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The Global Component of Local Inflation: Revisiting the Empirical Content of the Global Slack Hypothesis with Bayesian Methods[*]

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Abstract

The global slack hypothesis is central to the discussion of the trade-offs that monetary policy faces in an increasingly more integrated world. The workhorse New Open Economy Macro (NOEM) model of Martínez-García and Wynne (2010), which fleshes out this hypothesis, shows how expected future local inflation and global slack affect current local inflation. In this paper, I propose the use of the orthogonalization method of Aoki (1981) and Fukuda (1993) on the workhorse NOEM model to further decompose local inflation into a global component and an inflation differential component. I find that the log-linearized rational expectations model of Martínez-García and Wynne (2010) can be solved with two separate subsystems to describe each of these two components of inflation. I estimate the full NOEM model with Bayesian techniques using data for the U.S. and an aggregate of its 38 largest trading partners from 1980Q1 until 2011Q4. The Bayesian estimation recognizes the parameter uncertainty surrounding the model and calls on the data (inflation and output) to discipline the parameterization. My findings show that the strength of the international spillovers through trade—even in the absence of common shocks—is reflected in the response of global inflation and is incorporated into local inflation dynamics. Furthermore, I find that key features of the economy can have different impacts on global and local inflation—in particular, I show that the parameters that determine the import share and the price-elasticity of trade matter in explaining the inflation differential component but not the global component of inflation.

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1 Introduction

Martínez-García (2008) and Martínez-García and Wynne (2010) build on the New Open Economy Macro (NOEM) literature (see, e.g., the related work of Clarida et al. (2002)) to develop a tractable theory of the relationship between the cyclical component of local inflation and developments in global economic activity as measured by global slack—the so-called 'global slack hypothesis.' As the economy becomes more integrated with the rest of the world through trade, the direct contribution of inflation on imported goods to local inflation naturally rises. However, as explained in Martínez-García and Wynne (2013), the 'global slack hypothesis' suggests that the changing dynamics of local inflation may be the result of increased international competition and reflect the fact that increasingly local producers can charge more for their goods in their domestic market when they face increases in world demand even when domestic demand remains unchanged.

A closer inspection of the empirical evidence on both the role that trade openness plays on the dynamics of inflation and on the support that the data provides for the global slack hypothesis is warranted. There are well-known drawbacks and mixed evidence found with reduced-form estimates of the empirical relationship between cyclical inflation and global slack (see, e.g., Borio and Filardo (2007), Ihrig et al. (2007), Martínez-García and Wynne (2013) for further discussion). Therefore, a structural approach for estimation and empirical inference has been suggested instead.

However, a fully structural approach to the estimation of the 'global slack hypothesis' requires a general-equilibrium model that incorporates the many factors and diverse channels that are influencing the global economy which can then be taken to the data for validation. The NOEM model of Martínez-García and Wynne (2010) is an important step in the direction of building such a model, but bringing it to the data is not without its challenges (as shown in Martínez-García et al. (2012) and Martínez-García and Wynne (2014)).

In order to explore further the dynamics of local inflation through the lens of the NOEM model, I propose an alternative approach with less ambitious aims but with concrete results. On the one hand, I propose to use the orthogonalization method advocated by Aoki (1981) and Fukuda (1993) to re-express the workhorse model of Martínez-García and Wynne (2010) into two separate sub-systems which describe global inflation and the inflation differentials across countries. The decomposition is arguably model-specific, but it illustrates that when open to trade the dynamics of local inflation fluctuate around the path of global inflation (whereby global inflation helps explain and even predict future local inflation). Local inflation has a common component (measured by global inflation) even when all shocks driving business cycle fluctuations are country-specific—that is, even when there are no common shocks driving the global cycle—through those trade linkages.

On the other hand, I argue that beyond the theory data is needed to assess the empirical significance of the global component of local inflation. In order to better understand the strength of the international transmission mechanism of shocks embedded in the model of Martínez-García and Wynne (2010), I estimate a standard version of it for the U.S. and for an aggregate of its 38 largest trading partners—using data from 1980Q1 until 2011Q4 on PPP-adjusted real GDP and CPI inflation.

The Bayesian estimation and forecasting methods that I use have a long history in econometrics—one of the seminal works cited in this field is Zellner (1971). Adolfson et al. (2005), Adolfson et al. (2007) and Adolfson et al. (2008) are among the recent papers that have attempted a more structural approach to open-economy estimation using Bayesian techniques.

In contrast to classical methods, the main advantages of Bayesian techniques for evaluating open-economy models are: (a) They treat unobserved variables (such as measures of slack) and parameters as jointly distributed random variables implying that the Bayesian estimates of each more appropriately reflect the uncertainty about the others; and (b) They take advantage of subjective and/or out-of-sample prior information for inference. I follow this route and estimate the NOEM model with Bayesian techniques. However, given that this workhorse model remains quite stylized, I interpret my estimation results from a more limited perspective. Simply put, I estimate the NOEM model to discipline its parameterization and to ensure that its predictions—on which I base my assessment—are not out of line with the actual data that I seek to better understand.

The model presented in this paper can be used to evaluate how global inflation and inflation differentials are incorporated into the dynamics of local inflation. More specifically, it demonstrates that the nature of shocks and the structure of the economy matter when investigating how local inflation responds to shocks—but that those features work differently on the global component of local inflation than on the inflation differential component. Even without common (or strongly correlated) shocks, I show empirically that spillovers from shocks occurring in one country get incorporated into the inflation process of other economies so long as those countries are intertwined through trade. These spillovers go above and beyond the effects that may arise from the exogenous comovement between country-specific shocks. However, changes in global inflation which affect all economies are not the only factor to consider. The features of the economy that affect the differential responses in inflation in response to the direct impact from shocks can also play a crucial role in how the local inflation response unfolds.

Thus, with the additional insights and evidence presented here to help understand how local inflation is influenced by foreign developments, the contribution of the global component of inflation may be better delineated. My hope is that these ideas will contribute to a deeper understanding of foreign influences on local inflation and that they can be used to develop better tests of the 'global slack hypothesis' but also better tools/indicators for forecasting inflation and for policymaking.

The remainder of the paper proceeds as follows: Section 2 outlines the building blocks of the workhorse NOEM model of Martínez-García and Wynne (2010), and discusses the log-linearized equilibrium conditions that I use to approximate its solution. In Section 3, I discuss the data and priors used to estimate the model with Bayesian methods. Section 4 applies the Aoki (1981) and Fukuda (1993) decomposition to the model illustrating the theoretical role that global inflation can play on the dynamics of local inflation. Then, it proceeds to discuss the Bayesian estimation of the model and its predictions for both global and local inflation. Section 5 provides a recap of the insights gained from this exercise, and concludes. A brief Appendix with the relevant proofs is also provided.

2 A Model of Inflation Determination in the Global Economy

In this paper I investigate how global inflation arises from country-specific shocks in an open-economy setting, what drives global and local inflation, and the contribution of the global component to local inflation. I build my analysis on the workhorse New Open Economy Macro (NOEM) model laid out in Martínez-García and Wynne (2010)[1] The two-country dynamic stochastic general equilibrium model of Martínez-García and

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[1] A seminal contribution in the development of the workhorse NOEM framework of Martínez-García and Wynne (2010) is the model of Clarida et al. (2002).

Wynne (2010) provides a very tractable environment under monetary non-neutrality to more deeply explore the dynamics of global and local inflation and the international propagation mechanism for country-specific shocks.

The model features nominal rigidities modelled with two standard distortions in the markets for goods: monopolistic competition in production and price-setting behavior constrained by contracts à la Calvo (1983). Monopolistic competition distorts labor allocation which can be undone with a labor subsidy for local firms funded with non-distortionary, lump-sum taxes raised from local households. Short-run monetary non-neutrality—the implication that monetary shocks have real effects—hinges on the assumption of price stickiness. However, the introduction of price stickiness à la Calvo (1983) does not overturn long-run monetary neutrality in the model.

As in Martínez-García and Wynne (2010), only country-specific shocks are considered explicitly in the model. Hence, the response of global inflation to shocks and its influence on local inflation must arise entirely through the effect of cross-border spillovers arising through trade. In the model I retain the conventional distinction between aggregate supply-side drivers of the business cycle (aggregate productivity shocks) and aggregate demand-side drivers (monetary policy shocks) in order to identify the international transmission of country-specific shocks and its impact on local inflation, conditional upon different sources of business cycle movements.

I adopt the standard cashless economy specification where money only plays the role of unit of account—for further discussion on this, see chapter 2 in Woodford (2003). I assume pass-through is complete (even with price stickiness) and that the law of one price holds at the variety level because prices are set domestically and in the export markets in the producer's own currency.[2] Deviations from purchasing power parity (PPP) still arise in the aggregate whenever households put a higher weight on domestic varieties in their consumption basket than on the share domestically-produced varieties represent of the world production of differentiated varieties (local-consumption bias).

For simplicity, I abstract from capital accumulation—considering only linear-in-labor technologies—and I assume complete domestic and international asset markets. The model can be augmented with capital accumulation and the assumption of complete international asset markets can also be relaxed, but the added complexity that comes from including those features does not seem warranted for the general goals of this paper. As shown extensively in the work of Martínez-García and Søndergaard (2009), Martínez-García (2011) and Martínez-García and Søndergaard (2013), those features do not necessarily change qualitatively—even though they may change quantitatively—the implication that international spillovers through trade play a key role in explaining the dynamics of global inflation and its contribution to local inflation.

2.1 Building Blocks of the New Open-Economy Macro (NOEM) Model

Households. The lifetime utility for the representative household in the Home country is additively separable into consumption, C_t, and labor, L_t, i.e.,

$$\sum\nolimits_{\tau=0}^{+\infty} \beta^{\tau} \mathbb{E}_t \left[\frac{1}{1-\gamma} \left(C_{t+\tau}\right)^{1-\gamma} - \frac{\kappa}{1+\varphi} \left(L_{t+\tau}\right)^{1+\varphi} \right], \tag{1}$$

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[2] For details on the role of international price-setting in the conduct of optimal monetary policy and the international propagation mechanism see Engel (2009).

where $0 < \beta < 1$ is the subjective intertemporal discount factor, $\gamma > 0$ is the inverse of the intertemporal elasticity of substitution, and $\varphi > 0$ is the inverse of the Frisch elasticity of labor supply. The scaling factor $\kappa > 0$ determines the steady-state labor. The Home household maximizes its lifetime utility subject to the sequence of budget constraints,

$$P_t C_t + \int_{\omega_{t+1} \in \Omega} Q_t(\omega_{t+1}) B_t(\omega_{t+1}) \leq B_{t-1}(\omega_t) + W_t L_t + Pr_t - T_t, \tag{2}$$

where W_t is the nominal wage in the Home country, P_t is the Home consumption price index (CPI), T_t is a nominal lump-sum tax (or transfer) from the Home government, and Pr_t are (per-period) nominal profits from all firms producing the Home varieties. The budget constraint includes a portfolio of one-period Arrow-Debreu securities (contingent bonds) traded internationally and in zero net supply, $B_t(\omega_{t+1})$. For simplicity, these contingent bonds are quoted in the unit of account of the Home country. The Home price of the contingent bonds is denoted $Q_t(\omega_{t+1})$, while S_t is the nominal exchange rate and the Foreign price of the contingent bonds is simply $Q_t^*(\omega_{t+1}) = \frac{1}{S_t} Q_t(\omega_{t+1})$. Similarly, for the representative household in the Foreign country.

Access to a full set of internationally-traded, one-period Arrow-Debreu securities completes the local and international asset markets recursively. Under complete asset markets, households can perfectly share risks domestically and internationally. Hence, the intertemporal marginal rate of substitution is equalized across countries in every state of nature,

$$\beta \left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} \frac{P_t}{P_{t+1}} = \beta \left(\frac{C_{t+1}^*}{C_t^*} \right)^{-\gamma} \frac{P_t^* S_t}{P_{t+1}^* S_{t+1}}, \tag{3}$$

where P_t^* is the Foreign CPI and C_t^* stands for Foreign consumption. I define the real exchange rate as $RS_t \equiv \frac{S_t P_t^*}{P_t}$, so by backward recursion the *perfect international risk-sharing condition* in (3) becomes,

$$RS_t = \upsilon \left(\frac{C_t^*}{C_t} \right)^{-\gamma}, \tag{4}$$

where $\upsilon \equiv \frac{S_0 P_0^*}{P_0} \left(\frac{C_0^*}{C_0} \right)^{\gamma}$ is a constant that depends on initial conditions. If the initial conditions correspond to the symmetric steady state, then the constant υ is equal to one. From the price of the contingent Arrow-Debreu securities, I obtain a standard pair of stochastic Euler equations for both countries,

$$\frac{1}{1+i_t} = \beta \mathbb{E}_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} \frac{P_t}{P_{t+1}} \right], \tag{5}$$

$$\frac{1}{1+i_t^*} = \beta \mathbb{E}_t \left[\left(\frac{C_{t+1}^*}{C_t^*} \right)^{-\gamma} \frac{P_t^*}{P_{t+1}^*} \right], \tag{6}$$

where i_t is the riskless, nominal interest rate in the Home country and i_t^* is its Foreign country counterpart.

The households' optimization problem also results in a pair of labor supply equations,

$$\begin{aligned}
\frac{W_t}{P_t} &= \kappa \left(C_t\right)^{\gamma} \left(L_t\right)^{\varphi}, \qquad (7) \\
\frac{W_t^*}{P_t^*} &= \kappa \left(C_t^*\right)^{\gamma} \left(L_t^*\right)^{\varphi}, \qquad (8)
\end{aligned}$$

plus the appropriate (no-Ponzi games) transversality conditions and the budget constraints of both representative households.

