Dissecting the dynamics of the US trade balance in an estimated equilibrium model[☆]

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ABSTRACT

In an estimated two-country DSGE model, we find that shocks to the marginal efficiency of investment account for more than half of the forecast variance of cyclical fluctuations in the US trade balance. Both domestic and foreign marginal efficiency shocks generate a strong effect on the variability of the imbalance, through shifts in international relative absorption. On the other hand, shocks to uncovered interest parity and foreign export prices, which transmit mainly *via* the terms of trade and exchange rate, have a strong influence at short forecast-horizons, before the investment disturbances begin their dominance.

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1. Introduction

A vast literature in international macroeconomics has focused on the deterioration of the external position of the United States (US) and its consequences for the global economy.[1] This paper disentangles the stochastic influences on the US trade balance over the last three decades by estimating a two-country dynamic stochastic general equilibrium (DSGE) model with seventeen structural innovations using Bayesian methods. The model can be seen as a two-country version of the closed-economy models described in Smets and Wouters (2007) and Justiniano et al. (2011), where the second 'country' is a trade-weighted aggregate of sixteen OECD partners with whom the US has experienced deficits for a reasonably long span of time.

Several authors, examining different facets of the US external position using diverse methodologies, have identified a causal link between movements in US productivity and the external balance. The international real business cycle literature, *e.g.* Backus et al. (1994), Kollmann (1998) and Raffo (2008), explains counter-cyclical trade balance dynamics on the basis of neutral technology shocks in theoretical two-country DSGE models. More recently, Raffo (2010) has also appealed to investment-specific technological shocks. In the empirical literature, Bussière et al. (2010) find support for shifts in neutral productivity having a significantly negative impact on the US current account. Corsetti et al. (2006) report a negative association between productivity shocks in US manufacturing and US net-exports, while Corsetti and Konstantinou (2012) find that permanent supply shocks raise US consumption and lead to a persistent external deficit. Finally, Bems et al. (2007) find that neutral as well as investment-specific technological shocks generate a significant negative influence on the trade balance.

In line with the above literature, we find that technological shocks, both neutral and investment-specific, can generate counter-cyclical swings in the trade balance. However, their *relative* importance in generating trade balance dynamics is negligible. We find that disturbances

stimulating investment demand, which the empirical literature interprets as marginal efficiency of investment shocks, contribute more than half of the forecast volatility of the US trade balance. When we disaggregate the trade balance dynamics into movements in international relative absorption and prices, we observe that the critical determinant of the dominance of marginal efficiency shocks is their ability to generate strong movements in relative international absorption. In contrast, disturbances which transmit mainly *via* the international relative prices, in particular uncovered interest parity shocks and export-price mark-up shocks from the Rest of the World (RoW), are potent in the very short-run after impact, before the marginal efficiency shocks begin to dominate. Furthermore, we find a limited role for domestic and foreign wage mark-up, consumption time-impatience, US export mark-up, monetary and fiscal policy shocks.

This paper lies at the interface of several strands of the literature. First, our results that underscore the importance of marginal efficiency shocks for the US trade balance complement the findings of closed-economy studies that emphasize the relevance of these shocks for the overall US business cycle. For instance, Justiniano et al. (2011) find that marginal efficiency shocks are the most important drivers of US business cycle fluctuations in the post-war period. In fact, we even find a significant greater importance of domestic and foreign investment shocks for the external position of the US than for domestic GDP. This is not a surprise given that about three quarters of US non-fuel imports and exports are capital goods and consumer durables, which contrasts with an investment share in domestic GDP of about 20%, as documented by Erceg et al. (2008).[2] For this reason, we allow for the investment basket to be more import-intensive than consumption. When we employ the traditional specification seen in *e.g.* Backus et al. (1994), that allows imports to be dependent only on aggregate absorption, the reaction of the trade balance to investment shocks is more subdued.

Justiniano et al. (2011) observe that their estimate of the marginal efficiency disturbance is negatively correlated to data-based measures of the external finance premium and may, in reduced-form, reflect the efficiency of the latent financial intermediation sector in allocating credit. Our estimate of the marginal efficiency shock is also significantly negatively correlated with interest-rate spreads, both in the US and abroad, suggesting an important role of financial factors for trade balance dynamics.

The paper is also related to a number of macroeconometric studies that assess the driving forces of the US trade balance. Bems et al. (2007) find that monetary and fiscal shocks together with neutral and investment-specific technological shocks have had a negative influence on the trade balance, but they focus solely on the influence of domestic shocks in a structural vector autoregression framework. Bergin (2006) uses maximum likelihood techniques to estimate a small-scale New Keynesian model of the US and the remaining of the G-7 countries and finds that UIP, taste and home-bias shocks explain the bulk of trade balance fluctuations. We find a more suppressed role for these shocks as we employ other frictions, observable data series and shocks, in particular investment and corresponding disturbances.[3]

Finally, we contribute to the tradition of New Keynesian two-country models estimated with Bayesian methods seen in Rabanal and Tuesta (2010) and Lubik and Schorfheide (2006). These authors study the dynamics of the Euro-Dollar exchange rate, while we focus on the trade balance. Our model is also much less stylized and the considerably richer data-set that we employ in its empirical implementation enables the identification of a wider array of structural shocks.

We proceed as follows. The next section details the baseline theoretical model we set up. Section 3 presents the estimation results from this model. We also offer a structural interpretation of the marginal efficiency of investment shocks by contrasting our estimates of the shocks with movements in the external finance premium in the US and abroad. In Section 4, we carefully evaluate the robustness of the main findings by subjecting the baseline model to perturbations and examine the sources of differences relative to the existing literature. Finally, Section 5 concludes.

2. A benchmark two-country model

The baseline specification we use can be seen as a two-country version of the closed-economy models described in Smets and Wouters (2007) and Justiniano et al. (2011), henceforth Smets and Wouters (2007) and Justiniano et al. (2011). The open-economy segment of the model differs from conventional two-country models in only one aspect, *i.e.* the treatment of the intensity of imports in aggregate consumption and investment.[4] Erceg et al. (2008) note that in the data, US exports and imports are heavily concentrated towards capital goods and durables, making the consumption basket considerably less open to imports than the investment basket. Hence, following these authors, we allow for different shares of imports in each.[5]

The production of intermediate goods in both countries is affected by neutral labor-augmenting technological progress that has distinct components. A non-stationary, deterministic component is common to both countries and grows at a rate denoted by $\overline{\gamma} > 1$. The stationary components are country-specific stochastic processes. Parameters governing the steady-state are assumed to be the same across regions. $\sigma_C > 0$ is a parameter that governs the economy's degree of risk aversion. The economy's subjective discount factor $\beta \in (0,1)$ is adjusted for the fact that the marginal utility of consumption grows at the rate of $\overline{\gamma}^{-\sigma_C}$ in steady-state and we define $\overline{\beta} \equiv \beta \overline{\gamma}^{-\sigma_C}$. Along the steady-state growth path, we impose balanced trade and zero exchange rate depreciation.

Since the two countries in the model are isomorphic, we only present stationarized, log-linearized equilibrium conditions for the Home economy. The non-linear optimality conditions and the functional forms for preferences and technology are detailed in the Appendix. Steady-state variables are indicated by an upper bar and variables presented as logarithmic deviations from the steady-state are denoted by a superscript '^'. Δ indicates the temporal difference operator. Typically, foreign-country variables and parameters are denoted with a superscript '*'. The innovations in all the AR(1) processes, η_t^j are *i.i.d.* $N(0,\sigma_j)$ and $\rho_j \in [0,1) \, \forall j$. As in Smets and Wouters (2007), all the shocks in the theoretical model are normalized so that they enter the estimation with a unit coefficient. In Section 4, we discuss the robustness of the results when alternative specifications for our benchmark model are used.

2.1. Aggregation

Perfectly competitive firms produce Armington (CES) aggregates of the composite Home and imported bundles for final consumption

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[2] The predominance of capital goods and consumer durables in international trade has also been documented by Engel and Wang (2011).

[3] Importantly, Bergin (2006) also estimates the model in country-differences and hence can only identify *relative* shocks. Our model is asymmetric as we allow parameters and shocks to vary across countries.

[4] In line with the empirical New Keynesian literature, *e.g.* Rabanal and Tuesta (2010), Bergin (2006), Lubik and Schorfheide (2006) and De Walque et al. (2005), we impose the open-economy parameters across the two countries. To preserve empirical tractability, we do not model non-tradables and distribution services.

[5] Capital goods and durables account for 76 and 80% of non-energy imports and exports respectively over our sample period, while investment expenditures account for about 20% of output. Erceg et al. (2008) compare such a 'disaggregated' specification with the popular 'aggregated' Armington specification, which assumes the existence of a final good sector that combines domestic and imported goods to produce a composite good that is used for both consumption and investment, disallowing the use of different import-intensities. The two-country models of Backus et al. (1994), De Walque et al. (2005), Bergin (2006) and Raffo (2008) use the aggregated specification. On the other hand, Adolfson et al. (2007) estimate a small open economy model using the disaggregated specification.

(C) and final investment (I). $Z \in \{C,I\}$ denotes the output of the aggregator firms for *either* consumption or investment. In the Home (foreign) Armington production function, Z (Z^*) is a combination of the domestic bundle Z_H (Z_F^*) and the imported bundle Z_F (Z_H^*) that are in turn Dixit–Stiglitz aggregates of differentiated intermediate varieties. For both consumption and investment, the home and imported bundles are imperfect substitutes with an elasticity of substitution given by $\mu > 0$. However, the aggregation differs in important ways. Firstly, the share of imports in the aggregators for consumption and investment differs and we denote it by $m_Z \in [0,1]$. Secondly, we follow Basu and Thoenissen (2011) in allowing for an investment-specific technological (IST) shock in the production function for final investment goods. In particular, if $F(.)$ is the CES function, $I_t = \varepsilon_t^{IST} F(I_{Ht}, I_{Ft})$ where $\hat{\varepsilon}_t^{IST} = \rho_{IST} \hat{\varepsilon}_{t-1}^{IST} + \eta_t^{IST}$.

