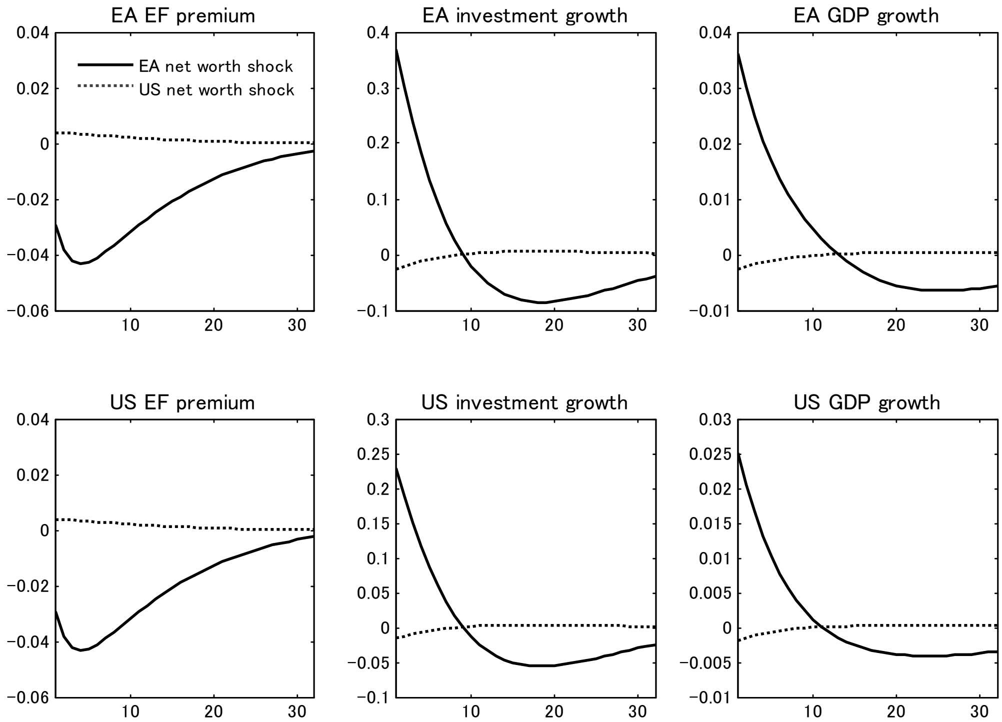

Figure 2: Impulse responses to the net worth shocks in the Euro Area and the United States.

Note: The figure shows the impulse responses to a positive one-standard-deviation innovation to the net worth shocks in the EA and the US, based on the posterior mean estimates of parameters.