C_t is a CES aggregator of Home and Foreign goods for the representative Home household defined as,[3]

$$C_t = \left[(\xi)^{\frac{1}{\sigma}} \left(C_t^H\right)^{\frac{\sigma-1}{\sigma}} + (1-\xi)^{\frac{1}{\sigma}} \left(C_t^F\right)^{\frac{\sigma-1}{\sigma}} \right], \qquad (9)$$

where $\sigma > 0$ is the elasticity of substitution between the Home-produced consumption bundle C_t^H and the Foreign-produced consumption bundle C_t^F. Analogous preferences are assumed for the Foreign representative household, except that C_t^* is defined as a CES aggregator of Home and Foreign goods in the following terms,

$$C_t^* = \left[(1-\xi)^{\frac{1}{\sigma}} \left(C_t^{H*}\right)^{\frac{\sigma-1}{\sigma}} + (\xi)^{\frac{1}{\sigma}} \left(C_t^{F*}\right)^{\frac{\sigma-1}{\sigma}} \right]. \qquad (10)$$

The share of Home-produced goods in the Home consumption basket and Foreign-produced goods in the Foreign basket must satisfy that $\frac{1}{2} \leq \xi < 1$.

The sub-indexes C_t^H and C_t^{H*} indicate respectively Home and Foreign consumption of the bundle of differentiated varieties produced in the Home country. Similarly, C_t^F and C_t^{F*} denote Home and Foreign consumption of the bundle of differentiated varieties produced in the Foreign country. These sub-indexes are defined as follows,

$$\begin{aligned}
C_t^H &= \left[\left(\frac{1}{2}\right)^{-\frac{1}{\theta}} \int_0^{\frac{1}{2}} C_t\left(h\right)^{\frac{\theta-1}{\theta}} dh \right]^{\frac{\theta}{\theta-1}}, \; C_t^F = \left[\left(\frac{1}{2}\right)^{-\frac{1}{\theta}} \int_{\frac{1}{2}}^1 C_t\left(f\right)^{\frac{\theta-1}{\theta}} df \right]^{\frac{\theta}{\theta-1}}, \qquad (11) \\
C_t^{H*} &= \left[\left(\frac{1}{2}\right)^{-\frac{1}{\theta}} \int_0^{\frac{1}{2}} C_t^*\left(h\right)^{\frac{\theta-1}{\theta}} dh \right]^{\frac{\theta}{\theta-1}}, \; C_t^{F*} = \left[\left(\frac{1}{2}\right)^{-\frac{1}{\theta}} \int_{\frac{1}{2}}^1 C_t^*\left(f\right)^{\frac{\theta-1}{\theta}} df \right]^{\frac{\theta}{\theta-1}}, \qquad (12)
\end{aligned}$$

where $\theta > 1$ is the elasticity of substitution across differentiated varieties within a country. Similarly, total output and labor are expressed as,

$$\begin{aligned}
\frac{1}{2}Y_t &= \left[\left(\frac{1}{2}\right)^{-\frac{1}{\theta}} \int_0^{\frac{1}{2}} Y_t\left(h\right)^{\frac{\theta-1}{\theta}} dh \right]^{\frac{\theta}{\theta-1}}, \; \frac{1}{2}Y_t^* = \left[\left(\frac{1}{2}\right)^{-\frac{1}{\theta}} \int_{\frac{1}{2}}^1 Y_t^*\left(f\right)^{\frac{\theta-1}{\theta}} df \right]^{\frac{\theta}{\theta-1}}, \qquad (13) \\
\frac{1}{2}L_t &= \left[\left(\frac{1}{2}\right)^{-\frac{1}{\theta}} \int_0^{\frac{1}{2}} L_t\left(h\right)^{\frac{\theta-1}{\theta}} dh \right]^{\frac{\theta}{\theta-1}}, \; \frac{1}{2}L_t^* = \left[\left(\frac{1}{2}\right)^{-\frac{1}{\theta}} \int_{\frac{1}{2}}^1 L_t^*\left(f\right)^{\frac{\theta-1}{\theta}} df \right]^{\frac{\theta}{\theta-1}}, \qquad (14)
\end{aligned}$$

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[3] Unlike in Martínez-García and Wynne (2010), I assume an equal population size of households in both countries and an even split of the total varieties to be produced in each country (i.e., $\frac{1}{2}$ of the population and the varieties is located in each country). Moreover, I also adopt symmetric local-product bias in preferences as reflected in the composition of each country's consumption basket (i.e., the share of imported goods for both countries is set at $(1 - \xi)$).

where Y_t and Y_t^* denote the total output per household produced by firms in the Home and Foreign countries, respectively, while L_t and L_t^* refer to the per household total labor employed. The CPIs that correspond to this specification of consumption preferences are,

$$P_t = \left[\xi \left(P_t^H\right)^{1-\sigma} + (1-\xi)\left(P_t^F\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \tag{15}$$

$$P_t^* = \left[(1-\xi)\left(P_t^{H*}\right)^{1-\sigma} + \xi\left(P_t^{F*}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \tag{16}$$

and,

$$P_t^H = \left[2\int_0^{\frac{1}{2}} P_t(h)^{1-\theta}\, dh\right]^{\frac{1}{1-\theta}},\ P_t^F = \left[2\int_{\frac{1}{2}}^1 P_t(f)^{1-\theta}\, df\right]^{\frac{1}{1-\theta}}, \tag{17}$$

$$P_t^{H*} = \left[2\int_0^{\frac{1}{2}} P_t^*(h)^{1-\theta}\, dh\right]^{\frac{1}{1-\theta}},\ P_t^{F*} = \left[2\int_{\frac{1}{2}}^1 P_t^*(f)^{1-\theta}\, df\right]^{\frac{1}{1-\theta}}, \tag{18}$$

where P_t^H and P_t^F are the price sub-indexes for the Home-produced and Foreign-produced bundles of varieties in the Home market. The Home and Foreign price of the Home-produced variety h is given by $P_t(h)$ and $P_t^*(h)$, respectively. Similarly, for the sub-indexes P_t^{H*} and P_t^{F*} in the Foreign market and for the prices $P_t(f)$ and $P_t^*(f)$ of the Foreign-produced variety f.

Firms. Each firm supplies the Home and Foreign markets with its own differentiated variety under monopolistic competition. I assume producer currency pricing (PCP), so firms set Home and Foreign prices by invoicing local sales and exports in their local currency. The PCP assumption implies that the law of one price (LOOP) holds at the variety level (i.e., $P_t(h) = S_t P_t^*(h)$ and $P_t(f) = S_t P_t^*(f)$), so it follows that $P_t^H = S_t P_t^{H*}$ and $P_t^F = S_t P_t^{F*}$. However, $\xi \neq \frac{1}{2}$ leads to deviations from purchasing power parity (PPP) (i.e., $P_t \neq S_t P_t^*$) and so the real exchange rate deviates from one (i.e., $RS_t \equiv \frac{S_t P_t^*}{P_t} \neq 1$).

Given households' preferences, I can derive the demand for any Home variety h and for any Foreign variety f as,

$$\begin{aligned} Y_t(h) = \tfrac{1}{2}C_t(h) + \tfrac{1}{2}C_t^*(h) = \left(\tfrac{P_t(h)}{P_t^H}\right)^{-\theta}\left\{\left(\tfrac{P_t^H}{P_t}\right)^{-\sigma}\left[\xi C_t + (1-\xi)\left(\tfrac{1}{RS_t}\right)^{-\sigma} C_t^*\right]\right\}, \\ \text{if } h \in \left[0, \tfrac{1}{2}\right], \end{aligned} \tag{19}$$

$$\begin{aligned} Y_t^*(f) = \tfrac{1}{2}C_t(f) + \tfrac{1}{2}C_t^*(f) = \left(\tfrac{P_t(f)}{P_t^F}\right)^{-\theta}\left\{\left(\tfrac{P_t^F}{P_t}\right)^{-\sigma}\left[(1-\xi) C_t + \xi\left(\tfrac{1}{RS_t}\right)^{-\sigma} C_t^*\right]\right\}, \\ \text{if } f \in \left(\tfrac{1}{2}, 1\right]. \end{aligned} \tag{20}$$

Firms maximize profits subject to a partial adjustment rule à la Calvo (1983) on nominal prices at the variety level. In each period, every firm receives, with probability $0 < \alpha < 1$, a signal to maintain their prices and, with probability $1 - \alpha$, a signal to re-optimize. The re-optimizing Home firms in any given period choose a price $\widetilde{P}_t(h)$ optimally to maximize the expected discounted value of their profits, i.e.,

$$\sum\nolimits_{\tau=0}^{+\infty} \mathbb{E}_t\left\{(\alpha\beta)^\tau\left(\frac{C_{t+\tau}}{C_t}\right)^{-\gamma}\frac{P_t}{P_{t+\tau}}\left[\widetilde{Y}_{t,t+\tau}(h)\left(\widetilde{P}_t(h) - (1-\phi)\, MC_{t+\tau}\right)\right]\right\}, \tag{21}$$

subject to the constraint of always satisfying demand given by (19) at the chosen price $\widetilde{P}_t(h)$ for as long as those prices remain unchanged. $\widetilde{Y}_{t,t+\tau}(h)$ indicates the total consumption demand of variety h at time $t+\tau$ whenever the prevailing prices are unchanged since time t, i.e., whenever $P_{t+\tau}(h) = \widetilde{P}_t(h)$. Similarly, I describe the problem of the re-optimizing Foreign firms and define their optimal price $\widetilde{P}_t^*(f)$ and their corresponding demand schedule $\widetilde{Y}_{t,t+\tau}^*(f)$.

Local governments raise lump-sum taxes from households in order to subsidize labor employment. I introduce the labor subsidy ϕ as proportional to the nominal marginal cost and assume it to be time-invariant. Firms produce their own varieties subject to a linear-in-labor technology. Moreover, I impose competitive local labor markets and homogeneity of the labor input (although labor is immobile across countries) ensuring that wages equalize within a country (but not across countries). Hence, the (before-subsidy) nominal marginal cost is given by,

$$MC_t \equiv \left(\frac{W_t}{A_t}\right),\ MC_t^* \equiv \left(\frac{W_t^*}{A_t^*}\right), \tag{22}$$

where MC_t and MC_t^* are the Home and Foreign (before-subsidy) nominal marginal cost respectively. Home and Foreign nominal wages are denoted by W_t and W_t^*, while Home and Foreign productivity shocks are A_t and A_t^*.

The stochastic process for aggregate productivity in each country evolves according to the following bivariate autoregressive process,

$$\begin{pmatrix} \ln A_t \\ \ln A_t^* \end{pmatrix} = \begin{pmatrix} \delta_a & \delta_{a,a^*} \\ \delta_{a,a^*} & \delta_a \end{pmatrix} \begin{pmatrix} \ln A_{t-1} \\ \ln A_{t-1}^* \end{pmatrix} + \begin{pmatrix} \varepsilon_t^a \\ \varepsilon_t^{a*} \end{pmatrix}, \tag{23}$$

$$\begin{pmatrix} \varepsilon_t^a \\ \varepsilon_t^{a*} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_a^2 & \rho_{a,a^*}\sigma_a^2 \\ \rho_{a,a^*}\sigma_a^2 & \sigma_a^2 \end{pmatrix}\right). \tag{24}$$

The Home and Foreign productivity shock innovations are labeled ε_t^a and ε_t^{a*} respectively. I assume a common volatility $\sigma_a^2 > 0$, a common autoregressive parameter δ_a and a spillover parameter δ_{a,a^*} such that the corresponding eigenvalues are within the unit-circle and the VAR(1) system remains stationary, and allow the cross-correlation of innovations between the two countries to be $-1 < \rho_{a,a^*} < 1$.

The optimal pricing rule of the re-optimizing Home firms at time t is given by,

$$\widetilde{P}_t(h) = \left(\frac{\theta}{\theta-1}(1-\phi)\right) \frac{\sum_{\tau=0}^{+\infty} (\alpha\beta)^\tau \mathbb{E}_t\left[\left(\frac{C_{t+\tau}^{-\gamma}}{P_{t+\tau}}\right)\widetilde{Y}_{t,t+\tau}(h)\, MC_{t+\tau}\right]}{\sum_{\tau=0}^{+\infty} (\alpha\beta)^\tau \mathbb{E}_t\left[\left(\frac{C_{t+\tau}^{-\gamma}}{P_{t+\tau}}\right)\widetilde{Y}_{t,t+\tau}(h)\right]}, \tag{25}$$

and the optimal pricing rule of the re-optimizing Foreign firms is,

$$\widetilde{P}_t^*(f) = \left(\frac{\theta}{\theta-1}(1-\phi)\right) \frac{\sum_{\tau=0}^{+\infty} (\alpha\beta)^\tau \mathbb{E}_t\left[\left(\frac{C_{t+\tau}^{*-\gamma}}{P_{t+\tau}^*}\right)\widetilde{Y}_{t,t+\tau}^*(f)\, MC_{t+\tau}^*\right]}{\sum_{\tau=0}^{+\infty} (\alpha\beta)^\tau \mathbb{E}_t\left[\left(\frac{C_{t+\tau}^{*-\gamma}}{P_{t+\tau}^*}\right)\widetilde{Y}_{t,t+\tau}^*(f)\right]}. \tag{26}$$

Monopolistic competition in production introduces a mark-up between prices and marginal costs, $\frac{\theta}{\theta-1}$, which is a function of the elasticity of substitution across varieties within a country $\theta > 1$. I choose an optimal labor subsidy $\phi = \frac{1}{\theta}$ in both countries to neutralize this mark-up wedge.

Given the inherent symmetry of the Calvo-type pricing scheme, the price sub-indexes P_t^H and P_t^{F*} evolve according to the following pair of equations,

$$\left(P_t^H\right)^{1-\theta} = \alpha\left(P_{t-1}^H\right)^{1-\theta} + (1-\alpha)\left(\widetilde{P}_t(h)\right)^{1-\theta} = \left(S_t P_t^{H*}\right)^{1-\theta}, \tag{27}$$

$$\left(P_t^{F*}\right)^{1-\theta} = \alpha\left(P_{t-1}^{F*}\right)^{1-\theta} + (1-\alpha)\left(\widetilde{P}_t^*(f)\right)^{1-\theta} = \left(\frac{P_t^F}{S_t}\right)^{1-\theta}. \tag{28}$$

The price sub-indexes, P_t^{H*} and P_t^F, follow from the LOOP condition.