The distinction between the investment and the consumption aggregators reflects in the price indices. The aggregate price levels, *i.e.* the consumer price index (CPI) and the investment deflator, are convex combinations of the domestic output deflator (P_H) and the price of imports (P_F).

$$\hat{P}_{Ct} = (1 - m_C)\hat{P}_{Ht} + m_C \hat{P}_{Ft} \tag{1}$$

$$\hat{P}_{It} = (1 - m_I)\hat{P}_{Ht} + m_I \hat{P}_{Ft} - \hat{\varepsilon}_t^{IST} \tag{2}$$

We define $\widehat{tot} \equiv \hat{P}_F - \hat{P}_H$ and $\widehat{tot}^* \equiv \hat{P}_H^* - \hat{P}_F^*$ as the Home and Foreign terms of trade that determine the rate at which agents substitute the imported bundle for the domestically produced bundle. The demand functions for the domestic and imported bundles are given as

$$\hat{c}_{Ht} = \hat{c}_t + \mu m_C \widehat{tot}_t, \hat{i}_{Ht} = \hat{i}_t + \mu m_I \widehat{tot}_t - \hat{\varepsilon}_t^{IST} \tag{3}$$

$$\hat{c}_{Ft} = \hat{c}_t - \mu(1 - m_C)\widehat{tot}_t, \hat{i}_{Ft} = \hat{i}_t - \mu(1 - m_I)\widehat{tot}_t - \hat{\varepsilon}_t^{IST} \tag{4}$$

2.2. Consumption and investment

Consumers have access to domestic and foreign currency denominated private risk-free bonds as well as the domestic capital stock to facilitate the inter-temporal transfer of wealth. The optimal choice of consumption, bonds and physical capital implies three asset-pricing conditions.

$$\hat{c}_t = c_1 \hat{c}_{t-1} + (1 - c_1)\mathbf{E}_t \hat{c}_{t+1} + c_2 \mathbf{E}_t[\hat{n}_t - \hat{n}_{t+1}] - c_3[\hat{R}_t - \mathbf{E}_t \hat{\pi}_{Ct+1}] + \hat{\varepsilon}_t^{TI} \tag{5}$$

$$\mathbf{E}_t \Delta \widehat{NEx}_{t+1} = \hat{R}_t - [\hat{R}_t^* - \kappa \widehat{nfa}_t + \hat{\varepsilon}_t^{UIP}] \tag{6}$$

$$\widehat{tq}_t = t_1 \mathbf{E}_t \widehat{tq}_{t+1} + (1 - t_1)\mathbf{E}_t \hat{r}_{t+1}^k - [\hat{R}_t - \mathbf{E}_t \hat{\pi}_{Ct+1}] \tag{7}$$

Eq. (5) presents the consumption Euler. We define reduced-form parameters $c_1 \equiv h/(\overline{\gamma} + h), c_2 \equiv (1 - c_1)(\overline{wn}/\overline{c})(\sigma_C - 1)/\sigma_C$ and $c_3 \equiv (\overline{\gamma} - h)/(\overline{\gamma} + h)\sigma_C$. R is the gross interest rate on domestic bonds set by the monetary authority while π_C is the gross inflation in the CPI. The curvature parameter $\sigma_C > 0$ and the external habit coefficient $h \in [0,1)$ together govern the inter-temporal elasticity of substitution. The underlying preferences (see Appendix) guarantee the feasibility of a balanced growth path as in King et al. (1988), without resorting to the logarithmic utility restriction, *i.e.* $\sigma_C = 1$ considered in Justiniano et al. (2011). Consumption and hours worked (N) are complements in the utility function when $\sigma_C > 1$. As we will see later in the dynamics, the consumption-hours worked complementarity plays an important role in generating macroeconomic comovement. ε^{TI} is a disturbance that can be interpreted as a 'time-impatience' shock to the subjective discount factor and evolves as $\hat{\varepsilon}_t^{TI} = \rho_{TI} \hat{\varepsilon}_{t-1}^{TI} + \eta_t^{TI}$. Eq. (6) presents uncovered interest

parity (UIP), the arbitrage condition for home and foreign bonds, which relates the expected changes in the nominal exchange rate (NEx) to the interest rate differential between the two regions. Since the failure of UIP in its primitive form has been well documented, we add to this condition a stochastic term ε^{UIP} whose evolution obeys $\hat{\varepsilon}_t^{UIP} = \rho_{UIP} \hat{\varepsilon}_{t-1}^{UIP} + \eta_t^{UIP}$. The additional cost of acquiring net foreign assets NFA measured by $\kappa > 0$ acts as a stationarity-inducing device.[6] Finally, Eq. (7) is the first order condition for physical capital which relates Tobin's Q (tq), the marginal value of physical capital, to its expected value, the CPI-based rental rate of capital r^k and the *ex-ante* real interest rate. t_1 is defined as $\overline{\beta}(1 - \delta)$ where $\delta \in [0,1]$ denotes the depreciation rate of the capital stock.

Two relationships that are central to the empirical results of this paper are the law of accumulation of physical capital ($\overline{K}$) and the investment Euler equation:

$$\hat{\overline{k}}_t = k_1 \hat{i}_t + (1 - k_1)\hat{\overline{k}}_{t-1} + k_2 \hat{\varepsilon}_t^{MEI} \tag{8}$$

where $k_1 \equiv \overline{i}/\overline{k}$ and $k_2 \equiv k_1 \overline{\gamma}^2 \phi(1 + \overline{\beta}\overline{\gamma})$

$$\hat{i}_t = i_1 \hat{i}_{t-1} + (1 - i_1)\mathbf{E}_t \hat{i}_{t+1} + i_2\left[\widehat{tq}_t - (m_I - m_C)\widehat{tot}_t + \hat{\varepsilon}_t^{IST}\right] + \hat{\varepsilon}_t^{MEI} \tag{9}$$

where $i_1 \equiv 1/(1 + \overline{\beta}\overline{\gamma})$ and $i_2 \equiv i_1/\overline{\gamma}^2 \phi$. The inertia in the capital accumulation process is increasing in the adjustment cost parameter $\phi > 0$. ε^{MEI} is a stochastic shifter that denotes a disturbance to the marginal efficiency of investment (MEI) and evolves as $\hat{\varepsilon}_t^{MEI} = \rho_{MEI} \hat{\varepsilon}_{t-1}^{MEI} + \eta_t^{MEI}$. Aggregate investment rises if the marginal value of capital exceeds the marginal cost of producing the new investment good. The marginal cost is given by the relative price of investment in terms of consumption which is a negative function of the IST shock and, if investment is more import-intensive than consumption, a positive function of the terms of trade: $(m_I - m_C)\widehat{tot}_t - \hat{\varepsilon}_t^{IST}$.[7]

Observe that, as in Justiniano et al. (2011), two distinct disturbances enter the investment Euler equation. The first is the IST shock which is interpreted as sector-specific productivity in the spirit of Greenwood et al. (2000) and is reflected by a fall in the relative price of investment. The second, the MEI disturbance stimulates the capital accumulation constraint in Eq. (8). It increases the efficiency of the conversion of finished investment goods – idle pieces of machinery exiting the factory – into the economy's stock of installed physical capital which is used to produce intermediate goods in the next period. Empirically, the IST shock is restricted by the use of time series on the price of investment goods in the estimation, while the MEI shock can freely adjust to fit the investment quantity series.

It has been customary in the empirical DSGE literature, *e.g.* Rabanal and Tuesta (2010), Smets and Wouters (2007) and De Walque et al. (2005), to label the linear combination of the two investment disturbances in Eq. (9) as an IST shock.[8] These studies do not use the price of investment goods in their estimation and instead identify the combined investment shock from quantity data. Justiniano et al. (2011) report that estimates of the investment shock are much more volatile and only weakly correlated to available measures of the relative price of investment.[9] Hence, they emphasize the need of allowing investment

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[6] See Bergin (2006) and the references therein for details of the non-stationarity problem in incomplete markets models.

[7] The relative price of investment can easily be derived by subtracting the CPI in Eq. (1) from the investment deflator in Eq. (2). The terms of trade effect disappears when $m_C = m_I$ or when the economy is closed. See also Basu and Thoenissen (2011).

[8] However, Guerrieri et al. (2010) demonstrate that the *exact* inverse relationship is violated when production functions differ across competitive sectors specializing in the production of consumption and investment goods in a closed economy. Justiniano et al. (2011) show how the equality is disturbed by sector-specific mark-ups under imperfect competition. The relationship also breaks down in an open-economy setting as the terms of trade enters the definition of the relative price of investment.

[9] In an open-economy context, Mandelman et al. (2011) also document the inability of investment-specific shocks used in standard models to replicate the properties of the relative price of investment goods in the data.

volatility to emanate from sources beyond purely technological factors which make investment goods less expensive. Justiniano et al. (2011) demonstrate that the disentangling of the sources of investment volatility has profound implications for the US business cycle under closed-economy assumptions. As we will see in Section 3.3.2, this distinction is even more important for the dynamics of the US trade balance.

Optimal capacity utilization implies that the rate of capacity utilization $u^{\bar{k}}$ is a positive function of the (output deflator-based) rental rate of capital.

$$\hat{u}_t^{\bar{k}} = \hat{r}_{y,t}^k(\varphi-1)/\varphi \tag{10}$$

such that $\varphi \in (0,1)$ governs the strength of capacity utilization. The agent provides a differentiated labor service in the factor market and has monopoly power. Nominal wage stickiness is modeled à la Calvo. If $\theta_W \in (0,1)$ is the Calvo parameter for nominal wage stickiness and $\iota_W \in [0,1]$ measures the degree of indexation of wages to lagged CPI-inflation, the dynamics of nominal wage inflation (π_W) are governed by the wage Phillips curve:

$$\hat{\pi}_{Wt} - \iota_W \hat{\pi}_{Ct-1}$$
$$= \overline{\beta}\overline{\gamma}\mathbf{E}_t(\hat{\pi}_{Wt+1} - \iota_W\hat{\pi}_{Ct}) - w_1\left[\hat{w}_t - \sigma_N\hat{n}_t - \frac{\overline{\gamma}\hat{c}_t - h\hat{c}_{t-1}}{\overline{\gamma} - h}\right] + \hat{\varepsilon}_t^{WM} \tag{11}$$

where $w_1 \equiv (1 - \overline{\beta}\overline{\gamma}\theta_W)(1-\theta_W)/\theta_W(1 + \sigma_N v_N)$. $\sigma_N > 0$ is the inverse of the Frisch elasticity of labor-supply and $v_N > 1$ is the steady-state demand elasticity for the individual labor-type. ε^{WM} is a cost-push disturbance emanating from short-run time-variation in the labor-demand elasticity and can be interpreted as a shock to the mark-up (in square brackets) of the CPI-based real wage (w) over the marginal rate of substitution between consumption and leisure. The shock follows an ARMA (1,1) process defined as $\hat{\varepsilon}_t^{WM} = \rho_{WM}\hat{\varepsilon}_{t-1}^{WM} + \eta_t^{WM} - v_{WM}\eta_{t-1}^{WM}$ such that $v_{WM} \in [0,1)$.