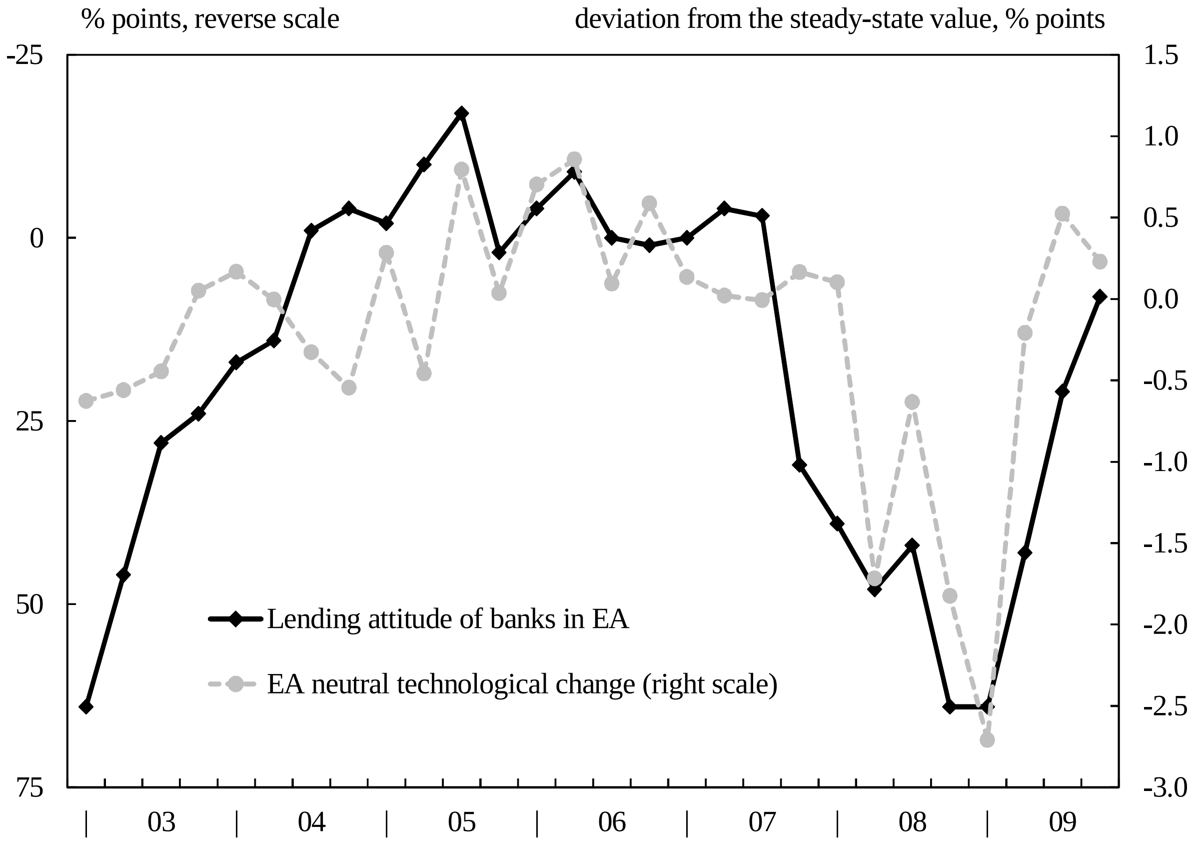

Figure 3: The estimated rate of neutral technological change and the lending attitude of banks in the Euro Area.

Note: The figure shows the time series of the estimated rate of EA neutral technological change and the net tightening of credit standards for loans to enterprises in the Euro Area Bank Lending Survey by the European Central Bank.