Monetary Policy. I model monetary policy in the Home and Foreign countries according to Taylor (1993)-type rules on the short-term nominal interest rates, i_t and i_t^*, i.e.,

$$1 + i_t = \left(1+\bar{i}\right)\frac{M_t}{M}\left[\left(\frac{\Pi_t}{\overline{\Pi}}\right)^{\psi_\pi}\left(\frac{Y_t}{\overline{Y}_t}\right)^{\psi_x}\right], \tag{29}$$

$$1 + i_t^* = \left(1+\bar{i}^*\right)\frac{M_t^*}{M^*}\left[\left(\frac{\Pi_t^*}{\overline{\Pi}^*}\right)^{\psi_\pi}\left(\frac{Y_t^*}{\overline{Y}_t^*}\right)^{\psi_x}\right], \tag{30}$$

where M_t and M_t^* are the Home and Foreign monetary policy shocks, and $\psi_\pi > 1$ and $\psi_x > 0$ represent the sensitivity of the monetary policy rule to changes in inflation and the output gap, respectively. $\bar{i}$ and $\bar{i}^*$ are the steady-state Home and Foreign nominal interest rates, and $M = M^*$ is the unconditional mean of the Home and Foreign monetary shocks. $\Pi_t \equiv \frac{P_t}{P_{t-1}}$ and $\Pi_t^* \equiv \frac{P_t^*}{P_{t-1}^*}$ are the (gross) CPI inflation rates, while $\overline{\Pi}$ and $\overline{\Pi}^*$ are the corresponding steady-state inflation rates. The ratios $\frac{Y_t}{\overline{Y}_t}$ and $\frac{Y_t^*}{\overline{Y}_t^*}$ define the output gap in levels for the Home and Foreign country, where Y_t and Y_t^* define the per household output levels and $\overline{Y}_t$ and $\overline{Y}_t^*$ are the potential per household output levels—potential output being defined as the output level that would prevail if nominal rigidities could be eliminated, that is, in a frictionless economy with competitive firms and flexible prices.

The stochastic process for the monetary policy shocks in each country evolves according to the following bivariate autoregressive process,

$$\begin{pmatrix} \ln M_t \\ \ln M_t^* \end{pmatrix} = \begin{pmatrix} \delta_m & 0 \\ 0 & \delta_m \end{pmatrix}\begin{pmatrix} \ln M_{t-1} \\ \ln M_{t-1}^* \end{pmatrix} + \begin{pmatrix} \varepsilon_t^m \\ \varepsilon_t^{m*} \end{pmatrix}, \tag{31}$$

$$\begin{pmatrix} \varepsilon_t^m \\ \varepsilon_t^{m*} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_m^2 & \rho_{m,m^*}\sigma_m^2 \\ \rho_{m,m^*}\sigma_m^2 & \sigma_m^2 \end{pmatrix}\right). \tag{32}$$

The Home and Foreign monetary policy shock innovations are labeled ε_t^m and ε_t^{m*} respectively. I assume a common volatility $\sigma_m^2 > 0$, a common autoregressive parameter $-1 < \delta_m < 1$, and allow the cross-correlation of innovations between the two countries to be $-1 < \rho_{m,m^*} < 1$.

2.2 The Workhorse NOEM Model

I derive a deterministic, zero-inflation steady state for the model and log-linearize the equilibrium conditions around that steady state. I denote $\widehat{g}_t \equiv \ln G_t - \ln \overline{G}$ as the deviation of a variable in logs from its steady state. In the NOEM model, price stickiness preserves monetary policy neutrality in the long run while allowing a break from it in the short run. The NOEM dynamics are summarized in Tables 1 and 2. Absent nominal rigidities (under flexible prices and with competitive firms), monetary policy has no real effects in the long run (steady state) or the short run (dynamics). The dynamics absent nominal rigidities are described in Table 3. The steady state with or without price stickiness in the model is the same, as indicated in Table 4. In this paper, I solve and estimate the resulting linear rational expectations model from Tables 1 through 4.

As shown in Table 1, the log-linearized core equilibrium conditions can be summarized with an open-economy Phillips curve, an open-economy investment-savings (IS) equation and a Taylor rule for monetary policy in each country.[4] The core (or state) endogenous variables $\widehat{\pi}_t$ and $\widehat{\pi}_t^*$ denote Home and Foreign inflation (quarter-over-quarter changes in the consumption-based price index), $\widehat{x}_t$ and $\widehat{x}_t^*$ define the Home and Foreign output gaps (deviations of output from its potential in the frictionless environment), while $\widehat{i}_t$ and $\widehat{i}_t^*$ are the short-term nominal interest rates instrumented by the monetary policymakers. The Fisherian equation for real interest rates in the Home and Foreign country defines them as $\widehat{r}_t \equiv \widehat{i}_t - \mathbb{E}_t \left[\widehat{\pi}_{t+1}\right]$ and $\widehat{r}_t^* \equiv \widehat{i}_t^* - \mathbb{E}_t \left[\widehat{\pi}_{t+1}^*\right]$ respectively, while the natural (real) rates of interest that would prevail in the frictionless model are denoted $\widehat{\overline{r}}_t$ for the Home country and $\widehat{\overline{r}}_t^*$ for the Foreign country. Potential output in the Home and Foreign countries is denoted as $\widehat{\overline{y}}_t$ and $\widehat{\overline{y}}_t^*$.

[Insert Table 1 about here.]

The open-economy Phillips curve fleshes out the global slack hypothesis—that is, the idea that in a world open to trade under short-run monetary non-neutrality, the relevant trade-off for monetary policy is between domestic inflation and global (rather than local) slack. Martínez-García and Wynne (2010) provides some further discussion of the open-economy Phillips curve and describes other extensions. Nominal rigidities are fundamental in explaining the dynamics of the model; therefore, the open-economy Phillips curve is crucial for the propagation of shocks (monetary shocks in particular).

The open-economy IS equation illustrates how output deviations from potential are tied to both Home and Foreign demand forces, where potential output is defined as the output that would prevail in a frictionless environment with the same shock realizations. Nominal rigidities à la Calvo (1983) introduce an intertemporal wedge between the actual real interest rate (the opportunity cost of consumption today versus consumption tomorrow) and the natural rate of interest that would prevail in the same economy without frictions yet subject to the same shocks. Demand itself responds to deviations of each country's real interest rate from its natural real rate as those deviations shift consumption across time, but the open-economy

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[4] The core of the model refers to a (minimal) set of equations that uniquely determines the path of a subset of endogenous variables (the core or state variables) by their initial conditions and the path of the exogenous shocks specified. In turn, all non-core (or non-state) variables can be expressed as functions of the core endogenous variables and the specified exogenous shocks. The core system of the model, therefore, suffices to uniquely determine the future paths of all the core and non-core endogenous variables. Often there is no unique way of characterizing the core and solving the model through the orthogonalization technique pioneered by Aoki (1981)—the work of Fukuda (1993) would be a practical example of that. Moreover, for Bayesian estimation purposes the number of observables—and, therefore, the number of estimating equations (core or noncore)—is tied to the number of shocks to be estimated from the data. Hence, the core equations may need to be complemented with non-core equations for estimation purposes (e.g., if exogenous labor supply and government consumption shocks in each country were added to our model).

IS equation recognizes that local aggregate production will be driven by global (not just local) aggregate demand.

Whenever the real interest rate is above its natural real rate, more consumption today is postponed for consumption tomorrow than would be in the frictionless environment. *Ceteris paribus*, this implies a demand shortfall today and an expected decline in the output gap. Analogously, when the real interest rate is below the natural rate, the resulting boost in consumption today (at the expense of future consumption) leads to an expected increase in the output gap. The open-economy IS equation illustrates that demand for local goods can be either domestic or foreign (in the form of exports), so real interest rate deviations in both countries matter.

The natural real interest rate does not equalize across countries despite the symmetry of the model because the assumption of Home-production bias in consumption translates (except in a knife-edge case where $\xi = \frac{1}{2}$) into different consumption baskets for the Home and Foreign countries. Differences in the consumption baskets across countries, in turn, imply that each country's consumption demand responds differently to domestic and foreign demand forces (resulting in differences among the natural rates of interest in the Home and Foreign countries). The model derivations indicate that the natural real rates can be expressed as a function of expected changes in Home and Foreign potential output. Potential output for each country is a function of the Home and Foreign productivity shocks, since monetary shocks (the only other shock in the model) have no real effects absent nominal rigidities.

The Home and Foreign monetary policy rules close the model, reflecting the standard view on the prevailing monetary policy regime and playing a crucial role in the international transmission of shocks. The conventional approach that I follow here is that monetary policy pursues the goal of domestic stabilization (even in a fully integrated world) and, hence, solely responds to changes in domestic economic conditions. Monetary policy is modelled with a Taylor (1993)-type rule and is assumed to react to local conditions as determined by each country's inflation and output gap alone. I assume that the persistence in policy rates reflects inertia that is *extrinsic* or exogenous to the policymaking process and out of the policymakers' control.

There are two types of country-specific, exogenous shocks in the model: productivity shocks, $\widehat{a}_t$ and $\widehat{a}_t^*$, and monetary shocks, $\widehat{m}_t$ and $\widehat{m}_t^*$. Productivity and monetary policy shocks follow VAR(1) stochastic processes each, but I have only incorporated spillovers in the stochastic process for productivity shocks (and not for monetary shocks). Productivity and monetary policy innovations can be correlated across countries but not with each other.

An observation equation for each country relating the output gap to other observables (to current output) and a model-consistent specification of the output potential must be added to the core model in Table 1 for estimation purposes. Table 2 summarizes the standard observation equation relating output (i.e., $\widehat{y}_t$ and $\widehat{y}_t^*$) to output potential and the output gap as well as other endogenous (non-core) variables of the model. Those (non-core) endogenous variables in Table 2 provide theoretical constraints on the data that can also be exploited to estimate the model.

Consistent with the structure of the model, Table 2 characterizes aggregate consumption, $\widehat{c}_t$ and $\widehat{c}_t^*$, aggregate employment, $\widehat{l}_t$ and $\widehat{l}_t^*$, and real wages, $\widehat{w}_t - \widehat{p}_t$ and $\widehat{w}_t^* - \widehat{p}_t^*$, in both countries. I also derive expressions for the terms of trade, $\widehat{tot}_t$, the real exchange rate, $\widehat{rs}_t$, and the real exports and real imports, $\widehat{exp}_t$ and $\widehat{imp}_t$. Finally, I define the real trade balance, $\widehat{tb}_t$, as $\widehat{tb}_t \equiv \frac{\overline{EXP}}{\overline{Y}} \widehat{exp}_t - \frac{\overline{IMP}}{\overline{Y}} \widehat{imp}_t$ where $\frac{\overline{EXP}}{\overline{Y}} =$

$\frac{\overline{IMP}}{\overline{Y}} = (1-\xi)$ refer to the steady-state export and import shares and are tied to the parameter ξ that regulates the degree of openness in the model.

[Insert Table 2 about here.]

2.3 The Frictionless Model

Table 3 describes the full dynamics of the economy in the frictionless environment with flexible prices and perfect competition. I distinguish variables from the frictionless equilibrium by marking them with an upper bar but still maintain a caret above to indicate that those variables are expressed in log deviations from steady state. The exogenous monetary and productivity shocks are invariant to the specification of the model—they are the same for both the frictionless and the NOEM models.

The complete system of log-linearized equations that describes the frictionless equilibrium can be found in Table 3. I characterize the frictionless model reported in Table 3 as a special case of the NOEM model discussed before where nominal rigidities are completely removed, assuming that prices are flexible and that markets for goods are perfectly competitive. All endogenous variables described in Sub-section 2.2 have a natural counterpart in the frictionless model except for the output gaps because, by construction, current and potential output are the same in a model without any frictions.

The main change in the frictionless setting occurs on the supply-side and is reflected in the pricing behavior of firms. In the frictionless model, the decisions of firms can simply be described with a standard rule whereby prices must equate marginal costs. Home and Foreign inflation $\widehat{\overline{\pi}}_t$ and $\widehat{\overline{\pi}}_t^*$ are still determined by monetary policy and are sensitive to both productivity and monetary shocks. However, it follows from the characterization of the dynamics of the frictionless model that neither the monetary policy rule nor monetary shocks have an impact on any real variables (i.e., monetary policy has no effect on potential output, consumption, employment, real wages, or the natural interest rates), as monetary neutrality holds in the short run as well as in the long run absent any nominal rigidities.

[Insert Table 3 about here.]