2.3. Intermediate firms

There exists a continuum of intermediate monopolistic firms, each of which produces a differentiated variety. The firm rents capital services and labor at (output deflator-based) real rates r_y^k and w_y and combines the factors in a Cobb–Douglas aggregate.

$$\hat{y}_{Ht} = \frac{v_Y}{v_Y - 1}\left[(1-\alpha)\hat{n}_t + \alpha\hat{k}_t^S + \hat{\varepsilon}_t^{NEU}\right] \tag{12}$$

$\hat{k}_t^S = \hat{u}_t^{\bar{k}} + \hat{\bar{k}}_{t-1}$ represents capital services and $\alpha \in [0,1]$ governs its share in the production function. $v_Y > 1$ is the elasticity of substitution between individual goods varieties which determines the steady-state mark-up of prices over marginal costs. ε^{NEU} is the stationary region-specific component of neutral technology and follows $\hat{\varepsilon}_t^{NEU} = \rho_{NEU}\hat{\varepsilon}_{t-1}^{NEU} + \eta_t^{NEU}$. The rental rate of capital is determined by

$$\hat{r}_{y,t}^k = \hat{w}_{y,t} + \hat{n}_t - \hat{k}_t^S \tag{13}$$

As seen in Rabanal and Tuesta (2010), the firm sets prices in the local currency in the market of destination and exchange rate pass-through is decreasing in the degree of price stickiness. $\{\theta_H, \theta_H^*\} \in (0,1)$ and $\{\iota_H, \iota_H^*\} \in [0,1]$ denote the Calvo probability parameters and the degrees of price-indexation for domestic and export sales respectively. The Phillips curve for domestic sales is given by

$$\hat{\pi}_{Ht} = \pi_1\iota_H\hat{\pi}_{Ht-1} + \pi_2\mathbf{E}_t\hat{\pi}_{Ht+1} + \pi_3\widehat{rmc}_t \tag{14}$$

where $\pi_1 \equiv 1/(1 + \overline{\beta}\overline{\gamma}\iota_H), \pi_2 \equiv \pi_1\overline{\beta}\overline{\gamma}$ and $\pi_3 \equiv \pi_1(1-\overline{\beta}\overline{\gamma}\theta_H)(1-\theta_H)/\theta_H$. The real marginal cost is given by

$$\widehat{rmc}_t = (1-\alpha)\hat{w}_{y,t} + \alpha\hat{r}_{y,t}^k - \hat{\varepsilon}_t^{NEU} \tag{15}$$

The assumption of local currency pricing implies that the real exchange rate (rex^Y) and the terms of trade enter the Phillips curves for export sales.

$$\hat{\pi}_{Ht}^* = x_1\iota_H^*\hat{\pi}_{Ht-1}^* + x_2\hat{\pi}_{Ht+1}^* + x_3\left[\widehat{rmc}_t - \widehat{rex}_t^Y - \widehat{tot}_t^*\right] + \hat{\varepsilon}_t^X \tag{16}$$

where $x_1 \equiv 1/(1 + \overline{\beta}\overline{\gamma}\iota_H^*), x_2 \equiv x_1\overline{\beta}\overline{\gamma}$ and $x_3 \equiv x_1(1-\overline{\beta}\overline{\gamma}\theta_H^*)(1-\theta_H^*)/\theta_H^*$. ε^X is a time-varying demand elasticity that the exporter faces in the foreign market and follows $\hat{\varepsilon}_t^X = \rho_X\hat{\varepsilon}_{t-1}^X + \eta_t^X - v_X\eta_{t-1}^X$ such that $v_X \in [0,1)$.[10]

Eq. (17) represents the goods market clearing condition. Output is absorbed by domestic and export sales for consumption and investment, domestic government spending and the cost of capacity utilization.

$$\hat{y}_{Ht} = \frac{\overline{c}}{\overline{y}}(1-m_C)\hat{c}_{Ht} + \frac{\overline{i}}{\overline{y}}(1-m_I)\hat{i}_{Ht} + \frac{\overline{c}}{\overline{y}}m_C\hat{c}_{Ht}^* + \frac{\overline{i}}{\overline{y}}m_I\hat{i}_{Ht}^* + \frac{\overline{r}^k\overline{k}^S}{\overline{y}}\hat{u}_t^{\bar{k}}$$
$$+ \hat{\varepsilon}_t^{GOV} \tag{17}$$

We follow the convention in the literature by reducing government spending to a residual shock in aggregate demand that follows $\hat{\varepsilon}_t^{GOV} = \rho_{GOV}\hat{\varepsilon}_{t-1}^{GOV} + \eta_t^{GOV}$. Government spending is financed by lump-sum taxes and falls exclusively on the domestic bundle.[11]

2.4. Balance of payments

The inter-temporal flow of net foreign assets is determined by

$$\widehat{nfa}_t - \frac{1}{\overline{\beta}\overline{\gamma}}\widehat{nfa}_{t-1} = \frac{\overline{c}}{\overline{y}}m_C\left[\widehat{NEx}_t + \hat{P}_{Ht}^* + \hat{c}_{Ht}^* - \hat{P}_{Ft} - \hat{c}_{Ft}\right]$$
$$+ \frac{\overline{i}}{\overline{y}}m_I\left[\widehat{NEx}_t + \hat{P}_{Ht}^* + \hat{i}_{Ht}^* - \hat{P}_{Ft} - \hat{i}_{Ft}\right] \tag{18}$$

The aggregate net-exports to GDP ratio of the Home economy, which subsumes the prices as well as volumes of imports and exports, are given by the right-hand-side of Eq. (18). Net-exports for consumption and investment are each weighted by their respective shares of imports and steady-state shares in GDP. Using the conditional import demand functions in Eq. (4) (and its foreign analog), the definitions of the consumption- and investment-based real exchange rates and the home and foreign terms of trade, we can decompose the trade balance into the sum of differences in the consumption and investment levels between the US and the RoW, the real exchange rates and the differential in the terms of trade. Such a disaggregation

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[10] In steady-state, the demand-elasticities for the intermediate variety in the domestic and foreign markets are imposed to be the same.

[11] The assumption of a balanced budget implies that this paper does not provide an empirical evaluation of the Twin Deficits hypothesis. This view suggests that the deterioration of the trade balance is determined by the lack of saving by the Federal government. See Corsetti and Müller (2006) and the references therein for more details.

will aid our analysis of the impact of the various structural shocks on each of these components.[12] Specifically, the trade balance is redefined as

$$
\widehat{rtb}_t = \overbrace{\frac{\overline{c}}{\overline{y}} m_C\{\hat{c}_t^*\}}^{\text{Weighted International Relative Consumption Absorption}}
$$

$$
+ \overbrace{\frac{\overline{\iota}}{\overline{y}} m_I\{\hat{\iota}_t^* - \hat{\iota}_t\}}^{\text{Weighted International Relative Investment Absorption}}
$$

$$
+ \overbrace{\frac{\overline{c}}{\overline{y}} m_C \widehat{rex}_t^C + \frac{\overline{\iota}}{\overline{y}} m_I \widehat{rex}_t^I}^{\text{Weighted Real Exchange Rates}}
$$

$$
+ \overbrace{\left[\frac{\overline{c}}{\overline{y}} m_C(1 - m_C) + \frac{\overline{\iota}}{\overline{y}} m_I(1 - m_I)\right]\{\widehat{tot}_t - \widehat{tot}^*\}}^{\text{Weighted Relative Terms of Trade}}
$$

(19)

2.5. Monetary policy

The model is closed with the monetary authority following a simple empirical Taylor-type rule to set the nominal interest rate, targeting CPI-inflation and the level as well as changes in the output-gap. The output-gap is defined as the difference between output under sticky prices and that would prevail under flexible prices (y_H^{flex}). In addition, the policy rule is subject to exogenous monetary disturbances.

$$
\hat{R}_t = \rho_{\text{MON}}\hat{R}_{t-1} + (1 - \rho_{\text{MON}})\left[\phi_\pi \hat{\pi}_{Ct} + \phi_y\{\hat{y}_{Ht} - \hat{y}_{Ht}^{\text{flex}}\}\right]
$$
$$
+ \phi_{\Delta y}\left[\Delta\hat{y}_{Ht} - \Delta\hat{y}_{Ht}^{\text{flex}}\right] + \eta_t^{\text{MON}}
$$

(20)

3. Estimation

3.1. Data and estimation method

The empirical treatment of the foreign region in the model, the RoW, poses a significant challenge. Long macroeconomic time series are unavailable for high-saving emerging economies as China that have centered in recent debates in the context of the US deficit. This impedes our effort to disentangle the effect of external disturbances on the imbalance. To remedy the lack of data to form the RoW aggregate, we propose an alternative strategy. More specifically, we use the bilateral trade balance between the US and a group of sixteen industrialized economies – Canada, Japan, Korea, the UK and twelve economies from the Euro-Area – as a proxy for the actual US trade balance. Fig. 1 compares the constructed intra-OECD trade balance series with the actual non-energy trade balance since the 1980s. Clearly, a trade imbalance prevails even within the industrialized countries, which motivates our decision to use the bilateral trade balance between the US and this group of OECD economies in the estimations. The OECD series tracks the actual non-energy trade balance rather well between the early 1980s through the late 1990s before the omitted
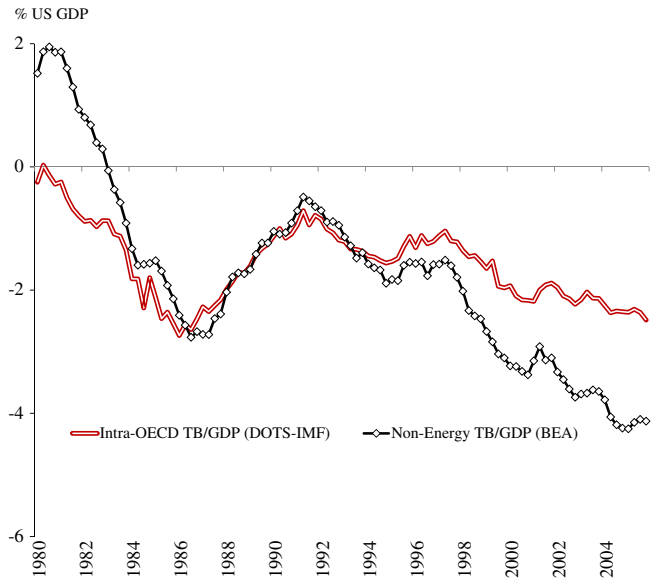

Fig. 1. Comparing the intra-OECD US Trade to the aggregate non-energy trade balance. *Note*: The Rest of the World (RoW) is a trade-weighted aggregate of the United Kingdom, Canada, Japan, Korea and 12 members of the Euro-Area.

economies started to play a dominant role. As can be seen in Table 1, the two series are highly correlated. Towards the later years of the sample, the disparity between the two series increases even though they continue to display the high cross-correlation, which is what really matters if we want to analyze the cycle of the balance. Time series from the OECD trade-partners are aggregated using time-varying trade-shares to embody the RoW in the empirical analysis.[13] In a robustness check, we have also employed the actual trade balance in the estimations and obtain similar results (see Section 4).

To identify the seventeen structural innovations in the theoretical model – $\eta^{\text{NEU}}, \eta^{\text{NEU*}}, \eta^{\text{MEI}}, \eta^{\text{MEI*}}, \eta^{\text{IST}}, \eta^{\text{IST*}}, \eta^{\text{UIP}}, \eta^{\text{TI}}, \eta^{\text{TI*}}, \eta^{\text{GOV}}, \eta^{\text{GOV*}}, \eta^{\text{WM}}, \eta^{\text{WM*}}, \eta^{\text{MON}}, \eta^{\text{MON*}}, \eta^X$ and η^{X*} – an equal number of macroeconomic time series are matched with their analogs in the model. As in Justiniano et al. (2010, 2011), we adjust the data definition of US investment to include changes in inventories and consumer durables while subtracting expenditures on durables from consumption.[14] The addition of these components to aggregate investment data makes it more volatile and procyclical. Note that due to non-availability of data especially for the Euro-Area, we are unable to make similar adjustments to the RoW series on investment and consumption. We use US and RoW series on real consumption, real investment, real GDP, GDP deflator inflation, investment deflator inflation, export price inflation, real wage inflation, and the nominal interest rates along with the net-exports to US GDP ratio spanning 1980.Q1-2005.Q4.[15] Since the model endogenously allows for an average growth rate, we do not need to filter any series before the estimation.