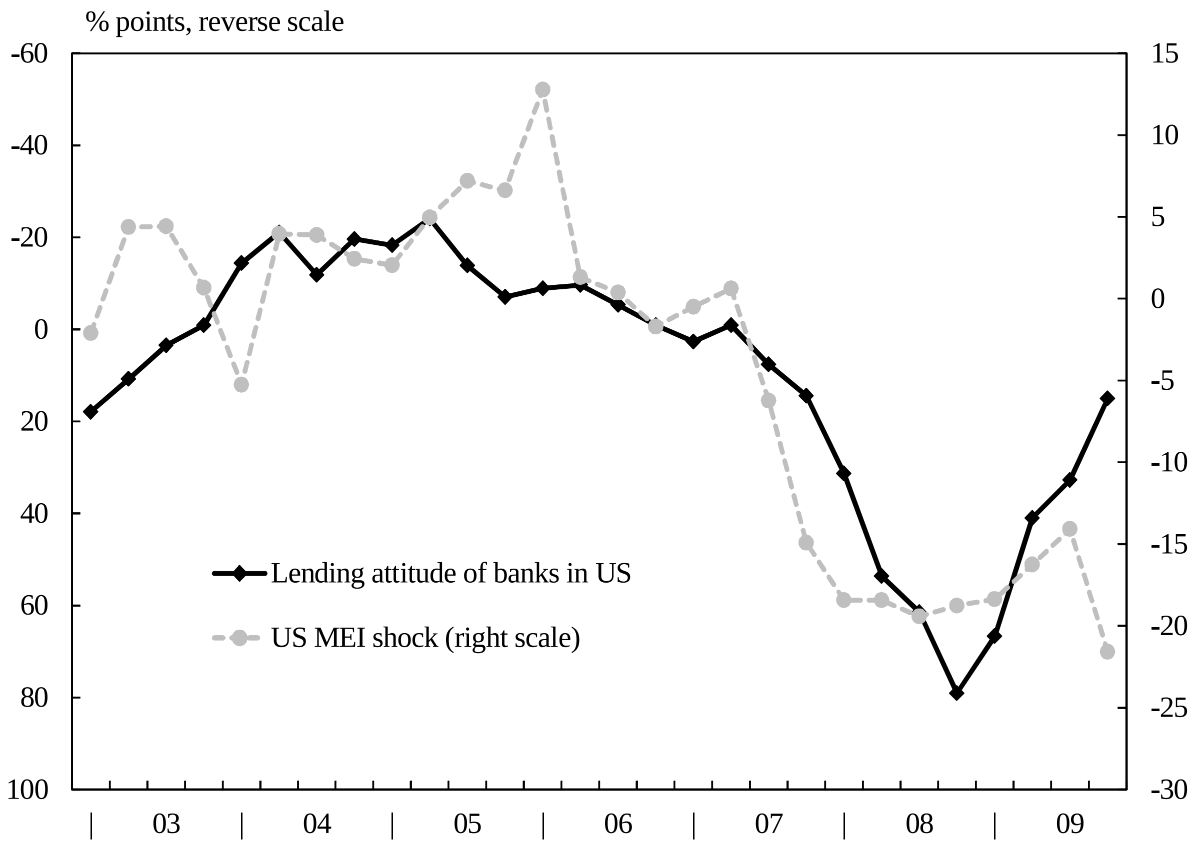

Figure 4: The estimated marginal efficiency of investment (MEI) shock and the lending attitude of banks in the United States.

Note: The figure shows the time series of the estimated US MEI shock and domestic respondents' tightening standards for C&I loans in the Senior Loan Officer Opinion Survey on Bank Lending Practices by the Board of Governors of the Federal Reserve System.