For the purposes of this paper, the frictionless equilibrium matters only in so far as it determines the potential output and the natural rates of interest for the Home and Foreign countries that serve as the benchmark targets for monetary policymaking in the NOEM model. In that spirit, the following proposition gives a precise characterization of the potential output and the natural rates of interest for both countries derived from the properties of the stochastic VAR(1) for productivity shocks in the following terms,

Proposition 1 *Given the $VAR(1)$ structure assumed for the productivity shocks, the vector of Home and Foreign potential output, $\widehat{\overline{y}}_t$ and $\widehat{\overline{y}}_t^*$ respectively, follows a $VAR(1)$ stochastic process,*

$$\begin{pmatrix} \widehat{\overline{y}}_t \\ \widehat{\overline{y}}_t^* \end{pmatrix} \approx \begin{pmatrix} \delta_a & \delta_{a,a^*} \\ \delta_{a,a^*} & \delta_a \end{pmatrix} \begin{pmatrix} \widehat{\overline{y}}_{t-1} \\ \widehat{\overline{y}}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \widehat{\varepsilon}_t^y \\ \widehat{\varepsilon}_t^{y*} \end{pmatrix}, \tag{33}$$

$$\begin{pmatrix} \widehat{\varepsilon}_t^y \\ \widehat{\varepsilon}_t^{y*} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \sigma_y^2 \begin{pmatrix} 1 & \rho_{y,y^*} \\ \rho_{y,y^*} & 1 \end{pmatrix} \right), \tag{34}$$

where,

$$\sigma_y^2 = \sigma_a^2 \left(\frac{1+\varphi}{\gamma+\varphi}\right)^2 \left((\Lambda)^2 + 2\rho_{a,a^*}\Lambda\left(1-\Lambda\right) + \left(1-\Lambda\right)^2\right), \tag{35}$$

$$\rho_{y,y^*} = \frac{\rho_{a,a^*}\left(\Lambda\right)^2 + 2\Lambda\left(1-\Lambda\right) + \rho_{a,a^*}\left(1-\Lambda\right)^2}{\left(\Lambda\right)^2 + 2\rho_{a,a^*}\Lambda\left(1-\Lambda\right) + \left(1-\Lambda\right)^2}. \tag{36}$$

Similarly, the vector of Home and Foreign natural rates of interest, $\widehat{\overline{r}}_t$ and $\widehat{\overline{r}}_t^*$ respectively, follows a VAR(1) stochastic process,

$$\begin{pmatrix} \widehat{\overline{r}}_t \\ \widehat{\overline{r}}_t^* \end{pmatrix} \approx \begin{pmatrix} \delta_a & \delta_{a,a^*} \\ \delta_{a,a^*} & \delta_a \end{pmatrix} \begin{pmatrix} \widehat{\overline{r}}_{t-1} \\ \widehat{\overline{r}}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \widehat{\varepsilon}_t^r \\ \widehat{\varepsilon}_t^{r*} \end{pmatrix}, \tag{37}$$

$$\begin{pmatrix} \widehat{\varepsilon}_t^r \\ \widehat{\varepsilon}_t^{r*} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \sigma_r^2 \begin{pmatrix} 1 & \rho_{r,r^*} \\ \rho_{r,r^*} & 1 \end{pmatrix}\right), \tag{38}$$

where,

$$\begin{aligned} \sigma_r^2 &= \sigma_a^2\gamma^2 \left(\frac{1+\varphi}{\gamma+\varphi}\right)^2 \left((\Pi_1)^2 + 2\rho_{a,a^*}\Pi_1\Pi_2 + (\Pi_2)^2\right), \\ \rho_{r,r^*} &= \frac{\rho_{a,a^*}\left(\Pi_1\right)^2 + 2\Pi_1\Pi_2 + \rho_{a,a^*}\left(\Pi_2\right)^2}{\left(\Pi_1\right)^2 + 2\rho_{a,a^*}\Pi_1\Pi_2 + \left(\Pi_2\right)^2}, \\ \Pi_1 &\equiv \delta_{a,a^*} - \xi\left(\frac{\varphi\left(\sigma\gamma - \left(\sigma\gamma-1\right)\left(2\xi-1\right)\right)+\gamma}{\varphi\left(\sigma\gamma - \left(\sigma\gamma-1\right)\left(2\xi-1\right)^2\right)+\gamma}\right)\left(1+\delta_{a,a^*}-\delta_a\right), \\ \Pi_2 &\equiv \left(\delta_a - 1\right) + \xi\left(\frac{\varphi\left(\sigma\gamma - \left(\sigma\gamma-1\right)\left(2\xi-1\right)\right)+\gamma}{\varphi\left(\sigma\gamma - \left(\sigma\gamma-1\right)\left(2\xi-1\right)^2\right)+\gamma}\right)\left(1+\delta_{a,a^*}-\delta_a\right). \end{aligned}$$

Home and Foreign potential output—as well as the Home and Foreign natural rates—inherit the VAR(1) stochastic structure of the productivity shocks and, moreover, some of the basic features of the underlying productivity shocks—in particular, their persistence δ_a and spillovers δ_{a,a^*}. In turn, Proposition 1 also indicates that the variance-covariance matrix (both the volatility and the correlation) of the potential output and natural rate processes is different from the one posited for the exogenous productivity shocks. Other structural parameters of the model apart from the parameters on the variance-covariance matrix for the exogenous productivity shocks modify the variance-covariance matrix of the endogenous natural rates.

Productivity shocks enter into the dynamics of the NOEM model described in Table 1 only through their impact on the natural real rates, $\widehat{\overline{r}}_t$ and $\widehat{\overline{r}}_t^*$. Having established the solution to the natural rates in Proposition 1 simplifies the specification of the NOEM model because the stochastic processes for the natural rates and the monetary shocks suffice to describe its stochastic forcing processes. The Home and Foreign monetary shock processes $\widehat{m}_t$ and $\widehat{m}_t^*$ enter directly into the model through the Taylor rule for monetary policy in each country.

2.4 The Deterministic Steady State

The deterministic steady state of the model is presented in Table 4. With an optimal labor subsidy to neutralize the distortionary effect of monopolistic competition, the resulting steady state for the NOEM model of Martínez-García and Wynne (2010) with nominal rigidities is the same as that of the frictionless model. Monetary policy has no direct impact on the real variables in steady state, so long-run neutrality is preserved even when the nominal rigidities in the NOEM model introduce a verifiable trade-off between local inflation and the global output gap in the short-run dynamics.

[Insert Table 4 about here.]

3 Bayesian Estimation: Bringing Data to Discipline the Theory

The theoretical model of Martínez-García and Wynne (2010) synthesized in Section 2 provides the backbone of the New Open Economy Macro (NOEM) literature's understanding of the channels through which foreign factors determine local inflation, which arguably has been the hallmark of international macro over the past 15 years. There remains uncertainty, however, regarding the specification of certain features of the model—such as the monetary policy rules—and also about how to parameterize the NOEM model.

The parameterization choices, in particular, have consequences for the sensitivity of local inflation to foreign developments implied by the model, so I adopt Bayesian estimation methods to discipline those parameterization choices with the data. While the difficulties associated with Bayesian estimation and identification are well-known (see, e.g., An and Schorfheide (2007), Ríos-Rull et al. (2012), and Martínez-García et al. (2012)), these methods are still useful—for instance, being able to recognize and account for the parameter uncertainty discussed in the literature in addition to also being able to incorporate additional information from the observable data into the parameter estimates that I use to investigate the implications of the NOEM model.

In this section, I describe the data that disciplines the estimation, the mapping between the observable variables and the endogenous variables of the model. I also give a brief overview of the selection of priors for the structural parameters of the model, and I explain how extraneous information factors into my choice of priors for the estimation.

3.1 Variables and Data

The NOEM model presented in Tables 1 through 3 is estimated using quarterly data from 1980Q1 until 2011Q4 for the U.S. and an aggregate of its 38 largest trading partners. In my estimation, I take the NOEM model specification as given and choose the priors so that they reflect the uncertainty surrounding the structural parameters. In this section, I discuss the data to inform both the choice of priors and the Bayesian estimation of the model.

As in Martínez-García and Wynne (2010), the NOEM model build for this paper is a stationary model that only describes the behavior of the two-country economy around its balanced growth path (BGP). Given that the NOEM model does not explicitly specify the underlying trend process for the data and defines only stationary variables, the detrending of the observable variables used for the estimation must be done outside the model. In this section, therefore, I discuss the detrending of the data and how to specify the mapping between the detrended observable data and the stationary model variables needed for the estimation of the model.

Observables for Estimation. The estimation of any model requires the specification of a set of observables. There are no precise guidelines, however, on how to choose observables for estimation. The research on data selection is still rather limited, but a set of guidelines on the matter can be inferred from the recent contributions of Guerron-Quintana (2010), Martínez-García et al. (2012), and Martínez-García and Wynne (2014):

(a) Use observables that facilitate the identification of the parameters of interest, since even structural parameters that are theoretically identified may not always be identifiable given the chosen observables; the structural parameters of interest are those that determine the behavior of the model along the dimensions that are novel to the specification or that relate to the particular model features that are being tested.

(b) Be aware of poorly measured data that introduce noise and error into the estimation; if precisely measured data are hard to come by, modelling measurement error in the mapping between the observable data and the model variables is warranted.

The NOEM model posits monetary non-neutrality and allows the international propagation of shocks through the trade channel. Hence, given the emphasis of the model on the international transmission of monetary shocks and monetary non-neutrality, it seems natural under the set of best practices described before to include both real and nominal variables in the set of observables in order to detect any real effects from monetary shocks in the data.

In order to avoid stochastic singularity in Bayesian estimation, the same number of observable variables as structural shocks is necessary in the model. Since I have monetary and productivity shocks that are country-specific, I have four structural shocks; accordingly, I should have four observable variables. I take the observable variables to be Home and Foreign output as well as Home and Foreign inflation.

The underlying data that I use to define the output and inflation observables is quarterly real GDP in PPP-adjusted terms and headline CPI data for the U.S. and 38 of its largest trading partners—including Argentina, Australia, Austria, Belgium, Brazil, Canada, China, Czech Republic, Denmark, Finland, France, Germany, Greece, Hong Kong, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Luxembourg, Malaysia, Mexico, The Netherlands, New Zealand, Norway, Peru, Poland, Singapore, South Africa, Spain, Sweden, Switzerland, Taiwan, Thailand, Turkey, and the United Kingdom.

The GDP and headline CPI data covers the period from 1980Q1 to 2011Q4 at quarterly frequency, although a few countries have shorter time series. The GDP data comes from the OECD and from various national statistics offices, while headline CPI is from the OECD, the IMF International Financial Statistics (IFS), and various national statistics offices.

To construct the real GDP series in PPP-adjusted terms, I start with the nominal GDP in local currency for each country from 2005Q1 to 2005Q4, adjusted by the IMF's purchasing power parity (PPP) conversion rates for 2005 to facilitate international comparisons. The 2005 data is then extended using the quarterly growth rates of real GDP in local currency (with 2005 as its base year) backwards and forwards. Gross inflation is defined as the ratio of the headline CPI in two subsequent quarters. For the NOEM model, however, it is useful to work with the net inflation rate (in percent terms) instead as the observable. Net inflation is computed as gross inflation minus one, but I approximate it for each country with the log of gross inflation times 100—that is, with the log-difference of the quarterly headline CPI in two subsequent quarters times 100 (where the quarterly CPI is the average of the reported monthly CPI).

The individual country series for PPP-adjusted real GDP and headline CPI inflation are combined, excluding the U.S., to compute a foreign aggregate for output and inflation with fixed weights based on the PPP-adjusted GDP shares for 2005 from the IMF corresponding to the 38 countries in the sample. Countries with missing observations are excluded for the time period for which they have no observations and the aggregate is re-weighted accordingly.[5]

The NOEM model is not built to capture variations at seasonal frequency. Accordingly, all data I use is seasonally adjusted by the source or has been seasonally-adjusted with the Census X-12 procedure whenever reported not seasonally-adjusted. For countries that have experienced periods of high inflation (Argentina, Brazil, and Peru), the seasonal-adjustment is performed by parts rather than on the whole time series.

Mapping the Observable Data to Model Variables. The core of the NOEM model described in Table 1 suggests that the trade-off between nominal and real variables can be articulated in terms of inflation and the output gaps (more precisely, between local inflation and a combination of Home and Foreign output gaps). However, output gaps are not directly measured in the available macro data. In order to map the observable data into model variables, I have to complete the estimation model with a measurement equation that relates actual observed output to the output gap and its output potential (from Table 2). This requires that I take a stand on what potential output is in the context of this model (which is given in Table 3). Hence, I must jointly estimate a model for the natural rates of interest and potential output—as synthesized in Proposition 1—together with the fully-fledged NOEM model of Table 1.

The observed series for U.S. output and for Foreign output grow over time, so a mapping between the non-stationary data and the corresponding output variables in the NOEM model is needed. Typically, the trend is ascribed to long-term growth in the labor force and to technological progress (that is, to the long-term growth in aggregate productivity). There are different ways of removing the trend from output—irrespective of what the ultimate sources of long-term growth are. Since the NOEM model itself does not specify a trend, I simply follow Stock and Watson (1999) and use the one-sided Hodrick-Prescott (HP) filter to retain only the fluctuations of the time series at business cycle frequencies.[6]

I impose a standard penalty parameter of $\lambda = 1,600$ on the one-sided HP-filter and apply it to the log of observed output multiplied by 100. Taking the log of output makes the resulting series scale invariant. Then, multiplying the logged series by 100 means that the cyclical component extracted by the one-sided HP-filter can be interpreted as the percent deviation from trend. Different filters may lead to different characteristics of the implied business cycles—e.g., the one-sided HP-filter is likely to generate less persistent deviations from trend than a deterministic polynomial trend would. The one-sided HP-filtered series also has (approximately) zero mean, so there is no mismatch in this regard with the corresponding model variable which has zero mean in population terms.

In contrast to output data, nontrending observable variables like net CPI inflation (in percent terms) have more direct counterparts in the stationary variables of the NOEM model. The corresponding model variables are defined as the percentage deviation of net inflation from a zero-inflation steady state. Hence,

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[5] The GDP series can be reconstructed back to 1980Q1 for most countries (except Czech Republic and Poland which start in 1990Q1, and Taiwan in 1981Q1). Similarly, the headline CPI series can be reconstructed back to 1980Q1 for most countries (except Brazil which starts in 1992Q4, Czech Republic in 1991Q2, China in 1984Q2, and Argentina and Peru in 1982Q4).

[6] For a recent discussion on pre-filtering the data versus estimating the trend jointly with the rest of the model, see Ferroni (2011).

I need to remove the steady state inflation term from the data to accurately match the observable data on net CPI inflation to the inflation variables in the model. One common approach to deal with this issue is to simply use demeaned net inflation rates—which, by construction, results in a zero-mean observable series. However, I would argue that using a filter that removes a time-varying trend component from net inflation is more appropriate for the series that I investigate here. For that reason, I use the same detrending procedure—the one-sided HP-filter with penalty parameter $\lambda = 1,600$—used for output, so the filtered series still has (approximately) zero mean.

3.2 Eliciting Priors

All priors are summarized in Table 5 and Figure 1. I only consider prior densities of the beta, gamma, inverse gamma, normal, uniform, and the degenerate distribution that puts mass one on a single value of the parameter space since they are the distributions most commonly used in Bayesian estimation. While a case can be made for defining the prior distribution jointly on all structural parameters, I follow the standard practice in the empirical literature of assigning independent prior distributions for each parameter.