Table 1 provides the unconditional moments of the data. Observe that due to the incorporation of the additional components, US investment growth is twice as volatile as the RoW analog. Hence, a qualification to our results is that we may be *underestimating* the

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[12] Alternatively, as in Raffo (2008), we can separate the effects from the net-export volumes $\hat{c}_{Ht}^* + \hat{i}_{Ht}^* - \hat{c}_{Ft} - \hat{i}_{Ft}$ and the net-export prices $\widehat{NEx}_t + \hat{P}_{Ht}^* - \hat{P}_{Ft}$. However, this strategy will not highlight the expenditure-switching due to the terms of trade movements which is part of the demand functions for export and import volumes. These terms of trade effect are important for our discussion of the dynamics that follows in Section 3.3.3.

[13] Bergin (2006), Corsetti et al. (2006) and Bussière et al. (2010) are other studies that use multi-country data aggregates in empirical models of the US external balance.
[14] In Smets and Wouters (2007), durables expenditures are included in the consumption series while the investment series excludes the changes in inventories.
[15] In principle, the series that we use to measure investment prices should be quality-adjusted as in Cummins and Violante (2002). The quality-adjusted series for the US is available only through 2000 and similar series do not exist for the RoW. Hence, we use the best available substitutes (see Appendix).

Table 1
Unconditional moments of the data.

Correlation between the intra-OECD and the actual non-energy US trade balances					
Level					0.89
Linear detrending					0.96
Growth rates					0.56
Observable series	US		RoW		Model US variable
	Mean	SD	Mean	SD	
Real consumption growth	0.86	0.44	0.64	0.50	$\overline{\gamma} + \Delta\hat{c}_t + \hat{\pi}_{ct} - \hat{\pi}_{Ht}$
Real investment growth	0.61	2.56	0.60	1.27	$\overline{\gamma} + \Delta\hat{i}_t + \hat{\pi}_{It} - \hat{\pi}_{Ht}$
Real investment growth	0.71	0.70	0.65	0.55	$\overline{\gamma} + \Delta\hat{y}_{Ht}$
Real wage inflation	0.08	0.34	0.26	0.46	$\overline{\gamma} + \Delta\hat{w}_{y,t}$
GDP deflator inflation	0.82	0.53	0.82	0.78	$\overline{\pi} + \hat{\pi}_{Ht}$
Investment deflator inflation	0.53	0.73	0.62	0.65	$\overline{\pi} + \hat{\pi}_{It}$
Export price inflation	0.53	1.23	0.64	2.25	$\overline{\pi} + \hat{\pi}^*_{Ht}$
Nominal interest rate	1.66	0.95	1.70	0.85	$\overline{R} + \hat{R}_t$
Intra-OECD TB/GDP growth	−0.02	0.16			$\overline{\Delta rtb}^{OECD} + \Delta\hat{rtb}_t$
Non-energy TB/GDP growth	−0.04	0.18			$\overline{\Delta rtb}^{NE} + \Delta\hat{rtb}_t$

Note: Δ indicates the temporal difference operator. We adjust for the prices when we link aggregate consumption and investment to the data. For example, the level of real consumption, as we measure it in the data is given as $C^{DATA} = \frac{P_{CPI}}{P_{GDP}} C^{MODEL}$.

importance of RoW investment disturbances. Other particulars about the data are detailed in the Appendix.

We apply the Bayesian estimation methodology employed by Smets and Wouters (2007) and we refer to the original paper for a detailed description. In a nutshell, the Bayesian paradigm facilitates the combination of prior knowledge about structural parameters with information in the data as embodied by the likelihood function. The blend of the prior and the likelihood function yields the posterior distribution for the structural parameters which is then used for inference. The appendix also provides further technical details on the estimation methodology.

3.2. Priors

An overview of our priors can be found in Table 2. The prior distributions given to the estimated structural parameters are comparable to those used in other studies. The parameters that are not estimated are given dogmatic priors at calibrated values. We follow the strategy of Bergin (2006) and Rabanal and Tuesta (2010) in fixing, rather than estimating, the import-shares. We allow for different import-intensities for consumption and investment by computing the means of the shares of imports from annual data over 1980–2005 from the Bureau of Economic Analysis.[16] We set the import-share for consumption m_C at 0.023 and the investment analog m_I at 0.3994. These values are quite similar to those used by Erceg et al. (2008) in their simulations. It is also important to note from Fig. 1, that in the data, the trend in the trade balance is negative, quite unlike the positive trend in other quantities that we use in the estimation (see sample means of growth rates in Table 1). It is unrealistic to think of a trade balance that trends (downward in the US case) asymptotically in the sense of balanced growth. Furthermore, note from Eq. (19) that the model-based trade balance

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[16] In particular, we refer to Table 2b (U.S. Trade in Goods) from U.S. International Transactions Accounts Data from the BEA website. We define Investment Imports≡Non-energy industrial supplies + Capital goods, except automotive + Automotive vehicles, parts and engines + Consumer durables manufactured and Consumption Imports≡Consumer goods (nonfood), except automotive + Foods, feeds, and beverages − Consumer durables manufactured. The import-shares are computed by dividing these by aggregate investment and consumption.

is the difference between variables which inherit the same trend in the balanced growth-path and hence is stationary. Hence it is appropriate to calibrate the trend of the trade balance time-series using the sample mean. Other calibrations are very standard in the literature.

3.3. Baseline results

3.3.1. Posterior estimates

The medians and the 5th and 95th percentiles of the posterior distributions of the structural and shock parameters are also reported in Table 2. The estimates of the US parameters are in the ballpark of those obtained in Smets and Wouters (2007) and Justiniano et al. (2010, 2011). The RoW estimates of the structural parameters are similar except for the domestic price Calvo parameter which is quite low at about 0.30. A key estimate that is quite influential in the dynamics of the trade balance is that of the trade-elasticity μ. As also observed in Lubik and Schorfheide (2006), the 90% confidence bounds of this parameter are substantially below the threshold of unity, so that US and RoW output behave as complements in the final consumption and investment goods.

3.3.2. Determinants of trade balance fluctuations

To evaluate the relative importance of the shocks embedded in the model, Table 3 shows the variance of the forecast errors of the trade balance at different horizons. For all shocks, we report the mean of the posterior distribution of variance decompositions. For ease of exposition, we have aggregated the contributions of disturbances that are less relevant for the discussion into 'other' US and RoW shocks. The table also reports the forecast errors of some key US macroeconomic variables, *i.e.* real GDP, consumption and investment as well as the US terms of trade.

The relative contributions of the shocks to variability in US GDP, consumption and investment are comparable to Justiniano et al. (2010, 2011) or Smets and Wouters (2007).[17] Of special interest is the role of foreign and open-economy shocks for the overall US business cycle. For all three variables, these shocks explain less than 12% for forecast horizons below 1 year. At longer horizons, when the variables are returning to the steady-state, the RoW MEI shock and the RoW export price mark-up shock seem to explain respectively 12 and 7% of US GDP variability.[18] Not surprisingly, the influence of the external disturbances on the terms of trade and the trade balance is much higher. On impact, the UIP and the RoW export price mark-up shock explain together approximately half of the US terms of trade and trade balance volatility. Hence, focusing solely on the influence of domestic shocks to study the deterioration of the US trade balance (*e.g.* Bems et al., 2007), ignores an important source of volatility. The relevance of both disturbances for the forecast error variance of the trade balance variability, however, vanishes very quickly. In particular, their contribution already declines to about 25% after 1 quarter and to less than 10% at longer horizons.

The declining relevance for trade balance fluctuations of the shocks that mainly transmit through international relative prices can be explained by the rising dominance of MEI shocks. While these disturbances contribute approximately 30% on impact, this becomes more than 60% one period afterwards and even more than 85% from the one-year horizon onwards. Both US and foreign

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[17] Relative to Smets and Wouters (2007), we find a more important role for investment shocks in explaining the business cycle. Justiniano et al. (2010) demonstrate that this difference is due to the fact that Smets and Wouters (2007) include (more volatile) durable expenditures in consumption, while excluding the change in inventories from investment, but not from output. It must be noted that Justiniano et al. (2010, 2011) report variance decompositions at business-cycle frequencies. Our results and those of Smets and Wouters (2007) based in the time-domain, even though very related, are not strictly comparable with those of Justiniano et al. (2010, 2011).

[18] The increasing influence of the RoW MEI and export mark-up shocks over longer horizons is due to the high estimated persistence in the processes.

Table 2
Prior and posterior distributions in baseline estimation.