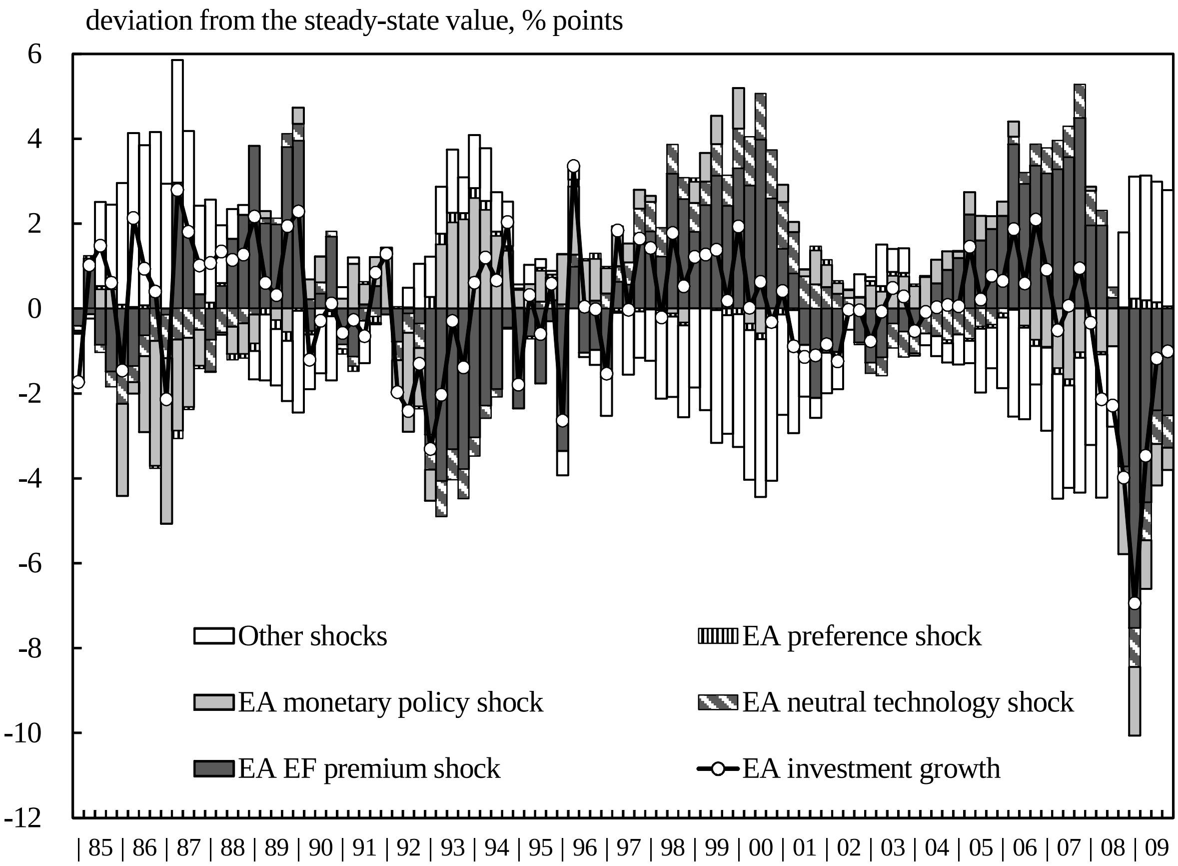

Figure 5: Historical decomposition of the investment growth rate in the Euro Area.

Note: This figure shows the historical decomposition of the EA investment growth rate, based on the posterior mean estimates of parameters and the Kalman smoothed mean estimates of shocks.