There is no uniquely agreed upon way of eliciting priors, so there is scope for disagreement. Other researchers may push for a different selection of prior distributions based on other sources of information or based on weighting differently the ones discussed here. I select priors that reflect my *ex ante* views and beliefs about the structural parameters of the NOEM model, incorporating both my current understanding of what are plausible values for the parameterization/calibration of the model and my own perceptions of how uncertain each one of those parameter values is.

For all parameters, I impose that the mean of the prior distribution must be equal to the conventional calibration of the parameter in the literature in order to be consistent and comparable. Then, I choose the prior distribution for each parameter—as well as its dispersion—to reflect the degree of uncertainty that exists around the prior mean of the parameters. While I discuss the basic aspects of my choice of priors and my selection strategy here, I refer the interested reader to Martínez-García et al. (2012) for a more in-depth discussion of the choice of priors and the sources of information most often cited to set the priors on the structural parameters of the NOEM model.[7]

The characterization of the priors may involve imposing restrictions on the feasible range on which the structural parameters are defined so as to minimize the number of draws from prior distributions coming from regions of the parameter space that produce multiple solutions or no solution for the NOEM model. Moreover, for some parameters I also restrict their feasible range because certain parts of the parameter space may be feasible in theory but in practice are deemed *unrealistic* to match the observed data.

Furthermore, I rely on transformations of a few relevant parameters in order to ensure that the range of values for the parameter conforms with the range of values on which the preferred prior distribution function is defined. In cases where a transformation of the parameter range is pertinent, a linear transformation suffices to match the ranges of the prior distribution with those implied by theory.

[Insert Table 5 and Figure 1 about here.]

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[7] Martínez-García et al. (2012) also provides suggested guidelines on the selection of priors and on using data sources to set economically-relevant values for the parameter values that characterize the prior distribution.

Structural Parameters. I extract the business cycle component from the observable output and CPI inflation data using the one-sided HP-filter recommended by Stock and Watson (1999), as indicated in Subsection 3.1. Hence, all the filtered series used for estimation have (approximately) zero mean. Both the steady state gross inflation rate $\Pi = \overline{\Pi}$ and the discount factor β represent two well-known examples of structural parameters for whose estimation I would need stationary variables (detrended output and inflation) that preserve their respective means (see, e.g., Fernández-Villaverde (2010)). Using the demeaned data that I described before, therefore, implies the loss of the mean and makes it impossible to estimate either one of those two parameters.

The NOEM model is log-linearized around a zero-net inflation steady state, so that demeaned inflation data would not be an issue in my application. The parameter β could be estimated with stationary data on short-term interest rates that preserves the mean. Taking as given a zero-inflation steady state, an observation equation would have to be added that links the observed interest rates to $\widehat{i}_t - \ln\beta$ and $\widehat{i}_t^* - \ln\beta$ for the Home and Foreign countries, where $-\ln\beta$ is the log of the steady state real interest rate.

Since I use demeaned data and do not include short-term interest rates among the observables for estimation, I forego any further attempts to estimate β. Instead, I use a degenerate prior for the intertemporal discount factor β and fix it at 0.99. I impose this degenerate prior on β targeting an average yearly interest rate of 4% which is standard in the literature. This parameter value is based on the long-run historical average of the real interest rate (nominal rate minus realized inflation) which, as indicated before, does not enter into the set of observables that I use for the estimation of the model.[8]

I choose a tight prior for the share of locally-produced goods in the consumption basket ξ to recognize that this parameter is tied to the import share through the steady state and hence cannot deviate too much from the import share's historical average. I use a Beta distribution for the prior and transform the parameter to $2\xi - 1$ in order to ensure that the range of possible values of the transformed parameter corresponds with the domain of the Beta distribution. Accordingly, I center the prior of the transformed parameter around 0.88, which implies a prior mean for ξ that is equal to 0.94 consistent with a long-run import share of just 6%. I impose a small standard deviation of 0.01, which implies that the prior Beta is single-peaked and puts most of its mass within a small neighborhood around the prior mean. This prior specification acknowledges that one should not expect *ex ante* the structural parameter $(1 - \xi)$—which defines the degree of trade openness—to be too large when the import shares observed for the U.S. have been rather low during most of the sample period under consideration.

The remaining (non-policy) structural parameters are also key for monetary non-neutrality and to determine the strength of the propagation mechanism through the trade channel in the NOEM model—those structural parameters are the inverse of the intertemporal elasticity of substitution, γ, the inverse of the Frisch elasticity of labor supply, φ, the elasticity of substitution between Home and Foreign bundles, σ, and the Calvo price stickiness parameter, α. The different information sources that can be brought to bear in calibrating them are sometimes hard to reconcile with each other or they give a wide range of possible values for these parameters. Those concerns will be subsumed into a wide-enough prior distribution, letting the data ultimately be the deciding factor to pick the value that attains the best fit in the estimation.

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[8] The parameter β illustrates how important the selection of observables is for the estimation. Guerron-Quintana (2010), Martínez-García et al. (2012), and Martínez-García and Wynne (2014) argue that the observables one chooses matter for how well identified the parameter estimates are. Here I show with the parameter β that the selection of observables may determine whether a parameter can be estimated at all or not. This case also highlights that first-order moments contain useful information for identification that cannot be disregarded without loss of generality.

Given the specification of preferences underlying the NOEM model, I impose $\varphi = \gamma$ to be consistent with the notion of a balanced growth path (BGP). Then, I adopt the Gamma distribution centered around 5 for γ with a wide standard deviation of 1 in order to encompass a broad range of values considered as plausible in the macro literature for both parameters. I adopt the Gamma distribution centered around 1.5 for σ. I recognize the importance of this parameter for the international transmission of shocks through the trade channel, but I impose a wide standard deviation of 1 to capture the uncertainty surrounding its true value. This prior specification results in a wide range of plausible values for the intratemporal elasticity of substitution between Home and Foreign bundles, with a unimodal distribution skewed towards the left.

I adopt the Beta distribution centered around 0.75 for the Calvo parameter, α.[9] For α, I pick a prior Beta distribution with a standard deviation of 0.02 which is not too tight. The Calvo parameter α indicates the fraction of firms that are unable to re-optimize in any given period, so I favor a unimodal Beta prior that internalizes the empirical evidence—mostly micro evidence—suggesting that an average duration of four quarters for each price spell ($\alpha = 0.75$) is plausible for the U.S. This prior distribution puts little mass on values of the parameter range above 0.85 (which implies expected durations of more than 6 quarters) and below 0.65 (which implies expected durations of less than three quarters).

Finally, I must consider the policy parameters ψ_π and ψ_x for both their impact on the distortionary effects of nominal rigidities and the strength of the propagation mechanism of the NOEM model. I center the policy parameters around their standard values, but I impose an Inverse Gamma distribution for both of them and select fairly wide priors. The parameter for the policy response to deviations from the inflation target needs to be transformed in order to be consistent with the domain of the Inverse Gamma distribution and to rule out violations of the Taylor principle where monetary policy is likely not aggressive *enough* to rule out indeterminacy or no equilibrium. Hence, I estimate $\psi_\pi - 1$ with a prior centered at 0.24 that implies a prior mean of 1.24 for the corresponding policy parameter. The prior mean on the sensitivity to the output gap ψ_x is set at 0.33. While these prior means are plausible based on the existing literature (see, e.g., Rudebusch (2006)), I still select a prior standard deviation of 2 for both parameters that puts positive mass over a reasonably wide range of values between 0 and 2.

Parameters of the Shock Processes. The prior distributions for the partial autocorrelations of both shocks are restricted to lie in the $(0, 1)$-interval, so as to rule out negative values for δ_a and δ_m which would imply dynamics for the endogenous variables of the model that are difficult to reconcile with the actual observable data. However, that does not suffice to ensure the stationarity of the productivity VAR(1) process because in that case I also need to consider the possible values of the spillover parameter δ_{a,a^*}.

For the prior mean on the parameters of the productivity shock process, I match the calibration used in Heathcote and Perri (2002). For the parameters of the monetary shock process I primarily rely on the estimates provided by Rudebusch (2006) to set their prior means. I adopt a Beta distribution for the persistence of the productivity shock δ_a to match the value of 0.97. Since there seems to be broad agreement that Solow residuals tend to be quite persistent, I set the standard deviation of the prior to be 0.02 so the

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[9] The Calvo parameter α regulates the impact of monetary non-neutrality in the short-run dynamics of the NOEM model. However, β and α are difficult to identify simultaneously through the Phillips curve relationship. This is where being able to relate the mean of the observable data on interest rates to the steady state interest rate would be important not just to identify β itself, but help identify α separately as well. The Calvo parameter α relates to the nominal friction of the model (the degree of nominal rigidity) that breaks with monetary neutrality in the short run, but is generally regarded as more uncertain than the intertemporal discount factor β. Hence, imposing a degenerate prior on β is meant (at least in part) to facilitate a more precise identification in the estimation of the Calvo parameter α.

mass is concentrated at high values but somewhat skewed to the left.

Adopting a prior mean of 0.97 for δ_a, I choose to impose a tight prior on the key spillover parameter δ_{a,a^*} while still guaranteeing the stationarity of the stochastic process for productivity around the prior mean. For δ_a arbitrarily close to 0.97, δ_{a,a^*} needs to be between -0.03 and 0.03 in order for the VAR(1) process of the productivity shocks to maintain stationarity (with both its eigenvalues inside the unit circle). I transform the spillover parameter to become $\frac{1}{2}+\frac{1}{2}\frac{\delta_{a,a^*}}{0.03}$ so that its range can be defined over the $(0,1)$-interval. I select the Beta distribution as the prior, and I center it around 0.91667 to be consistent with a value of δ_{a,a^*} equal to 0.025. Moreover, I set the prior standard deviation at 0.05 resulting in a unimodal distribution that is skewed to the left.

Having imposed *extrinsic* inertia on monetary policy, the first-order autocorrelation of the monetary shocks δ_m ought to be highly positive in order to match the parsimonious interest rate movements seen in the data. I reflect this in the prior for δ_m by restricting the parameter space to the interval $(0,1)$. I select a Beta distribution centered around 0.92 with a prior standard deviation equal to 0.09. This implies that the prior Beta for δ_m is unimodal, and it recognizes that the empirical evidence seems to favor values consistent with high persistence of the monetary shock. The prior means of the productivity shock and monetary shock volatilities, σ_a and σ_m, are set at 0.73 and 0.36, respectively. I then pick an Inverse Gamma distribution to represent the prior distribution of both volatility parameters. However, I impose a large standard deviation of 3 and 5 respectively, leaving it up the data to determine the contribution of each shock to explain the endogenous business cycle volatility.

Finally, I restrict the range of the parameter space for the cross-country correlation of innovations ρ_{a,a^*} and ρ_{m,m^*} to lie in the $(0,1)$-interval. I select the Beta distribution for both parameters. I choose rather diffuse priors for these cross-country correlations because these parameters can be important for propagation, but their values are often debated in calibrated and estimated models. I center ρ_{a,a^*} at 0.29 with a standard deviation of 0.18, and ρ_{m,m^*} at 0.5 with a standard deviation of 0.2. As a result, the prior Beta distribution for the cross-correlation of the productivity innovations is skewed toward the right while the Beta distribution for the cross-correlation of the monetary shock innovations is more symmetric around the prior mean. In choosing these disperse priors, I am suggesting that the proper value for these correlations is not well-established in the literature yet.

4 Understanding Local Inflation in an Open-Economy Setting

In order to understand the inflation dynamics through the lens of the NOEM model of Martínez-García and Wynne (2010), I establish a number of analytical results first. I discuss how inflation can be decomposed into one global component that is common to all countries and another term that accounts for the inflation differential across countries. Furthermore, I show that this decomposition leads to two separate sub-systems for global inflation and inflation differentials that can be solved independently. Finally, I also argue that some key features—structural parameters—of the model matter for the determination of local inflation only through their impact on the dynamics of one of these two components. Similarly, the nature of the shocks also matters for how these two components of local inflation behave.

Then, equipped with these insights about the NOEM model, I report the empirical findings from the Bayesian estimation of the full NOEM model. I use the data to discipline the parameterization of the model, and illustrate the strength of the transmission mechanism for the determination of both global and local inflation with the empirical evidence that follows from the estimated model.

4.1 The Global Component of Local Inflation

In order to clarify the dynamics of the two-country model in Martínez-García and Wynne (2010), I rely on the decomposition method into aggregates and differences postulated by Aoki (1981) and Fukuda (1993) to re-express the core linear rational expectations system described in Table 1 into two separate sub-systems with half the number of equations. Productivity shocks enter into the dynamics described in Table 1 only through their impact on the dynamics of the natural real rates in this economy, $\widehat{\overline{r}}_t$ and $\widehat{\overline{r}}_t^*$, established in Proposition 1. The Home and Foreign monetary shock processes, $\widehat{m}_t$ and $\widehat{m}_t^*$, enter through the specification of the monetary policy rule of each country.

The two countries are assumed to be symmetric in every respect, except on their consumption baskets due to the assumption of Home-product bias in consumption. Even so, this bias is inherently symmetric as the share of local goods in the local consumption basket is the same in both countries and determined by the parameter ξ. Hence, the Aoki (1981)-Fukuda (1993) decomposition approach is applicable to the NOEM model that I have developed in this paper.

I define the world aggregate and the difference variables $\widehat{g}_t^W$ and $\widehat{g}_t^R$ as,

$$\widehat{g}_t^W \equiv \frac{1}{2}\widehat{g}_t + \frac{1}{2}\widehat{g}_t^*, \tag{39}$$

$$\widehat{g}_t^R \equiv \widehat{g}_t - \widehat{g}_t^*, \tag{40}$$

which implicitly considers that both countries are identical in size (with the same share of the household population and varieties located in each country). I re-write the country variables $\widehat{g}_t$ and $\widehat{g}_t^*$ as,

$$\widehat{g}_t = \widehat{g}_t^W + \frac{1}{2}\widehat{g}_t^R, \tag{41}$$

$$\widehat{g}_t^* = \widehat{g}_t^W - \frac{1}{2}\widehat{g}_t^R. \tag{42}$$

Then, if I can characterize the dynamics for $\widehat{g}_t^W$ and $\widehat{g}_t^R$, the transformation above backs out the corresponding variables for each country $\widehat{g}_t$ and $\widehat{g}_t^*$. Naturally, these transformations can be applied to any of the endogenous and exogenous variables of the NOEM model.