Estimated structural parameters			Posterior	Shocks AR(1), MA(1)		Posterior
Symbol	Description	Prior (P1, P2)	Med [5th; 95th %ile]	Symbol	Prior (P1, P2)	Med [5th, 95th %ile]
μ	Trade elasticity	G (1.00, 0.25)	0.56 [0.40; 0.73]	ρ_{NEU}	B (0.50, 0.15)	0.97 [0.94; 0.98]
σ_C	Utility curvature	G (2.00, 0.50)	1.08 [1.05; 1.12]	ρ_{NEU}^*	B (0.50, 0.15)	0.88 [0.72; 0.96]
H	External habit	B (0.50, 0.15)	0.86 [0.82; 0.89]	ρ_{MEI}	B (0.50, 0.15)	0.86 [0.81; 0.89]
Φ	US investment adj. cost	N (4.00, 1.00)	6.60 [5.09; 8.11]	ρ_{MEI}^*	B (0.50, 0.15)	0.97 [0.94; 0.99]
ϕ^*	RoW investment adj. cost	N (4.00, 1.00)	5.04 [3.89; 6.35]	ρ_{IST}	B (0.50, 0.15)	0.99 [0.99; 0.99]
Φ	US capacity util. cost	B (0.50, 0.15)	0.67 [0.57; 0.77]	ρ_{IST}^*	B (0.50, 0.15)	0.94 [0.90; 0.97]
φ^*	RoW capacity util. cost	B (0.50, 0.15)	0.88 [0.77; 0.95]	ρ_{π}	B (0.50, 0.15)	0.31 [0.19; 0.45]
θ_H	US PPI Calvo	B (0.50, 0.10)	0.78 [0.72; 0.83]	ρ_{π}^*	B (0.50, 0.15)	0.21 [0.10; 0.36]
ι_H	US PPI indexation	B (0.50, 0.15)	0.16 [0.07; 0.30]	ρ_{GOV}	B (0.50, 0.15)	0.75 [0.65; 0.84]
θ_F^*	RoW PPI Calvo	B (0.50, 0.10)	0.29 [0.19; 0.39]	ρ_{GOV}^*	B (0.50, 0.15)	0.91 [0.87; 0.95]
ι_F^*	RoW PPI indexation	B (0.50, 0.15)	0.26 [0.11; 0.49]	ρ_{WM}	B (0.50, 0.15)	0.70 [0.57; 0.81]
θ_H^*	US export Calvo	B (0.50, 0.10)	0.84 [0.76; 0.90]	ν_{WM}	B (0.50, 0.15)	0.51 [0.30; 0.71]
ι_H^*	US export indexation	B (0.50, 0.15)	0.26 [0.13; 0.44]	ρ_{WM}^*	B (0.50, 0.15)	0.92 [0.86; 0.96]
θ_F	RoW export Calvo	B (0.50, 0.10)	0.54 [0.44; 0.63]	ν_{WM}^*	B (0.50, 0.15)	0.73 [0.53; 0.85]
ι_F	RoW export indexation	B (0.50, 0.15)	0.31 [0.15; 0.53]	ρ_{UIP}	B (0.50, 0.15)	0.92 [0.88; 0.95]
θ_W	US wage Calvo	B (0.50, 0.10)	0.95 [0.95; 0.95]	ρ_X	B (0.50, 0.15)	0.84 [0.66; 0.96]
ι_W	US Wage Indexation	B (0.50, 0.15)	0.49 [0.31; 0.66]	ν_X	B (0.50, 0.15)	0.53 [0.30; 0.72]
θ_W^*	RoW Wage Calvo	B (0.50, 0.10)	0.79 [0.66; 0.88]	ρ_X^*	B (0.50, 0.15)	0.98 [0.96; 0.99]
ι_W^*	RoW Wage Indexation	B (0.50, 0.15)	0.13 [0.06; 0.23]	ν_X^*	B (0.50, 0.15)	0.39 [0.20; 0.59]
ϕ_{π}	US Mon. Pol. (Inflation)	N (1.50,0.25)	1.29 [1.16; 1.47]			
ϕ_{π}^*	RoW Mon. Pol. (Inflation)	N (1.50,0.25)	1.60 [1.36; 1.92]			
ϕ_y	US Mon. Pol. (Y Gap)	G (0.125,0.05)	0.01 [0.00; 0.01]			
ϕ_y^*	RoW Mon. Pol. (Y Gap)	G (0.125,0.05)	0.03 [0.01; 0.05]			
$\phi_{\Delta y}$	US Mon. Pol. (Δ Y Gap)	G (0.125,0.05)	0.05 [0.03; 0.08]			
$\phi_{\Delta y}^*$	RoW Mon. Pol. (Δ Y Gap)	G (0.125,0.05)	0.05 [0.03; 0.08]			
ρ_{MON}	US Interest Smoothing	B (0.75,0.075)	0.80 [0.76; 0.83]	Shock innovations		
ρ_{MON}^*	RoW Interest Smoothing	B (0.75,0.075)	0.92 [0.89; 0.93]			
$100(\overline{\pi}-1)$	Steady-state Inflation	G (0.625, 0.10)	0.73 [0.57; 0.92]	$100\sigma^{NEU}$	IG (0.10, 2)	0.67 [0.52; 0.88]
$100(\overline{\gamma}-1)$	Trend Growth Rate	N (0.40, 0.10)	0.20 [0.16; 0.25]	$100\sigma^{NEU*}$	IG (0.10, 2)	0.54 [0.45; 0.67]
				$100\sigma^{MEI}$	IG (0.10, 2)	0.49 [0.43; 0.58]
				$100\sigma^{MEI*}$	IG (0.10, 2)	0.27 [0.22; 0.33]
Calibrated structural parameters				$100\sigma^{IST}$	IG (0.10, 2)	0.76 [0.68; 0.85]
				$100\sigma^{IST*}$	IG (0.10, 2)	0.49 [0.44; 0.56]
B	Discount factor	0.99		$100\sigma^{TI}$	IG (0.10, 2)	0.14 [0.11; 0.17]
A	Share of capital services in production	1/3		$100\sigma^{TI*}$	IG (0.10, 2)	0.20 [0.17; 0.24]
Δ	Quarterly rate of capital depreciation	0.025		$100\sigma^{GOV}$	IG (0.10, 2)	0.23 [0.20; 0.26]
υ_Y	Substitution elasticity of goods varieties	10		$100\sigma^{GOV*}$	IG (0.10, 2)	0.43 [0.38; 0.48]
υ_N	Substitution elasticity of labor varieties	10		$100\sigma^{WM}$	IG (0.10, 2)	0.11 [0.09; 0.14]
σ_N	Inverse of Frisch elasticity	2		$100\sigma^{WM*}$	IG (0.10, 2)	0.12 [0.08; 0.15]
K	Cost of adjusting foreign assets	0.001		$100\sigma^{MON}$	IG (0.10, 2)	0.30 [0.26; 0.34]
m_C	Import-share of consumption	0.023		$100\sigma^{MON*}$	IG (0.10, 2)	0.18 [0.16; 0.21]
m_I	Import-share of investment	0.3994		$100\sigma^{UIP}$	IG (0.10, 2)	0.19 [0.14; 0.27]
$\overline{g/y}$	Share of government spending in GDP	0.18		$1000\sigma^{X}$	IG (0.10, 2)	0.50 [0.39; 0.62]
$\overline{\Delta rtb}^{OECD}$	Mean Change in Trade Balance to GDP	-0.017		$100\sigma^{X*}$	IG (0.10, 2)	1.86 [1.46; 2.48]

Note: G = gamma, B = beta, IG = inverse gamma and N = normal distributions. P1 = mean and P2 = standard deviation for all distributions. Posterior moments are computed using 500,000 draws from the distribution simulated by the Random Walk Metropolis algorithm. Calibrations of the other steady-state parameters such as $\overline{\tau}/\overline{y}, \overline{c}/\overline{y}$ and $\overline{wn}/\overline{c}$ are derived from the model's steady-state restrictions and updated at every iteration of the posterior simulation.

investment efficiency shocks are important, but the US shock clearly dominates for explaining trade balance volatility. Remember, as discussed in Section 1, that US investment data is more volatile than the RoW series because it includes expenditures on consumer durables and inventories in contrast to the RoW investment series. Not surprisingly, the estimated RoW MEI innovation is only about half of the US analog (see Table 2), which could, in part, explain the lower contribution of the shock to trade balance fluctuations.

All other shocks, *i.e.* domestic and foreign neutral technology, IST, time-impatience, wage mark-up, export price mark-up, monetary and fiscal policy shocks turn out not to matter much for trade balance variability. This finding is particularly striking for neutral shocks given the fact that these disturbances are often considered as being important to understand trade balance movements in much of the theoretical as well as empirical literature. In our estimations, the US and RoW TFP shocks together contribute no more than 1% at all horizons, which is considerably lower than the contribution to domestic variables such as real GDP and consumption.

Why do MEI shocks overwhelmingly dominate the forecast volatility of the trade balance, in contrast to some other disturbances that are important for domestic fluctuations? In the following subsection, we

dissect the dynamic responses of the trade balance and its components to understand the mechanisms that strengthen the transmission of MEI disturbances as well as those that render some other shocks less potent.

3.3.3. Impulse response analysis

Fig. 2 shows the dynamic effects of selected structural shocks on the trade balance and its four main elements as described in Eq. (19), together with US consumption, investment and output. The dynamics of all the observables triggered by the full set of shocks used in the estimation are presented in the on-line appendix of the paper.

3.3.3.1. US neutral technology and MEI shocks. The solid lines and shaded areas in Panel 1 of Fig. 2 represent the 90% posterior probability regions of the estimated responses induced by a US neutral technology and MEI shock respectively. A persistent rise in US neutral technology draws positive responses from consumption, investment and output as the income of the agents rise. The dynamics for these variables are similar to those obtained in other studies, *e.g.* Smets and Wouters (2007). In the second row of the panel, we observe that the rise in US consumption leads to a significant decline in relative consumption absorption while relative investment absorption does not react significantly. As in Backus et al.

Table 3
Forecast error variance decomposition in baseline estimation.

Horizon → Shocks ↓	US trade balance/GDP				US GDP				US consumption				US investment				US terms of trade			
	0Q	1Q	4Q	10Q	0Q	1Q	4Q	10Q	0Q	1Q	4Q	10Q	0Q	1Q	4Q	10Q	0Q	1Q	4Q	10Q
US shocks																				
Neutral	1.43	0.48	0.21	0.33	0.23	1.11	3.28	5.06	0.73	1.71	5.33	7.55	0.62	0.71	0.97	1.40	4.09	4.93	6.12	5.73
IST	4.32	1.35	0.31	0.24	0.77	0.25	0.18	0.48	0.04	0.05	0.06	0.09	0.54	0.52	0.55	0.76	5.63	6.64	8.32	10.46
MEI	26.88	57.77	73.24	70.28	56.35	62.73	63.47	54.59	4.34	8.30	21.54	34.97	90.63	89.46	85.97	77.87	14.36	17.84	25.16	34.00
Time-impatience	0.07	0.04	0.02	0.01	11.51	8.02	3.34	1.35	72.38	58.84	28.43	8.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Other shocks	8.37	2.57	0.84	0.70	22.70	16.60	12.25	11.52	19.81	26.52	34.27	29.04	1.73	1.56	1.34	1.40	8.62	9.19	9.02	8.04
RoW shocks																				
Neutral	0.11	0.18	0.26	0.15	0.18	0.31	0.63	0.81	0.05	0.10	0.28	0.54	0.30	0.35	0.43	0.54	3.28	3.34	2.55	1.47
IST	0.25	0.53	0.72	0.79	0.07	0.04	0.14	0.32	0.02	0.05	0.13	0.29	0.01	0.01	0.01	0.05	0.10	0.11	0.13	0.16
MEI	2.97	8.56	13.24	16.13	4.86	6.11	8.24	11.93	1.44	2.37	5.05	9.21	0.07	0.09	0.19	0.81	1.98	2.22	2.62	3.76
Time-impatience	0.21	0.08	0.02	0.01	0.00	0.01	0.02	0.03	0.00	0.00	0.01	0.02	0.03	0.03	0.04	0.04	0.21	0.23	0.19	0.11
Other shocks	4.57	1.49	1.14	1.07	1.65	2.17	3.29	4.94	0.26	0.48	1.30	2.91	0.83	1.02	1.59	2.92	6.58	7.08	7.14	6.38
Open-economy shocks																				
UIP	30.43	16.95	7.93	7.66	0.03	0.05	0.12	0.15	0.01	0.02	0.07	0.12	1.40	1.65	2.19	2.74	7.65	7.95	6.60	3.90
RoW export price	19.85	9.72	1.90	1.80	0.59	1.29	3.37	6.83	0.88	1.51	3.44	6.45	3.84	4.59	6.69	11.44	47.48	40.44	32.11	25.94
US export price	0.53	0.27	0.17	0.85	1.05	1.30	1.66	2.00	0.03	0.04	0.09	0.33	0.02	0.02	0.03	0.03	0.02	0.03	0.03	0.03

Note: 'Other shocks' indicates the sum of the contributions of wage mark-up, government spending and monetary policy shocks. The influence of each shock at forecast horizon k is measured by the variability generated by a unit standard deviation shock at time 0, cumulated over the interval 0 to k which is then divided by the aggregate variability induced by all the shocks and expressed in percentage terms. We report the mean based on 150 random draws from the posterior distribution (Each column adds to 100). Error bands are available on request.