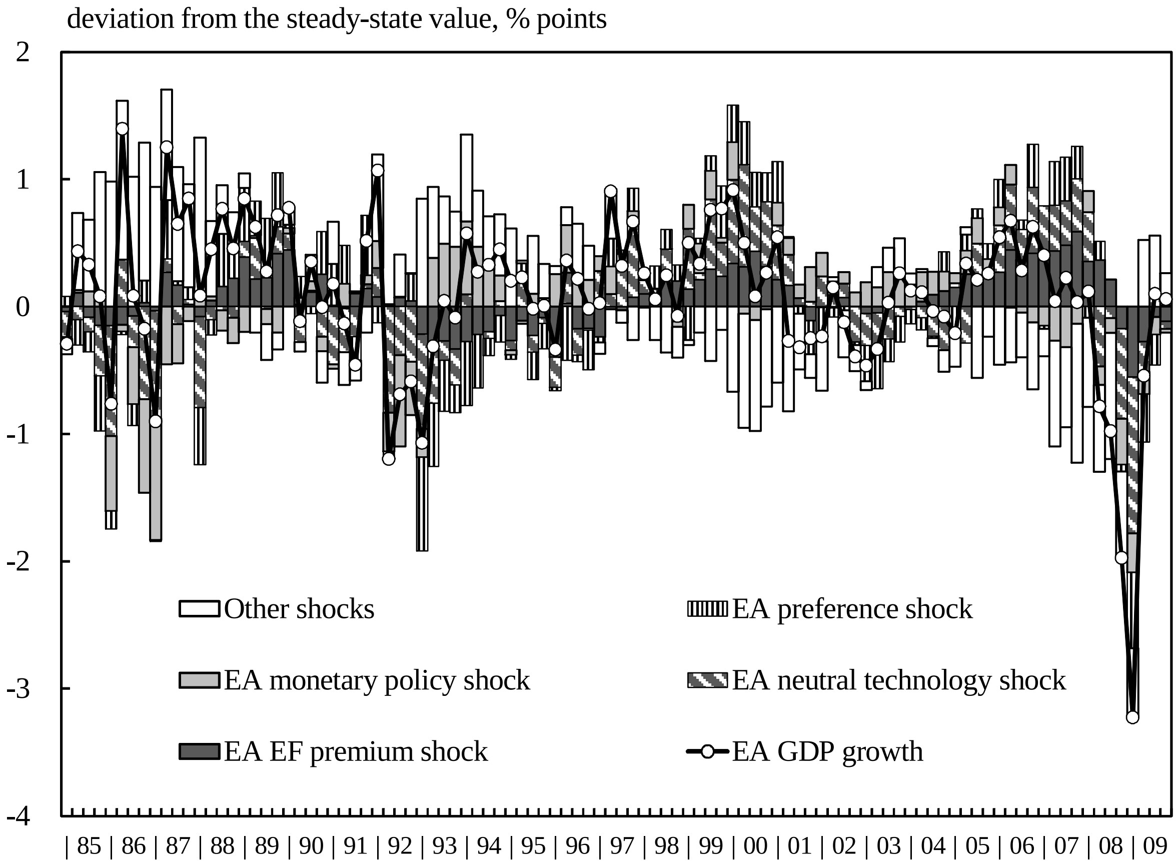

Figure 6: Historical decomposition of the GDP growth rate in the Euro Area.

Note: This figure shows the historical decomposition of the EA GDP growth rate, based on the posterior mean estimates of parameters and the Kalman smoothed mean estimates of shocks.

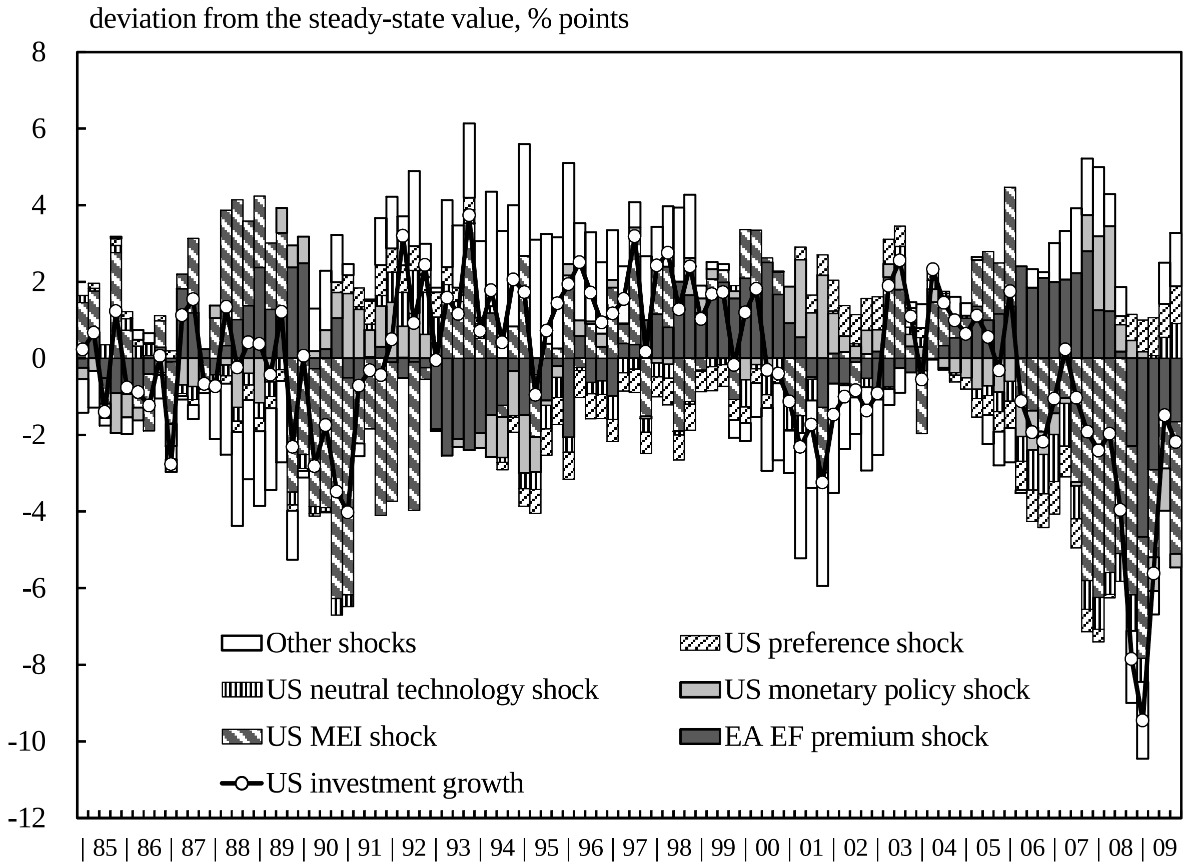

Figure 7: Historical decomposition of the investment growth rate in the United States.