Hence, I can orthogonalize the original two-country economic model presented in Table 1 into one aggregate (or world) economic system and one difference system that can be studied independently. Notice that the weights on the world aggregate variables $\widehat{g}_t^W$ implied by this orthogonalization are given by the economic size of these two countries, and not by the long-term (steady state) trade linkages between them. I have implicitly used this idea already in Section 3 when constructing a foreign aggregate with GDP-weighted data for 38 of the largest trading partners of the U.S.

However, it is important to emphasize this point here as well in order to correctly interpret my subsequent findings. The way these world aggregates—and global inflation in particular—are constructed is not affected by the degree of openness of the economy as measured by the parameter ξ in the model. Therefore, even a fairly closed economy such as the U.S. is expected to move along the global economy's path. The implication from this is that foreign developments have a larger impact on this global component than what trade alone can account for.[10]

In turn, I argue that differential variables—and inflation differentials in particular—$\widehat{g}_t^R$ do respond to key features of the economy related to trade (including to trade openness ξ and the elasticity of substitution between Home and Foreign varieties) and are critical to determine whether the movements in global variables get either amplified or dampened in the local variables (i.e., in $\widehat{g}_t$ and $\widehat{g}_t^*$).

The World or Global Economy System. The global system describes the world economy as if it were that of a closed economy based on the following system of three equations,

$$\widehat{\pi}_t^W \approx \beta \mathbb{E}_t \left[\widehat{\pi}_{t+1}^W \right] + \left(\frac{(1-\alpha)(1-\beta\alpha)}{\alpha} \right) (\varphi + \gamma) \widehat{x}_t^W, \tag{43}$$

$$\gamma \left(\mathbb{E}_t \left[\widehat{x}_{t+1}^W \right] - \widehat{x}_t^W \right) \approx \left(\widehat{i}_t^W - \mathbb{E}_t \left[\widehat{\pi}_{t+1}^W \right] \right) - \widehat{\overline{r}}_t^W, \tag{44}$$

$$\widehat{i}_t^W \approx \left[\psi_\pi \widehat{\pi}_t^W + \psi_x \widehat{x}_t^W \right] + \widehat{m}_t^W. \tag{45}$$

To close the global economy system, I derive the world forcing processes $\widehat{\overline{r}}_t^W$ and $\widehat{m}_t^W$ as follows,

Proposition 2 *Given the derivation of the natural rates for each country in Proposition 1 and the maintained assumptions on the monetary shock shocks, the world forcing processes for* $\widehat{\overline{r}}_t^W$ *and* $\widehat{m}_t^W$ *can be described as follows,*

$$\begin{pmatrix} \widehat{\overline{r}}_t^W \\ \widehat{m}_t^W \end{pmatrix} = \begin{pmatrix} \delta_a + \delta_{a,a^*} & 0 \\ 0 & \delta_m \end{pmatrix} \begin{pmatrix} \widehat{\overline{r}}_{t-1}^W \\ \widehat{m}_{t-1}^W \end{pmatrix} + \begin{pmatrix} \widehat{\varepsilon}_t^{rW} \\ \widehat{\varepsilon}_t^{mW} \end{pmatrix}, \tag{46}$$

$$\begin{pmatrix} \widehat{\varepsilon}_t^{rW} \\ \widehat{\varepsilon}_t^{mW} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_r^2 \left(\frac{1+\rho_{r,r^*}}{2} \right) & 0 \\ 0 & \sigma_m^2 \left(\frac{1+\rho_{m,m^*}}{2} \right) \end{pmatrix} \right), \tag{47}$$

where the volatility term for the world natural rates can be tied to parameters of the productivity shock and other structural parameters of the model as follows,

$$\sigma_r^2 \left(\frac{1+\rho_{r,r^*}}{2} \right) = \sigma_a^2 \left(\frac{1+\rho_{a,a^*}}{2} \right) \left[\gamma \left(\frac{1+\varphi}{\gamma+\varphi} \right) (\delta_a + \delta_{a,a^*} - 1) \right]^2. \tag{48}$$

The degree of openness ξ does not factor into the world system or the world forcing processes and neither does the intratemporal elasticity of substitution between Home and Foreign consumption bundles σ. The parameter σ regulates the price-elasticity of trade in the NOEM model, while ξ helps pin down the steady state import shares. Therefore, neither the composition of the consumption basket nor the sensitivity of the trade balance to movements in the terms of trade (that support risk-sharing across countries) matter for the dynamics of the world economy—and, in particular, for the dynamics of global inflation. The only structural parameters that affect the world dynamics are the Calvo parameter α, the intertemporal discount factor β, the inverse of the intertemporal elasticity of substitution γ, the inverse of the Frisch elasticity of labor supply φ, and the policy parameters ψ_π and ψ_x.[11]

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[10] In fact, although the model is not set-up to capture this explicitly, one can expect the effect to increase over time as the share of economic activity attributed to the Home country declines.

[11] The estimation of the world system does not suffice to identify the parameters of the exogenous shock processes in general. I am only able to precisely estimate $\sigma_a^2 \left(1 + \rho_{a,a^*}\right)$, $\left(\delta_a + \delta_{a,a^*}\right)$, and $\sigma_m^2 \left(1 + \rho_{m,m^*}\right)$. In other words, I can only identify the

This is an important implication of the decomposition method, as it reveals that the structural parameters that affect the world dynamics are not related to the trade channel. In fact, as it will be soon apparent, the features of the economy that matter for the global component of inflation are not the same ones that affect the local inflation dynamics. In the full linear rational expectations model presented in Table 1 the proper identification of ξ and σ appears to be crucial to understanding the dynamics of inflation and the international transmission mechanism of shocks. The world system discussed here, in turn, shows that the strength of these trade linkages is netted out when it comes to describing the global dynamics. This indicates that the global component of local inflation and its response to shocks is unconnected to the sensitivity and extent of trade on which the Home and Foreign countries are engaged.

As I mentioned earlier when describing the definition of world aggregates for the decomposition, the contribution of each country to the aggregate is determined not by the extent of the trade linkages between these countries either but by their respective economic sizes. Hence, even countries with traditionally low import shares such as the U.S. with incorporate a large contribution of inflation from the rest of the world through the global component of local inflation. Local inflation would, of course, also incorporate a differential component too. Understanding the cross-difference system that characterizes the differential path between the Home and Foreign economies is, therefore, important to determine whether the effects operating through global inflation will be amplified or diluted in the resulting dynamics of local inflation.

The Cross-Country Difference System. The world as a whole is completely unaffected by how open its constituent economies might be or how sensitive trade is to movements in the terms of trade. In fact, greater openness or increased international risk-sharing through terms of trade have an economic impact on the economy of each country; however, this is not because they influence the dynamics of the global economy, but because these features of the economy affect how divergent the economic performance of the Home and Foreign countries can be. In other words, the world economy behaves as a closed economy but key features of the model related to trade patterns affect the differences that arise across these two countries.

The cross-country difference system defines how far apart a country is from the rest of the world. Then, the difference system can be characterized as follows,

$$\widehat{\pi}_t^R \approx \beta \mathbb{E}_t\left[\widehat{\pi}_{t+1}^R\right] + \left(\frac{(1-\alpha)(1-\beta\alpha)}{\alpha}\right)\left((2\xi-1)\varphi + (2\Theta-1)\gamma\right)\widehat{x}_t^R, \tag{49}$$

$$\gamma(2\xi-1)\left(\mathbb{E}_t\left[\widehat{x}_{t+1}^R\right] - \widehat{x}_t^R\right) \approx \left((2\xi-1)+2\Gamma\right)\left[\left(\widehat{i}_t^R - \mathbb{E}_t\left[\widehat{\pi}_{t+1}^R\right]\right) - \widehat{\overline{r}}_t^R\right], \tag{50}$$

$$\widehat{i}_t^R \approx \left[\psi_\pi \widehat{\pi}_t^R + \psi_x \widehat{x}_t^R\right] + \widehat{m}_t^R. \tag{51}$$

Here, the degree of openness ξ plays an important role in the differential system and so does the elasticity of substitution between Home and Foreign consumption bundles σ (through the composite parameters Θ and Γ).

To close the difference economy system, I derive the difference forcing processes $\widehat{\overline{r}}_t^R$ and $\widehat{m}_t^R$ as follows,

Proposition 3 *Given the derivation of the natural rates for each country in Proposition 1 and the maintained assumptions on the monetary shocks, the difference forcing processes for* $\widehat{\overline{r}}_t^R$ *and* $\widehat{m}_t^R$ *can be described*

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reduced-form representation of the world shocks and not the underlying features of the Home and Foreign shocks.

as follows,

$$\left(\begin{array}{c}\widehat{r}_t^R \\ \widehat{m}_t^R\end{array}\right) = \left(\begin{array}{cc}\delta_a - \delta_{a,a^*} & 0 \\ 0 & \delta_m\end{array}\right)\left(\begin{array}{c}\widehat{r}_{t-1}^R \\ \widehat{m}_{t-1}^R\end{array}\right) + \left(\begin{array}{c}\widehat{\varepsilon}_t^{rR} \\ \widehat{\varepsilon}_t^{mR}\end{array}\right), \tag{52}$$

$$\left(\begin{array}{c}\widehat{\varepsilon}_t^{rR} \\ \widehat{\varepsilon}_t^{mR}\end{array}\right) \sim N\left(\left(\begin{array}{c}0 \\ 0\end{array}\right), \left(\begin{array}{cc}2\sigma_r^2\left(1-\rho_{r,r^*}\right) & 0 \\ 0 & 2\sigma_m^2\left(1-\rho_{m,m^*}\right)\end{array}\right)\right), \tag{53}$$

where the volatility term for the difference natural rate can be tied to parameters of the productivity shock and other structural parameters of the model as follows,

$$2\sigma_r^2\left(1-\rho_{r,r^*}\right) = 2\sigma_a^2\left(1-\rho_{a,a^*}\right)\left[\gamma\left(\frac{1+\varphi}{\gamma+\varphi}\right)(2\Theta-1)(2\Lambda-1)\left(\delta_a-\delta_{a,a^*}-1\right)\right]^2. \tag{54}$$

These findings indicate that the degree of openness ξ and the elasticity of substitution between Home and Foreign consumption bundles σ (through the composite parameters Θ and Λ) affect the dynamics of the difference system as well as the volatility of the forcing processes (the volatility of the natural rate), unlike what I showed for the world economy system. This is one important insight that needs to be recognized—the structural parameters that are most connected to the specification of the trade channel have an effect on the differential behavior of the economy (and in particular on the inflation differential component of local inflation), but not on global dynamics and global inflation.

Global inflation dynamics can be driven by common or correlated shocks. However, global inflation also reflects the spillover effects of country-specific shocks that are transmitted to the rest of the world through the trade channel and complete international asset markets. In the specification of the NOEM model used in this paper, I abstract entirely from common shocks to emphasize the importance of these cross-country spillovers. In turn, inflation differentials across countries can only be the result of asymmetric shocks across countries—but not common or symmetric (perfectly-correlated) shocks. The impact the differential component of inflation characterized by this difference system has on local inflation will depend not just on the specification of the trade channel implied by the model but on the nature of the shocks themselves.

To explore how global inflation and inflation differentials actually feed into local inflation, I will now rely on the posterior Bayesian estimates of the full NOEM model to both take parameter uncertainty explicitly into account and bring the observed data on output and CPI inflation to bear in the parameterization of the model dynamics.

4.2 Empirical Findings: What Matters Most for Local Inflation?

I estimate the full NOEM model developed in Section 2 using Bayesian techniques to quantify the importance of spillovers arising through trade linkages in the dynamics of local inflation and its global and differential components. I draw on the experience of the U.S. and its 38 largest trading partners between 1980 and 2011 to investigate the propagation of shocks and their effects on local inflation with an emphasis on the role of global inflation. I also explore how global inflation can help with other relevant tasks such as the identification of the type and origin of shocks or the forecasting of inflation.

The main empirical findings from the Bayesian estimation of the NOEM model are illustrated by the posterior Bayesian estimates, the Bayesian impulse response functions (IRFs), and the Bayesian forecasts—

all of which I review in the remainder of this section.

Posterior Distributions. Conventional beliefs about the structural parameters of the NOEM model are represented through the prior distributions I have discussed in Sub-section 3.2. Bayesian estimation aims to extract all useful information from the available observations of macro aggregates—that is, from observations on Home and Foreign output and Home and Foreign inflation—to modify those prior beliefs about the model parameters whenever the data calls for it. The posterior and prior distributions of each parameter can be compared to each other in Table 6 and Figure 2. With few exceptions, the estimated posterior means appear to be very close to the corresponding prior means chosen for each of the structural parameters of the model.

The exceptions where a gap between the posterior and prior means is more noticeable, interestingly, correspond to the two policy parameters that describe the Taylor rule and to parameters related to the specification of the monetary policy shock process. The evidence reported in Table 6, in particular, suggests that the posterior estimates of the sensitivity of the policy rule to inflation and the output gap (ψ_π and ψ_x respectively) are somewhat lower than indicated by the prior means. Both the volatility and the persistence of the monetary shock process (σ_m and δ_m respectively) are also lower than under the prior means.

Martínez-García et al. (2012) show that even if a model is identified in population moments, not all structural parameters may be well identified in general—that would depend, among other things, on the sample size and the set of observables used for the estimation. Hence, I cannot rule out that the similarity between the posterior mean estimates and the prior means of some of the structural parameters in my estimation may simply reflect that the data and sample are not informative enough to change my priors. If so, the resulting posterior estimates end up being dominated by their priors and should naturally align with them.

Therefore, I must provide a cautious interpretation of my posterior estimates in Table 6 and Figure 2. I say only that these empirical findings incorporate my priors updated with the additional information that I can bring to bear on the model given my available data and sample. The macro data on output and inflation serves to change my priors in some cases, but in other cases it tends to either confirm those prior beliefs or simply appears to be insufficiently informative to alter them.