(1994), the neutral shock is accompanied by a fall in domestic prices which results in a depreciation of the dollar and the US terms of trade.[19] Observe that the deterioration (rise) of the US terms of trade has a negative impact on the trade balance. Crucially, this is because our estimate of the trade-elasticity (μ) is substantially below unity. This implies that there prevails a high degree of complementarity between US and RoW goods, so that the rise in the demand for the US good which is triggered by a fall in its relative price, is also accompanied by a rise in the demand for the RoW good. Thus the impact of the terms of trade deterioration on the trade balance is negative. Overall, the trade balance improves slightly on impact due to the exchange rate effect but quickly becomes counter-cyclical because of the negative absorption and terms of trade effects.

A US MEI shock accelerates the conversion of the investment good into the capital stock by reducing installation costs, which raises the demand for both US and imported intermediate goods. As a result, US investment and output rise strongly. Unlike Justiniano et al. (2011), US consumption rises on impact. The reason for the increase of consumption can be traced to the interaction between three specific model ingredients: counter-cyclical mark-ups due to sticky prices, variable capacity utilization and consumption-hours complementarity.[20] The first two enter the firm's optimality condition for labor input and generate a rise in labor demand. Finally, since our estimate of the risk-aversion parameter σ_C exceeds unity (see Table 2), a rise in hours worked (not exhibited) raises the marginal utility of consumption and

positively stimulates consumption. Overall, the positive comovement between investment, hours and consumption in the US reflects in the negative impact of relative international consumption and investment absorption, the low import-intensity of consumption ensuring that the former reacts very mildly compared to the latter. The rise in investment demand is not potent enough to raise domestic prices significantly. However, the price of imports rises strongly, worsening the US terms of trade (not exhibited). The rising domestic terms of trade generates a negative effect on the trade balance owing to the low trade-elasticity, much as in the case of the neutral shock. The negative relative absorption and terms of trade effects swamp the positive effect from dollar depreciation and generates a very strong counter-cyclicality in the trade balance. In fact, the maximum quantitative impact of the US MEI shock – which is observed at a 6-quarter forecast horizon – is many times stronger than that of the neutral technology shock, which explains the vast disparity in strength between the two shocks in the variance decomposition as documented in the preceding section.

The strong and dominating role for MEI shocks for trade balance fluctuations is not a surprise. As documented by Erceg et al. (2008), US exports and imports are heavily concentrated in capital goods and consumer durables. Hence, a domestic or foreign shock that has a considerable impact on investment, also has a much larger effect on the US trade balance than a shock that rather boosts consumption.[21]

3.3.3.2. UIP and RoW export mark-up shocks. The dynamic effects for the two other shocks that matter for trade balance volatility in the short run, *i.e.* a UIP shock (dashed lines) and a RoW export-price mark-up shock (dotted lines), are plotted in the lower panel of Fig. 2. A positive UIP shock, which can be interpreted as a rise in the risk premium on foreign borrowing, creates a wedge between the two nominal interest

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[19] The relative price depreciation triggered by the home productivity shock should be viewed in the context of the debate surrounding this qualitative response. Specifically, Corsetti et al. (2008) demonstrate that an appreciation of the terms of trade is possible, for example when home-bias in absorption is very high and the trade-elasticity is very low. Corsetti et al. (2006) find reduced-form empirical support for this alternative mode of transmission of productivity shocks. Note that even though our estimate of the trade-elasticity is low, we set openness of investment high as in the data. Due to the mild home-bias in investment, the relative demand for the US intermediate goods does not rise strongly enough to appreciate the terms of trade (see also Thoenissen, 2011).

[20] In a calibrated closed-economy model, Furlanetto and Seneca (2010) demonstrate that the combination of these features can resolve the crowding out of consumption by investment shocks pointed out by Barro and King (1984). As a benchmark, they also analyze the case of logarithmic utility ($\sigma_C = 1$) examined by Justiniano et al. (2010, 2011) where consumption is crowded out by a rise in investment even in the presence of sticky prices and variable capacity utilization.

[21] The dynamics induced by the second investment disturbance, the IST shock, in most variables of interest are qualitatively similar to those of the MEI shock, but the magnitudes are mild. The trade balance responds counter-cyclically albeit the movement – just as that for the neutral technology shock – is much weaker than that triggered by the MEI shock. This is not a surprise given that IST shocks explain little of fluctuations in absorption, including investment (see Table 3), which is key for trade balance volatility. Notice that as in Justiniano et al. (2011), the MEI shock is estimated from investment quantity data while the IST shock is restricted by movements in the investment-deflator time series.
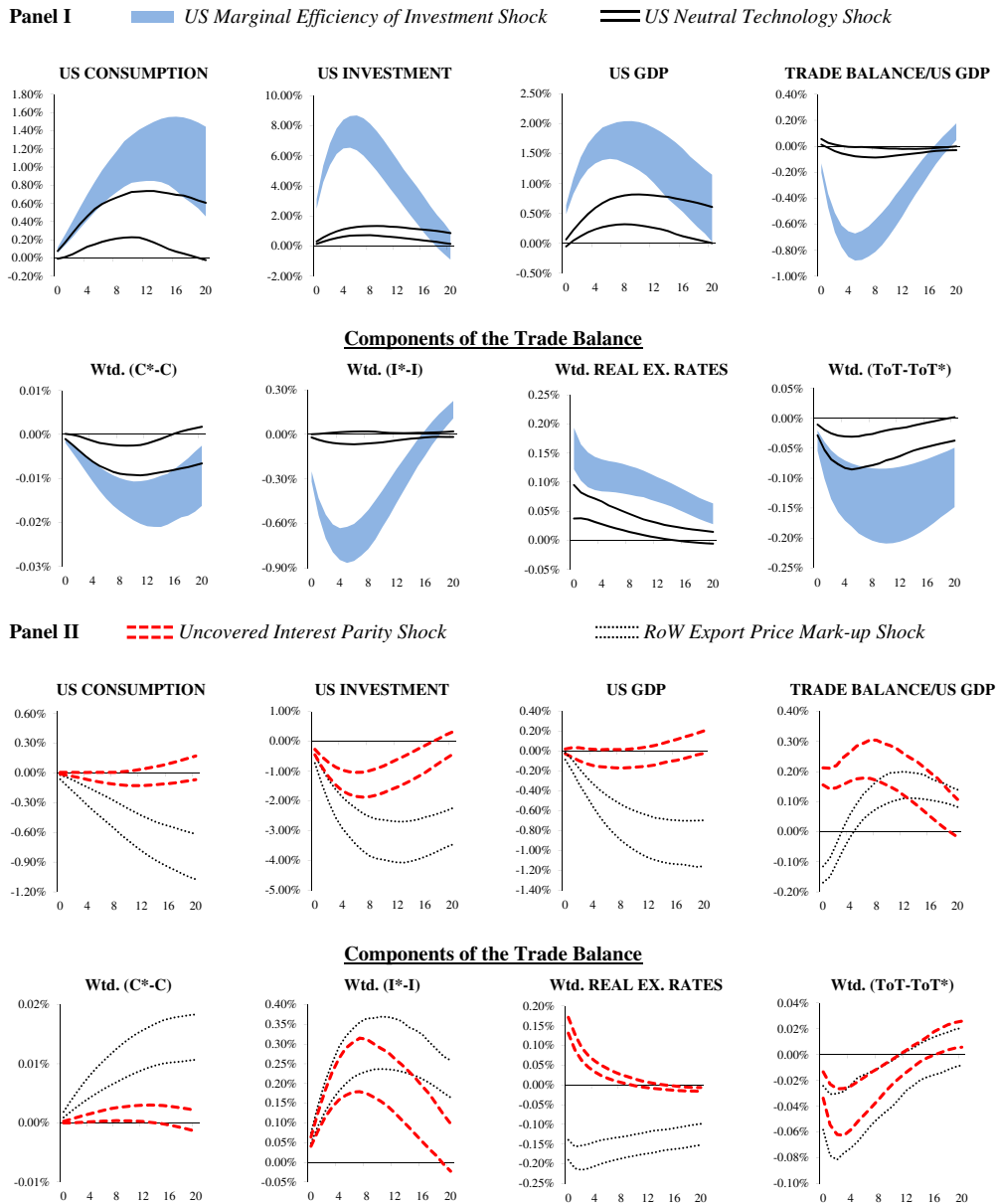
Panel I ▐ *US Marginal Efficiency of Investment Shock* ══ *US Neutral Technology Shock*

Components of the Trade Balance

Panel II ╌╌╌ *Uncovered Interest Parity Shock* ┈┈┈ *RoW Export Price Mark-up Shock*

Components of the Trade Balance

Fig. 2. Estimated impulse response functions of selected variables. *Note*: We present the 5th and 95th percentiles of IRFs computed from 150 random draws from the posterior distribution. The aggregate trade balance impulse response is the sum of the impulse responses of the components. The abbreviation 'Wtd.' indicates that the concerned variable has been multiplied by the coefficient in Eq. (19) in the main text. Importantly, the coefficient on the relative terms of trade is negative because the estimate of the trade-elasticity is below unity.

rates, raising the US interest rate and lowering the RoW analog while also depreciating the dollar in nominal terms. The rise in the home interest rate lowers US consumption and investment while the RoW analogs increase as a consequence of the fall in the RoW interest rate. Relative absorption in both consumption and investment rise, but the latter more strongly than the former. The movements are further reinforced by the strong positive shift in the exchange rate while the effect from the deteriorating relative terms of trade is negative. In effect, the US trade balance improves significantly.

An exogenous increase in the RoW export price deteriorates the US terms of trade very strongly on impact and raises the relative price of investment. Consequently, US investment falls strongly and persistently. The familiar comovement channel, as described above, operates here in reverse, so that US consumption also falls together with hours worked and capacity utilization. The real exchange rates appreciate because the US CPI and investment deflator increase

following the rise in the US import price. Observe that for a shock that emanates mainly from the US terms of trade, the influence of this channel is surprisingly small. This is because the RoW terms of trade also deteriorates due to the appreciation of the dollar which makes US exports more expensive. Thus the movement in the *relative* terms of trade is very small. Overall, the trade balance dynamics are mainly governed by the negative exchange rate appreciation effect on impact while the positive absorption effects from relative consumption and investment dominate after about 6 quarters.