Note: This figure shows the historical decomposition of the US investment growth rate, based on the posterior mean estimates of parameters and the Kalman smoothed mean estimates of shocks.

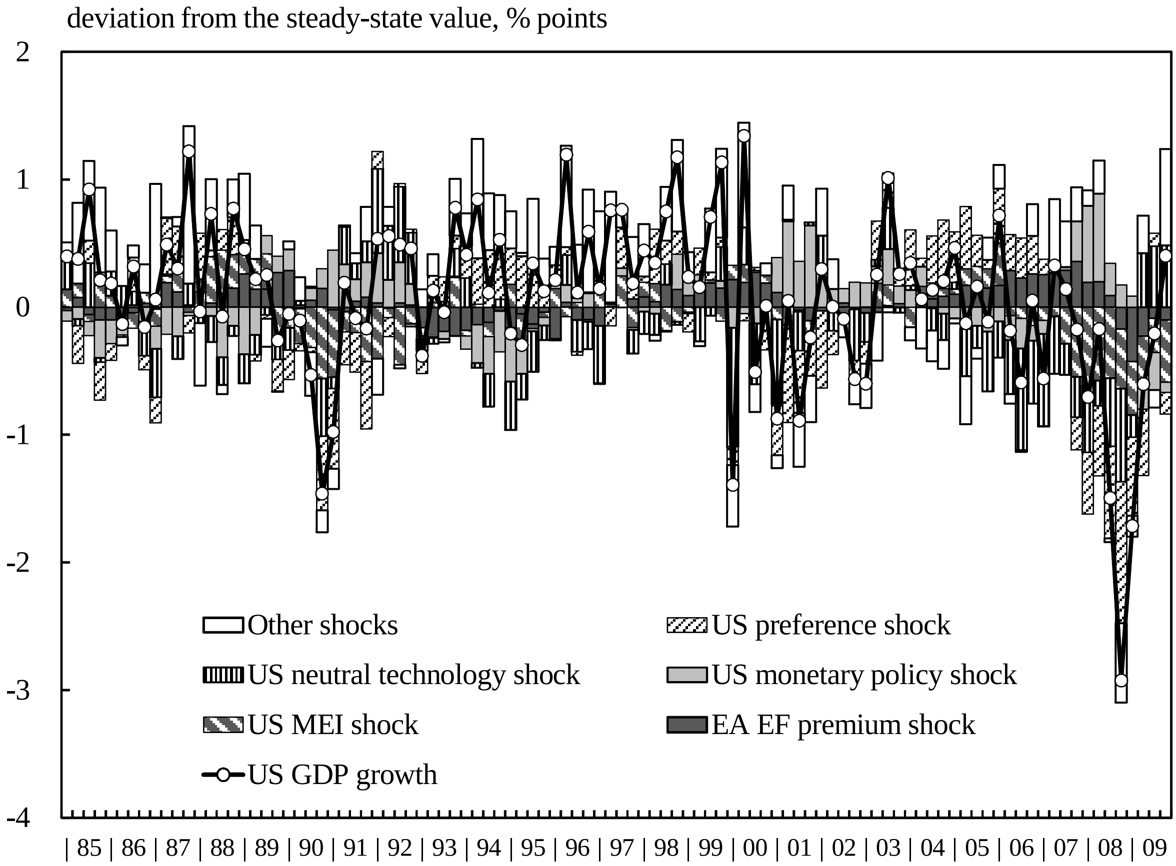

Figure 8: Historical decomposition of the GDP growth rate in the United States.

Note: This figure shows the historical decomposition of the US GDP growth rate, based on the posterior mean estimates of parameters and the Kalman smoothed mean estimates of shocks.