The evidence on the estimated posterior confidence intervals in Table 6 and the estimated posterior distributions in Figure 2 suggest that for some structural parameters the data and sample available results in posterior distributions that are dominated by their priors. This may be because the prior distribution for a given parameter reasonably approximates not just its mean, but also other higher moments of the distribution such as its dispersion or skewness. It can also be because the data and sample are neither informative enough to change the prior mean, nor to change the prior perceptions on the uncertainty surrounding the true value of the parameter (or other relevant features of the parameter distribution). Hence, the same cautious interpretation applies more generally to my reading of the posterior distributions and to my inferences on parameter uncertainty.

In other words, the information that can be extracted from output and inflation data through Bayesian estimation is simply insufficient to modify my initial priors on a number of the structural parameters of the NOEM model. Among those structural parameters for which I get fairly similar prior and posterior distributions, I find shock parameters like ρ_{a,a^*} and ρ_{m,m^*} in addition to the two main structural parameters related to the strength of the trade channel ξ and σ. The shock parameters ρ_{a,a^*} and ρ_{m,m^*} describe the correlation across countries in the innovations to both productivity and monetary policy shocks which are crucial to understanding the exogenous component of the international propagation of shocks. The findings reported show that it is quite difficult to infer the exogenous propagation of shocks from data on output and inflation.

In regards to the structural parameters ξ (which determines the openness to trade) and σ (which defines the elasticity of substitution between Home and Foreign varieties), my findings are consistent with those of Martínez-García et al. (2012). These two trade-related parameters tend to be difficult to pin down with the data that I use here, but they are central to describing the trade channel and the endogenous propagation of shocks. Martínez-García et al. (2012) recommend the use of trade data among the observables in order to help more tightly identify these trade parameters.[12]

A corollary of the decomposition presented in Sub-section 4.1 is that an alternative strategy can be worked out to estimate the model using its two constituent sub-systems (the world economy system and the differential economy system) to more tightly pin down the estimation of parameters like ξ and σ. The decomposition of the model allows us, for instance, to consider using aggregate output and inflation to estimate the world economy system and trade and real exchange rate (or terms of trade) data in order to estimate the differential economy system. Given that the trade parameters ξ and σ only enter into the differential economy system, estimating this block of the model separately but incorporating the posteriors estimated from the world system as priors for the rest of the parameters may help identify the trade channel while keeping the two blocks chained in the estimation.

I do not pursue this alternative strategy here formally, but I want to draw attention to the fact that the orthogonalization approach does not only provide insight to interpret the theory but it can also be a useful technique to facilitate the estimation by blocks of the NOEM model and other medium- to large-scale general equilibrium models. I see this as a potential added advantage of the methodology. In any event, I do not pursue in the paper the recommendation of Martínez-García et al. (2012) to include some trade data among the observables either. Hence, the uncertainty about the endogenous international propagation of shocks through the trade channel remains essentially the same one I incorporated in my priors before.

Without further work on the estimation—which is left for future research—the additional economic insight gained from the Bayesian estimation on the exogenous and endogenous international propagation mechanism is rather limited. Those parameters are, in fact, important for the questions posited by the paper because they affect the dynamic response of inflation differentials—so Bayesian estimation in its current implementation is not significantly shifting my initial views on them and the uncertainty surrounding them. This, in turn, has implications for the responses of differential inflation and the uncertainty about them that I get from the estimated NOEM model.

The structural (policy and non-policy) parameters with fairly different prior and posterior distributions are $\gamma = \varphi$ (which enter into the slope of the Phillips curve), α (which indicates the degree of price stickiness), ψ_π (which describes the policy response to inflation) and ψ_x (which describes the policy response to the output gap). Most shock parameters appear to report differences between their priors and posteriors too, including the volatility of the productivity and monetary policy shocks, σ_a and σ_m, as well as the persistence

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[12] To be more precise, what Martínez-García et al. (2012) show is that trade data can be useful to better pin down σ rather than ξ. One must also take into account that the trade balance and the real exchange rate (or terms of trade) are exactly related to each other through the observation equations in Table 2. Using trade data as an observable, in turn, requires an additional shock to be added or one of the current observables to be replaced to avoid the stochastic singularity in Bayesian estimation. Either that, or the parameter σ in particular should be parameterize with extraneous information not used in the estimation of the model.

and spillover parameters of the productivity and monetary policy shocks, δ_a, δ_{a,a^*} and δ_m. The posterior distributions appear particularly tight for the preference parameter, $\gamma = \varphi$, as well as for the productivity and monetary policy parameters, δ_a and δ_m.

[Insert Table 6 and Figure 2 about here.]

Figure 3 plots the filtered observable data used in the Bayesian estimation of the NOEM model. Another relevant aspect of the model estimation is illustrated through the recovered innovations to the productivity shocks ($\widehat{\varepsilon}_t^a$ and $\widehat{\varepsilon}_t^{a*}$) and monetary policy shocks ($\widehat{\varepsilon}_t^a$ and $\widehat{\varepsilon}_t^{a*}$), shown in Figure 3. Another way of looking at the empirical evidence plotted in Figure 3 is through the lens of these smoothed shocks obtained from the estimated NOEM model. Interestingly, the 2008 global recession is accounted for in the estimated NOEM model with a combination of both negative domestic and foreign productivity and a significant tightening through monetary policy shock innovations (through an unexpected increase in the monetary policy shock) affecting primarily the U.S. economy.

[Insert Figures 3 and 4 about here.]

Bayesian IRFs. Other than through posterior distributions, one can look at the Bayesian impulse response functions (IRFs) of the estimated NOEM model to assess the economic insight through Bayesian estimation. The structural parameters of the model should have a direct effect on the endogenous business cycle fluctuations generated by the country-specific productivity and monetary policy shocks driving the NOEM model. In practice, however, the dynamics of the model under the posterior Bayesian estimates do not appear qualitatively different from those expected based on the prior beliefs about the parameters.

Figures 5.A and 5.B summarize the Bayesian IRFs for output, the output gap and inflation with respect to Home and Foreign productivity shock innovations based on the estimated NOEM model that uses Home and Foreign output as well as Home and Foreign inflation as its observables. Each one of the endogenous variables whose response is plotted here is represented in four different perspectives: I include the Home (U.S.) and Foreign (an aggregate of the 38 largest trading partners of the U.S.) variables for each, but also a global or world aggregate and a differential variable that illustrates the variable gap between the Home and Foreign economies. Similarly, Figures 6.A and 6.B summarize the exact same information on the endogenous variables with the Bayesian IRFs for output, the output gap and inflation with respect to Home and Foreign monetary policy shock innovations.

The Bayesian IRFs suggest that the endogenous response to monetary policy shock innovations tends to be more tightly estimated than for productivity shock innovations. In other words, the precision by which the model estimation recovers the Bayesian IRFs is dependent upon both the type of shock and the endogenous variable that is being shocked. The international transmission of shocks implied by the model, however, is qualitatively plausible and quantitatively non-trivial.

The dynamics of the NOEM model reported through Figures 5.A, 5.B, 6.A and 6.B are cast in a different light when I take into account the decomposition of local variables proposed in the paper. Positive productivity shock innovations in the Home or the Foreign economies tend to increase global output, and lead to modest declines in the global output gap and in global inflation. The typical pattern of a supply-side shock appears at the aggregate level. An unexpected tightening in the form of a positive innovation to the monetary policy shock in the Home or the Foreign economies results in a noticeable decline of global output, the global output gap and global inflation. Hence, the typical pattern of a monetary policy shock hitting the aggregate demand appears at the aggregate level as well.

What the dynamics of the Bayesian IRFs reveal, then, is that these global dynamics are a significant part of the dynamics of output, the output gap and inflation at the country level. Differences between the two countries emerge that reflect the strength of the trade channel and its spillovers—those differences will reflect to a great extent how the different countries absorb the effects of these country-specific shocks, and the intensity of the effects will depend on the structural features of the economy, of course. However, the evidence illustrated by the Bayesian IRFs shows plainly that the global component of inflation in particular is more than a theoretical result that is qualitatively interesting but one that has quantitative bite.

[Insert Figures 5.A, 5.B, 6.A and 6.B about here.]

Finally, I want to make note of an important point on the origin and type of shocks. From the perspective of the Home country, the tightening of monetary policy in the Foreign country (a positive innovation to the Foreign monetary policy shock) looks qualitatively like a loosening of monetary policy in the Home country (a negative innovation to the Home monetary policy shock). If the only thing one looks at is the responses of Home output and inflation to monetary shocks, then Home and Foreign monetary policy shock innovations would be confounded, leading to potentially erroneous empirical inferences. Naturally, looser monetary policy at Home is not the same as tighter monetary policy in the Foreign economy. A similar argument can be made about confounding Home and Foreign productivity shock innovations.

The way to distinguish between Home and Foreign shocks is to look at the impact of each type of shock through the inflation differential and the output differential. A related way would be to look at how the gap between Home output and inflation relative to their respective global counterparts respond to shocks. In any event, looking at the rest of the world seems very important to avoid the type of confusion on the origin of shocks to which I allude here. While a simpler model that ignores the international dimension would still be able to distinguish between monetary policy and productivity shocks driving Home and Foreign inflation, in general it will not be enough to distinguish shocks that originate at Home from those that originate in the rest of the world. This, in turn, biases the measurement of the contribution of each type of shock to account for the observed business cycle fluctuations. It can also result in inaccurate interpretations of the forces driving the business cycle and even justify sub-optimal policies.

Bayesian Forecasts. Other than through posterior distributions and Bayesian IRFs, Bayesian forecasts can provide signs of empirical validation out-of-sample on which to evaluate the economic insight gained through the estimated NOEM model. Figure 7 summarizes the mean trajectory and the forecast deciles around the mean forecasts. The evidence of fairly broad confidence bands around the mean forecasts suggests that the estimated NOEM model cannot constrain the endogenous dynamics sufficiently in order to give tighter forecasts. This could be seen as evidence that the NOEM model is not rich enough (and possibly even misspecified), but could also be indicative of the fact that the transmission of shocks across countries through the trade channel remains quite uncertain even after estimation—as noted earlier.

The forecasts, however, suggest again that the global component of inflation is an important determinant for the forecasts of local inflation. While the workhorse NOEM model was not meant for forecasting, it can indicate whether the theory has some predictive content out-of-sample. Interestingly, the forecasts appear broadly consistent with a period of low inflation in the U.S. and for the world aggregate including the

U.S. (below their respective time-varying means) over the period 2012Q1-2014Q1 which I would regard as consistent with the path of cyclical inflation for those years.

[Insert Table 7 about here.]

5 Concluding Remarks

With the world becoming more globalized in recent years, the need to understand how countries are intertwined is ever increasing. Martínez-García and Wynne (2010) and Martínez-García and Wynne (2013) explain the connection between global factors and domestic inflation. The model in this paper adds to the New Open Economy Macro workhorse model of Martínez-García and Wynne (2010) by redefining the dynamics of inflation using the orthogonalization method by Aoki (1981) and Fukuda (1993). This approach conveys a novel perspective on how global factors can affect domestic inflation. Notably, it explains how international spillovers cause shocks that originate in one economy, affecting global inflation, and how these shocks are incorporated into local inflation in other countries. The model also explains why the structure of an economy and, in particular, features such as the degree of openness, matter when analyzing the impact of foreign shocks on local inflation through inflation differentials—even if they do not alter the effects of these shocks on global inflation and it describes the contribution of global inflation that accounts for the dynamics of local inflation.

The model presented relies on a framework that incorporates an open economy structure that allows for the exploration of the role that foreign forces play on the domestic economy. It uses Bayesian techniques and draws upon the observed time series (inflation and output) for the U.S. and an aggregate of its 38 largest trading partners since 1980Q1 until 2011Q4 to impose discipline on the theory. The estimated model can be used to evaluate the dynamic responses to different types of shocks and to assess the extent to which global inflation and inflation differentials contribute to the responses observed for local inflation. The estimated model highlights the importance of the nature of the shock and the structure of any given country but shows that certain structural features matter solely to the extent that they influence how the inflation differentials behave across countries rather than through a direct role on global inflation (among them, in particular, the openness to trade parameter). For instance, a relatively closed economy, such as the U.S., may not see significant effects through inflation differentials in response to country-specific shocks but it will still incorporate the spillover effects that are incorporated into global inflation (i.e. the spillovers permeate the global economy and eventually reach this apparently "closed economy").

The ability to build a better model that examines how foreign developments affect the local economy has many implications, particularly for a central bank. One of the major goals of a central bank is to maintain price stability and attain a sustainable output level. Being able to more accurately forecast inflation may help the central banks achieve this goal by granting the ability to monitor international developments and implement more effective monetary policy. Furthermore, with inflation (even deflation) being a major issue in many of the world's economies today, perhaps with more detail and further research on the relationship between foreign factors on local economies we will be able to help provide a more stable and predictable economic environment for the future.