3.3.4. Interpretation of MEI shocks

The importance of MEI shocks for trade balance dynamics necessitates a deeper understanding of their origin. One possible interpretation is offered by Justiniano et al. (2011) who view the MEI shock as a proxy for the efficiency of the latent financial sector in channeling the flow of household savings into new capital. In particular, they draw parallels

between the expansionary effect of the MEI shock on the supply curve of capital and similar effects of entrepreneurial net-worth in the agency cost model of Carlstrom and Fuerst (1997). In empirical support of their interpretation, Justiniano et al. (2011) report that the estimated MEI shock is highly correlated to a data-based measure of the external finance premium - the excess of the interest rate paid by entrepreneurs over the risk-free rate. They observe that typically in periods when the functioning of the financial markets is impaired – *i.e.* the external finance premium is high and net-worth is low – the MEI shock decreases. In what follows, along the lines of Justiniano et al. (2011), we present some evidence in favor of this interpretation of the MEI shock.

In Panel 1 of Fig. 3, we plot our posterior mode estimate of the US MEI shock against the US external finance premium, while Panel 2 displays the analogous series for the RoW. The risk premium is proxied by the excess of the Bank of America Merrill Lynch Corporate BBB Index over the treasury bill rate.[22] Overall, we find a significant negative correlation between the MEI shocks and the interest rate spreads, which is in line with the finding of Justiniano et al. (2011). More precisely, the correlation between the US MEI shock series and the domestic spread is −0.44 for the longest available sample period.[23] When we consider the shorter sample period for which we have spreads data for both regions in the model, *i.e.* 1998–2005, the correlation increases to −0.77. On the other hand, the analogous correlation for the RoW is −0.47.

The substantial correlations between the MEI shocks and the external finance premium, both home and abroad, suggest that these investment disturbances could indicate random variations in the efficiency of credit-allocation. However, our model environment, which abstracts from financial intermediation, constrains us from tracing their structural origin more precisely. Does the MEI shock mask more fundamental financial disturbances? The answer may lie in a recent strand of the closed-economy literature. Christiano et al. (2010, 2012) find that a shock that drives the cross-sectional dispersion of idiosyncratic productivity which stimulates the entrepreneurs' ability to create effective capital from loans, is the main driver of US output volatility. Christiano et al. (2010, 2012) refer to this disturbance as the 'risk' shock.[24] Crucially for the interpretation of the MEI shock as a veil for financial disturbances, Christiano et al. find that if they either do not use financial observables to identify the risk shock or abstract from financial intermediation, the MEI shock becomes the most important determinant of output volatility over the cycle. We stress that given the challenges in preserving empirical tractability, a more nuanced treatment of capital accumulation is difficult to achieve in an already richly specified two-country model as ours. However, the results from the closed-economy literature together with the substantial correlations with interest rate spreads that we find, add substance to the financial interpretation of the MEI shock in the spirit of Justiniano et al. (2011).

4. Sensitivity analysis

In this section, we present a suite of robustness checks to evaluate the strength of the MEI shock and to clarify which features of the

model are crucial to explain the differences of our results relative to the existing literature. The outcome of the analysis is summarized in Table 4, which reports the variance decompositions at a 4 quarter forecast horizon for the trade balance. Due to space constraints, we do not report all the changes in model equations and parameter estimates for each specification. For details and additional sensitivity checks, we refer to the Jacob and Peersman (2008) working paper version of this paper. In particular, the results turn out to be robust, *i.e.* we consistently find a dominant role for MEI shocks, when we (a) use the non-energy trade balance series (b) use detrended data (c) assume complete markets instead of incomplete markets and (d) assume Jaimovich and Rebelo (2009) preferences.

As a first check, we supplant the UIP shock with a (relative) US home-bias preference shock which decreases the import-shares of consumption and investment. This disturbance can potentially disconnect trade balance dynamics from other variables because it directly stimulates the import-demand functions and acts as the trade balance's own driving force. However, as shown in Column 2, MEI shocks also retain their dominant influence even after the introduction of this open-economy disturbance.

Why do our results differ from those of Bergin (2006) and De Walque et al. (2005), our precedents in the empirical open-economy literature who find no substantive effect of MEI shocks on US trade balance fluctuations?[25] First, both studies use the popular aggregation set-up as in Backus et al. (1994), henceforth BKK, so that the share of imports in the final good is specified in terms of total absorption. Column 3 of Table 4 shows the variance decomposition of the trade balance for this specification when we fix the import-share of aggregate absorption at 0.15 as in BKK. As can be seen, the contribution of MEI shocks is almost halved. This is not a surprise since the BKK aggregator does not distinguish between final investment and consumption goods, whereas our model allows investment to be more open to imports than consumption.

Bergin (2006) estimates a symmetric two-country model using five structural shocks for the US and a rest of the G-7 aggregate. He has a home-bias shock that directly affects the import-share in the Armington aggregator and does not use investment-specific shocks or data. He finds that shocks to UIP, consumption and home-bias matter most for the dynamics of the current account. The fourth column shows the results for a simplified version of our baseline model that is as close as possible to the Bergin (2006) small-scale set-up. This exercise suggests that, when MEI shocks are omitted from the analysis, the contribution of these shocks to the trade balance is indeed mainly absorbed by UIP, consumption and home-bias shocks.

De Walque et al. (2005) use a large-scale two-country model to examine the aggregate US and Euro-Area trade balances. Notably, they do not consider the bilateral balance between the two regions. In their trade structure, aggregate US (Euro-Area) exports are demanded by the Euro-Area (US) and an unmodeled Rest of the World that is captured through export-demand shocks that enter the definition of the US trade balance. They find that this shock accounts between 40 and 65% of trade balance volatility, whereas investment-specific shocks contribute less than 3%. To analyze the role of this omitted RoW export-demand shock more carefully, we have also estimated a model with the BKK aggregator and an additional demand shock for US exports. When we still assume an import-share of 15% in GDP (Column 5 of Table 4), MEI shocks still dominate, while the export-demand shock contributes about 17% to the forecast variance of the trade balance.

Fig. 3. The MEI shock and the external finance premium. *Note*: The MEI shocks are distilled by applying the Kalman smoother when the parameters are set at the posterior mode. The external finance premium is proxied by the excess of BBB bond yields over the treasury bill rates or government bond yields. All series presented in the figure are standardized.

However, the decomposition changes dramatically when we *estimate* the import-share as in De Walque et al. (2005). The posterior estimate of this parameter turns out to be close to 2%.[26] As one can observe in the last column of Table 4, the export shock now contributes about 54% of the forecast variance. The main reason is that the very low import-share makes the two regions behave almost as autarkic economies. The trade balance becomes a disconnected variable, with the more fundamental shocks having a minimal relative impact. Justiniano and Preston (2010) note that the openness parameter can reduce to unrealistic values if left unrestricted in an estimation exercise. Since the import-share of 2% obtained in this experiment is much lower than the unconditional import-share of about 15% observed in US data, it is hard to recognize the non-structural export demand shock as the dominant source of trade balance fluctuations. Openness clearly matters in the transmission of fundamental domestic disturbances to the external position.

5. Conclusions

This paper has highlighted the influence of marginal efficiency of investment shocks on the bilateral trade balance between the US and a trade-weighted aggregate of sixteen OECD economies within a two-country DSGE model estimated with Bayesian methods. The relative strength of the marginal efficiency shock is persistent and holds through a wide array of model specifications. This is primarily due to its strong impact on international relative absorption, investment absorption in particular. On the other hand, shocks which transmit mainly through the international relative prices, namely disturbances to uncovered interest parity and the foreign export price mark-up, have a substantial impact over very short forecast-horizons, before the investment shocks begin to dominate. Clearly, pinpointing the sources of the alterations to investment frictions is key to better understand the dynamics of the US trade balance.

Our estimates of the marginal efficiency shocks are substantially negatively correlated with measures of the external finance premium, both in the US and abroad. While these correlations suggest that these disturbances may be reduced-form indicators of random changes in the efficiency of credit-allocation, we emphasize that a refined interpretation requires a more sophisticated modeling of capital accumulation.

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[26] De Walque et al. (2005) uses a very restrictive prior centered on the share of 5% that is accounted by European exports in US GDP and their posterior estimates are exactly the same as the prior.

Table 4
4-quarter ahead trade balance variance decompositions in robustness checks.

	Specifications					
	Baseline	Home-bias	BKK	B-type	DSW-15%	DSW-2%
	(CvsI)	(CvsI)	(Ag.Ab.)	(Ag.Ab.)	(Ag.Ab.)	(Ag.Ab.)
Shocks						
Marginal efficiency of investment	86.48	87.31	43.82		41.48	6.23
Consumption time impatience	0.03	0.07	3.68	45.78	5.15	0.93
Uncovered interest parity	7.93		19.16	24.87	19.16	32.74
US home bias		7.07		20.73		
US export demand	16.77	53.82				
Others	5.56	5.54	33.34	8.63	17.44	6.28

Note: In all our checks, the number of shocks used equals the number of observables used in the estimation. The contributions of analogous US and RoW shocks are aggregated. All models using different import-intensities for consumption and investment are denoted by (CvsI) while the others using the traditional aggregate absorption-based specification are denoted by (Ag.Ab.). Whenever a shock is deactivated, the variance contribution is indicated by a blank cell. 'Baseline' indicates the baseline model. 'Home-Bias' indicates the use of a US import-share shock, instead of the UIP shock. 'BKK' employs the Backus et al. (1994) aggregation of home and imported goods specified in terms of aggregate absorption (Ag.Ab = C + I). 'B-Type' uses the BKK trade specification and strips the baseline model of many features, shocks and observables to facilitate a closer comparison with Bergin (2006). 'DSW- 15%' employs the export shock as in De Walque et al. (2005) while fixing the import-intensity at 15% as in Backus et al. (1994). 'DSW-2%', we estimate the import-share in the De Walque et al. (2005) model and obtain a value of about 2%.

Hence, the precise structural origin of this investment disturbance is still open to debate. A natural extension of our work, is to incorporate a financial intermediation sector and related shocks and data series, as in the closed-economy literature, *e.g.* Christiano et al. (2010, 2012) and Jermann and Quadrini (2012). An alternative source of investment frictions that the above-mentioned financial literature as well as this paper have abstracted from, is a time-varying distortionary tax on capital income as in *e.g.* McGrattan (1994). A quantitative evaluation of the cyclical dynamics triggered by shocks to these different sources of investment frictions would be an instructive exercise. Furthermore, the open-economy implications of these financial and policy disturbances are less known and it would be interesting to see whether they enable real exchange rate appreciations during domestic booms, an empirical regularity emphasized by Corsetti et al. (2008) and Raffo (2010). Observe that in our set-up, domestic booms triggered by investment shocks are accompanied by a depreciation of the terms of trade and real exchange rate, due to a strong rise in the import-demand for investment. A somewhat different avenue to explore, is to introduce energy imports as in Bodenstein et al. (2011). The aggregate trade balance can then be accommodated in our framework and one can examine the interactions between its energy and non-energy components together with the joint behavior of relative quantities and prices. The computational challenges notwithstanding, these extensions of the empirical agenda presented in this paper will considerably enhance our understanding of the open-economy business cycle.

Appendix A

A.1. The non-linear model

Here we list the original non-linear forms of the log-linearized conditions in the order followed in the main text. We also detail the underlying functional forms for preferences and technology. For brevity, we do not present the optimality conditions for price and wage-setting. Note that output, consumption, investment, net foreign assets and the real wage grow at the rate of permanent technological progress along the balanced growth path. Hence we stationarize the concerned variables, before we log-linearize the model to obtain the equations in the main text. After the log-linearization of the model, the shocks to impatience $\left(\tilde{\varepsilon}^{TI}\right)$, MEI $\left(\tilde{\varepsilon}^{MEI}\right)$, government spending $\left(\tilde{\varepsilon}^{G}\right)$, wage mark-up $\left(\tilde{\varepsilon}^{WM}\right)$ and export price mark-up $\left(\tilde{\varepsilon}^{X}\right)$ are rescaled so that they have unit coefficients when the model is linked to the data. The strategy of rescaling residuals is innocuous and is common in the empirical literature, *e.g.* Smets and Wouters (2007) and Justiniano et al. (2010, 2011),

because it improves the convergence properties of the parameter estimates. Further details pertaining to the stationarization and log-linearization of the model are available on request.

1. Consumption and investment deflators (Eqs. (1) and (2)

$$P_{Ct} = \left[(1-m_C)P_{Ht}^{1-\mu} + m_C P_{Ft}^{1-\mu}\right]^{\frac{1}{1-\mu}}$$

$$P_{It} = \frac{1}{\varepsilon_t^{IST}}\left[(1-m_I)P_{Ht}^{1-\mu} + m_I P_{Ft}^{1-\mu}\right]^{\frac{1}{1-\mu}}$$

The analogous CES aggregators given by $C_t = \left[(1-m_C)^{\frac{1}{\mu}}C_{Ht}^{\frac{\mu-1}{\mu}} + m_C^{\frac{1}{\mu}}C_{Ft}^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}}$ and $I_t = \varepsilon_t^{IST}\left[(1-m_I)^{\frac{1}{\mu}}I_{Ht}^{\frac{\mu-1}{\mu}} + m_I^{\frac{1}{\mu}}I_{Ft}^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}}$.

2. Demands for domestic and imported components (Eqs. (3) and (4))

$$C_{Ht} = (1-m_C)\left(\frac{P_{Ht}}{P_{Ct}}\right)^{-\mu}C_t, I_{Ht} = \left(\varepsilon_t^{IST}\right)^{\mu-1}(1-m_I)\left(\frac{P_{Ht}}{P_{It}}\right)^{-\mu}I_t$$

$$C_{Ft} = m_C\left(\frac{P_{Ft}}{P_{Ct}}\right)^{-\mu}C_t, I_{Ft} = \left(\varepsilon_t^{IST}\right)^{\mu-1}m_I\left(\frac{P_{Ft}}{P_{It}}\right)^{-\mu}I_t$$

3. Consumption Euler (Eq. (5))

$$\tilde{\varepsilon}_t^{TI}(C_t-hC_{t-1})^{-\sigma_c}\exp\left(\frac{\sigma_C-1}{1+\sigma_N}N_t^{1+\sigma_N}\right)$$
$$= \beta\mathbf{E}_t\tilde{\varepsilon}_{t+1}^{TI}(C_{t+1}-hC_t)^{-\sigma_c}\exp\left(\frac{\sigma_C-1}{1+\sigma_N}N_{t+1}^{1+\sigma_N}\right)\frac{R_t}{\pi_{Ct+1}}$$

The optimal consumption plan is based on the Smets and Wouters (2007) utility function: $U(C_t, N_t) = \frac{(C_t-hC_{t-1})^{1-\sigma_c}}{1-\sigma_c}\exp\left(\frac{\sigma_c-1}{1+\sigma_N}N_t^{1+\sigma_N}\right)$.

4. Uncovered interest parity (Eq. (6))

$$\frac{R_t}{R_t^*}\left(1 + \frac{\kappa}{\bar{y}}\frac{NFA_t}{\varepsilon_t^{WORLD}}\right) = \mathbf{E}_t\frac{NEx_{t+1}}{NEx_t}$$

5. Tobin's Q (Eq. (7))

$$TQ_t = \beta\mathbf{E}_t\frac{U_{Ct+1}}{U_{Ct}}\left[\frac{R_{t+1}^k}{P_{Ct+1}}U_{t+1}^{\bar{K}} - \frac{P_{Ht+1}}{P_{Ct+1}}a\left(U_{t+1}^{\bar{K}}\right) + TQ_{t+1}(1-\delta)\right]$$

where capacity utilization rate $U^{\bar{K}} = 1$ in steady-state and the utilization cost function $a(1) = 0$, $a'(1)$, $a''(1) > 0$. As in Smets and Wouters (2007), we define $(\varphi-1)/\varphi = a'(1)/a''(1)$.

6. Physical capital accumulation (Eq. (8))

$$I_t \tilde{\varepsilon}_t^{\text{MEI}} \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] + (1-\delta)\overline{K}_{t-1} = \overline{K}_t$$

where $S(.)$ is an adjustment cost function with the steady-state properties $S(\overline{\gamma}) = S'(\overline{\gamma}) = 0$ and $S''(\overline{\gamma}) = \phi > 0$.

7. Investment Euler (Eq. (9))

$$TQ_t \tilde{\varepsilon}_t^{\text{MEI}} \left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - \frac{I_t}{I_{t-1}} S'\left(\frac{I_t}{I_{t-1}}\right)\right]$$
$$+ \beta \mathbf{E}_t \frac{U_{Ct+1}}{U_{Ct}} TQ_{t+1} \tilde{\varepsilon}_{t+1}^{\text{MEI}} \frac{I_{t+1}^2}{I_t^2} S'\left(\frac{I_{t+1}}{I_t}\right)$$
$$= \frac{P_{It}}{P_{Ct}}$$

8. Optimal capacity utilization (Eq. (10))

$$\alpha'\left(U_t^{\overline{K}}\right) = \frac{R_t^k}{P_{Ht}}$$

9. Production FUNCTION (Eq. (12))

$$Y_{Ht} = \varepsilon_t^{\text{NEU}} \left(K_t^S\right)^\alpha \left(\varepsilon_t^{\text{WORLD}} N_t\right)^{1-\alpha} - \varepsilon_t^{\text{WORLD}} F$$

where capital services $K_t^S = U_t^{\overline{K}} \overline{K}_{t-1}$. ε^{NEU} is a stationary region-specific stochastic process while $\varepsilon_t^{\text{WORLD}}$ is a global non-stationary deterministic process such that $\varepsilon_t^{\text{WORLD}}/\varepsilon_{t-1}^{\text{WORLD}} = \overline{\gamma} > 1$. F is a fixed cost.

10. Rental rate of capital (Eq. (13))

$$\frac{R_t^k}{P_{Ht}} = \frac{W_t}{P_{Ht}} \frac{N_t}{K_t^S}$$

where R^k and W are the nominal payments to capital and labor.

11. Real marginal cost (Eq. (15))

$$RMC_t = \frac{1}{\alpha^\alpha (1-\alpha)^{1-\alpha} \varepsilon_t^{\text{NEU}}} \left(\frac{R_t^k}{P_{Ht}}\right)^\alpha \left(\frac{W_t}{P_{Ht} \varepsilon_t^{\text{WORLD}}}\right)^{1-\alpha}$$

12. Goods market clearing (Eq. (17))

$$Y_{Ht} = C_{Ht} + I_{Ht} + C_{Ht}^* + I_{Ht}^* + \tilde{\varepsilon}_t^G + a\left(U_t^{\overline{K}}\right)\overline{K}_{t-1}$$

13. Balance of payments (Eq. (18))

$$NEx_t NFA_t - R_t^* NEx_t NFA_{t-1} = NEx_t P_{Ht}^* (C_{Ht}^* + I_{Ht}^*) - P_{Ft}(C_{Ft} + I_{Ft})$$

14. Monetary policy (Eq. (20))

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_{\text{MON}}} \left[\left(\frac{\pi_t}{\overline{\pi}}\right)^{\phi_\pi} \left(\frac{Y_{Ht}}{Y_{Ht}^{flex}}\right)^{\phi_y}\right]^{1-\rho_{\text{MON}}} \left(\frac{Y_{Ht}/Y_{Ht-1}}{Y_{Ht}^{flex}/Y_{Ht-1}^{flex}}\right)^{\phi_{\Delta y}} \exp\eta_t^{\text{MON}}$$

A.2. Data series

All raw series are seasonally adjusted by the Census X12 method. We use the Direction of Trade Statistics (DOTS) database of the International Monetary Fund (IMF) to construct the annualized aggregated bilateral trade balance (net-exports in US dollars) between the US and the 16 OECD trade partners over 1980Q1–2005Q4. The series for nominal GDP, nominal consumption, nominal gross fixed capital formation, nominal interest rates and nominal wages for the US, Canada, Japan, Korea and the UK are obtained from the International Financial Statistics Database (IFS) of the IMF. For the Euro-Area series, we use data from the Area Wide Model (Fagan et al., 2001).[27] We draw import and export price series for the US from the IFS. The series for consumer durables for the US is drawn from the FRED II database of the Federal Reserve Bank of St. Louis. As mentioned in the main text, we add consumer durables and inventories (IFS) to the US series on gross fixed capital formation while subtracting expenditure on durables from US consumption. We use the gross private domestic investment deflator series from the Bureau of Economic Analysis while the investment deflators for the trade partners are drawn from the OECD Quarterly National Accounts database and the Area Wide Model. Shares of each individual economy are computed by dividing the sum of imports and exports with the individual economy by aggregate trade. We use these time-varying weights to aggregate individual economy series to make the RoW (Canada generally gets the highest weight while Korea gets the lowest). We multiply the natural logarithms of real consumption, real GDP, real investment, the investment deflator, the GDP deflator, the real wage, export prices and import price by 100. These series are fed into the model in first-differences. Since the model predicts that the trade balance is zero in steady-state, the trade balance to US GDP ratio is not logged and enters the estimation in first-differences. The nominal interest rates are divided by 4 to translate them into quarterly terms and enter the estimation in levels. To construct the trade-weighted high-yield bond rate for the RoW, we use Dex capital overall BBB index for Canada and Bank of America Merrill Lynch BBB (local currency) Indices for the Euro-Area and Japan and the IBoxx Non-Gilts BBB Index for the UK. We omit Korea which makes less than 5% of the RoW aggregate as the series its high-yield indices are very short. For the risk-free rate, we use the treasury bill rates for Canada and the UK, the government bond yield for Japan and the French treasury bill rate for the Euro-Area.

A.3. Estimation

All our estimations are implemented using the Matlab-based toolbox Dynare (see Adjemian et al., 2011). We use 525,000 iterations of the Random Walk Metropolis Hastings algorithm to simulate the posterior distributions and achieve acceptance rates of below 35% in all our specifications. We monitor the convergence of the marginal posterior distributions using CUMSUM statistics as defined by Bauwens et al. (1999). We discard the initial 25,000 draws to compute the posterior moments in each case. The distributions of impulse response functions and variance decompositions that we present are computed from 150 random draws from the posterior. This strategy ensures that our results are not contingent on a particular vector of parameter values such as the posterior median or the mode.

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