Appendix

A Proofs

Proof. The potential output of both countries can be expressed as a linear transformation of the productivity shocks as,

$$\begin{pmatrix} \widehat{\overline{y}}_t \\ \widehat{\overline{y}}_t^* \end{pmatrix} \approx \left(\frac{1+\varphi}{\gamma+\varphi}\right) \begin{pmatrix} \Lambda & 1-\Lambda \\ 1-\Lambda & \Lambda \end{pmatrix} \begin{pmatrix} \widehat{a}_t \\ \widehat{a}_t^* \end{pmatrix}.$$

Assuming invertibility, the vector of potential output inherits the VAR(1) stochastic structure of the productivity shocks. Accordingly, the potential output process takes the following stochastic form,

$$\begin{pmatrix} \widehat{\overline{y}}_t \\ \widehat{\overline{y}}_t^* \end{pmatrix} \approx \begin{pmatrix} \Lambda & 1-\Lambda \\ 1-\Lambda & \Lambda \end{pmatrix} \begin{pmatrix} \delta_a & \delta_{a,a^*} \\ \delta_{a,a^*} & \delta_a \end{pmatrix} \begin{pmatrix} \Lambda & 1-\Lambda \\ 1-\Lambda & \Lambda \end{pmatrix}^{-1} \begin{pmatrix} \widehat{\overline{y}}_{t-1} \\ \widehat{\overline{y}}_{t-1}^* \end{pmatrix} + \left(\tfrac{1+\varphi}{\gamma+\varphi}\right) \begin{pmatrix} \Lambda & 1-\Lambda \\ 1-\Lambda & \Lambda \end{pmatrix} \begin{pmatrix} \widehat{\varepsilon}_t^a \\ \widehat{\varepsilon}_t^{a*} \end{pmatrix},$$

$$\begin{pmatrix} \widehat{\varepsilon}_t^a \\ \widehat{\varepsilon}_t^{a*} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_a^2 & \rho_{a,a^*}\sigma_a^2 \\ \rho_{a,a^*}\sigma_a^2 & \sigma_a^2 \end{pmatrix} \right).$$

where,

$$\begin{pmatrix} \Lambda & 1-\Lambda \\ 1-\Lambda & \Lambda \end{pmatrix} \begin{pmatrix} \delta_a & \delta_{a,a^*} \\ \delta_{a,a^*} & \delta_a \end{pmatrix} \begin{pmatrix} \Lambda & 1-\Lambda \\ 1-\Lambda & \Lambda \end{pmatrix}^{-1} = \begin{pmatrix} \delta_a & \delta_{a,a^*} \\ \delta_{a,a^*} & \delta_a \end{pmatrix}.$$

This implies that the VAR(1) for potential output inherits the persistence structure of the underlying productivity shocks. Moreover, the innovations to the output potential process are related to the innovations of the underlying productivity shocks as follows,

$$\begin{aligned} \begin{pmatrix} \widehat{\varepsilon}_t^r \\ \widehat{\varepsilon}_t^{r*} \end{pmatrix} &\equiv \left(\frac{1+\varphi}{\gamma+\varphi}\right) \begin{pmatrix} \Lambda & 1-\Lambda \\ 1-\Lambda & \Lambda \end{pmatrix} \begin{pmatrix} \widehat{\varepsilon}_t^a \\ \widehat{\varepsilon}_t^{a*} \end{pmatrix}, \\ \begin{pmatrix} \widehat{\varepsilon}_t^r \\ \widehat{\varepsilon}_t^{r*} \end{pmatrix} &\sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \left(\frac{1+\varphi}{\gamma+\varphi}\right)^2 \begin{pmatrix} \Lambda & 1-\Lambda \\ 1-\Lambda & \Lambda \end{pmatrix} \begin{pmatrix} \sigma_a^2 & \rho_{a,a^*}\sigma_a^2 \\ \rho_{a,a^*}\sigma_a^2 & \sigma_a^2 \end{pmatrix} \begin{pmatrix} \Lambda & 1-\Lambda \\ 1-\Lambda & \Lambda \end{pmatrix}^T \right), \end{aligned}$$

where,

$$\begin{aligned} &\left(\frac{1+\varphi}{\gamma+\varphi}\right)^2 \begin{pmatrix} \Lambda & 1-\Lambda \\ 1-\Lambda & \Lambda \end{pmatrix} \begin{pmatrix} \sigma_a^2 & \rho_{a,a^*}\sigma_a^2 \\ \rho_{a,a^*}\sigma_a^2 & \sigma_a^2 \end{pmatrix} \begin{pmatrix} \Lambda & 1-\Lambda \\ 1-\Lambda & \Lambda \end{pmatrix}^T \\ &= \sigma_a^2 \left(\frac{1+\varphi}{\gamma+\varphi}\right)^2 \left((\Lambda)^2 + 2\rho_{a,a^*}\Lambda\left(1-\Lambda\right) + \left(1-\Lambda\right)^2 \right) \begin{pmatrix} 1 & \frac{\rho_{a,a^*}(\Lambda)^2 + 2\Lambda(1-\Lambda) + \rho_{a,a^*}(1-\Lambda)^2}{(\Lambda)^2 + 2\rho_{a,a^*}\Lambda(1-\Lambda) + (1-\Lambda)^2} \\ \frac{\rho_{a,a^*}(\Lambda)^2 + 2\Lambda(1-\Lambda) + \rho_{a,a^*}(1-\Lambda)^2}{(\Lambda)^2 + 2\rho_{a,a^*}\Lambda(1-\Lambda) + (1-\Lambda)^2} & 1 \end{pmatrix}. \end{aligned}$$

The natural rates of both countries can be expressed as a linear transformation of the productivity shocks as,

$$\begin{aligned}\begin{pmatrix}\widehat{\overline{r}}_t\\ \widehat{\overline{r}}_t^*\end{pmatrix} &\approx \gamma\left(\frac{1+\varphi}{\gamma+\varphi}\right)\begin{pmatrix}\Theta\Lambda+(1-\Theta)(1-\Lambda) & 1-(\Theta\Lambda+(1-\Theta)(1-\Lambda))\\ 1-(\Theta\Lambda+(1-\Theta)(1-\Lambda)) & \Theta\Lambda+(1-\Theta)(1-\Lambda)\end{pmatrix}\begin{pmatrix}\mathbb{E}_t\left[\Delta\widehat{a}_{t+1}\right]\\ \mathbb{E}_t\left[\Delta\widehat{a}_{t+1}^*\right]\end{pmatrix}\\ &\approx \gamma\left(\frac{1+\varphi}{\gamma+\varphi}\right)\begin{pmatrix}\Pi_1 & \Pi_2\\ \Pi_2 & \Pi_1\end{pmatrix}\begin{pmatrix}\widehat{a}_t\\ \widehat{a}_t^*\end{pmatrix},\end{aligned}$$

where,

$$\begin{aligned}\Theta\Lambda+(1-\Theta)(1-\Lambda) &= \xi\left(\frac{\varphi(\sigma\gamma-(\sigma\gamma-1)(2\xi-1))+\gamma}{\varphi\left(\sigma\gamma-(\sigma\gamma-1)(2\xi-1)^2\right)+\gamma}\right),\\ \Pi_1 &\equiv \delta_{a,a^*}-\xi\left(\frac{\varphi(\sigma\gamma-(\sigma\gamma-1)(2\xi-1))+\gamma}{\varphi\left(\sigma\gamma-(\sigma\gamma-1)(2\xi-1)^2\right)+\gamma}\right)(1+\delta_{a,a^*}-\delta_a),\\ \Pi_2 &\equiv (\delta_a-1)+\xi\left(\frac{\varphi(\sigma\gamma-(\sigma\gamma-1)(2\xi-1))+\gamma}{\varphi\left(\sigma\gamma-(\sigma\gamma-1)(2\xi-1)^2\right)+\gamma}\right)(1+\delta_{a,a^*}-\delta_a).\end{aligned}$$

Assuming invertibility, the natural interest rates inherit the VAR(1) stochastic structure of the productivity shocks. Accordingly, the natural rates take the following stochastic form,

$$\begin{aligned}\begin{pmatrix}\widehat{\overline{r}}_t\\ \widehat{\overline{r}}_t^*\end{pmatrix} &\approx \begin{pmatrix}\Pi_1 & \Pi_2\\ \Pi_2 & \Pi_1\end{pmatrix}\begin{pmatrix}\delta_a & \delta_{a,a^*}\\ \delta_{a,a^*} & \delta_a\end{pmatrix}\begin{pmatrix}\Pi_1 & \Pi_2\\ \Pi_2 & \Pi_1\end{pmatrix}^{-1}\begin{pmatrix}\widehat{\overline{r}}_{t-1}\\ \widehat{\overline{r}}_{t-1}^*\end{pmatrix}+\gamma\left(\frac{1+\varphi}{\gamma+\varphi}\right)\begin{pmatrix}\Pi_1 & \Pi_2\\ \Pi_2 & \Pi_1\end{pmatrix}\begin{pmatrix}\widehat{\varepsilon}_t^a\\ \widehat{\varepsilon}_t^{a*}\end{pmatrix},\\ \begin{pmatrix}\widehat{\varepsilon}_t^a\\ \widehat{\varepsilon}_t^{a*}\end{pmatrix} &\sim N\left(\begin{pmatrix}0\\ 0\end{pmatrix},\begin{pmatrix}\sigma_a^2 & \rho_{a,a^*}\sigma_a^2\\ \rho_{a,a^*}\sigma_a^2 & \sigma_a^2\end{pmatrix}\right).\end{aligned}$$

where,

$$\begin{pmatrix}\Pi_1 & \Pi_2\\ \Pi_2 & \Pi_1\end{pmatrix}\begin{pmatrix}\delta_a & \delta_{a,a^*}\\ \delta_{a,a^*} & \delta_a\end{pmatrix}\begin{pmatrix}\Pi_1 & \Pi_2\\ \Pi_2 & \Pi_1\end{pmatrix}^{-1}=\begin{pmatrix}\delta_a & \delta_{a,a^*}\\ \delta_{a,a^*} & \delta_a\end{pmatrix}.$$

This implies that the VAR(1) for the natural interest rates inherits the persistence structure of the underlying productivity shocks, just as it happened for potential output. Moreover, the innovations to the natural interest rate process can be related to the innovations of the productivity shocks as follows,

$$\begin{aligned}\begin{pmatrix}\widehat{\varepsilon}_t^r\\ \widehat{\varepsilon}_t^{r*}\end{pmatrix} &\equiv \gamma\left(\frac{1+\varphi}{\gamma+\varphi}\right)\begin{pmatrix}\Pi_1 & \Pi_2\\ \Pi_2 & \Pi_1\end{pmatrix}\begin{pmatrix}\widehat{\varepsilon}_t^a\\ \widehat{\varepsilon}_t^{a*}\end{pmatrix},\\ \begin{pmatrix}\widehat{\varepsilon}_t^r\\ \widehat{\varepsilon}_t^{r*}\end{pmatrix} &\sim N\left(\begin{pmatrix}0\\ 0\end{pmatrix},\gamma^2\left(\frac{1+\varphi}{\gamma+\varphi}\right)^2\begin{pmatrix}\Pi_1 & \Pi_2\\ \Pi_2 & \Pi_1\end{pmatrix}\begin{pmatrix}\sigma_a^2 & \rho_{a,a^*}\sigma_a^2\\ \rho_{a,a^*}\sigma_a^2 & \sigma_a^2\end{pmatrix}\begin{pmatrix}\Pi_1 & \Pi_2\\ \Pi_2 & \Pi_1\end{pmatrix}^T\right),\end{aligned}$$

where,

$$
\begin{aligned}
&\gamma^2\left(\frac{1+\varphi}{\gamma+\varphi}\right)^2\left(\begin{array}{cc}\Pi_1 & \Pi_2\\ \Pi_2 & \Pi_1\end{array}\right)\left(\begin{array}{cc}\sigma_a^2 & \rho_{a,a^*}\sigma_a^2\\ \rho_{a,a^*}\sigma_a^2 & \sigma_a^2\end{array}\right)\left(\begin{array}{cc}\Pi_1 & \Pi_2\\ \Pi_2 & \Pi_1\end{array}\right)^T\\
&=\sigma_a^2\gamma^2\left(\frac{1+\varphi}{\gamma+\varphi}\right)^2\left((\Pi_1)^2+2\rho_{a,a^*}\Pi_1\Pi_2+(\Pi_2)^2\right)\left(\begin{array}{cc}1 & \frac{\rho_{a,a^*}(\Pi_1)^2+2\Pi_1\Pi_2+\rho_{a,a^*}(\Pi_2)^2}{(\Pi_1)^2+2\rho_{a,a^*}\Pi_1\Pi_2+(\Pi_2)^2}\\ \frac{\rho_{a,a^*}(\Pi_1)^2+2\Pi_1\Pi_2+\rho_{a,a^*}(\Pi_2)^2}{(\Pi_1)^2+2\rho_{a,a^*}\Pi_1\Pi_2+(\Pi_2)^2} & 1\end{array}\right).
\end{aligned}
$$

■

B Tables and Figures

Table 1 - New Open-Economy Macro (NOEM) Model: Core Equations

	Home Economy
Phillips curve	$\widehat{\pi}_t \approx \beta \mathbb{E}_t \left(\widehat{\pi}_{t+1}\right) + \left(\frac{(1-\alpha)(1-\beta\alpha)}{\alpha}\right) \left[\left(\xi\varphi + \Theta\gamma\right) \widehat{x}_t + \left(\left(1-\xi\right)\varphi + \left(1-\Theta\right)\gamma\right) \widehat{x}_t^*\right]$
Output gap	$\gamma \left(2\xi - 1\right) \left(\mathbb{E}_t \left[\widehat{x}_{t+1}\right] - \widehat{x}_t\right) \approx \left(\left(2\xi - 1\right) + \Gamma\right) \left[\widehat{r}_t - \widehat{\overline{r}}_t\right] - \Gamma \left[\widehat{r}_t^* - \widehat{\overline{r}}_t^*\right]$
Monetary policy	$\widehat{i}_t \approx \left[\psi_\pi \widehat{\pi}_t + \psi_x \widehat{x}_t\right] + \widehat{m}_t$
Fisher equation	$\widehat{r}_t \equiv \widehat{i}_t - \mathbb{E}_t \left[\widehat{\pi}_{t+1}\right]$
Natural interest rate	$\widehat{\overline{r}}_t \approx \gamma \left[\Theta \left(\mathbb{E}_t \left[\widehat{\overline{y}}_{t+1}\right] - \widehat{\overline{y}}_t\right) + \left(1-\Theta\right) \left(\mathbb{E}_t \left[\widehat{\overline{y}}_{t+1}^*\right] - \widehat{\overline{y}}_t^*\right)\right]$
Potential output	$\widehat{\overline{y}}_t \approx \left(\frac{1+\varphi}{\gamma+\varphi}\right) \left[\Lambda \widehat{a}_t + \left(1-\Lambda\right) \widehat{a}_t^*\right]$
	Foreign Economy
Phillips curve	$\widehat{\pi}_t^* \approx \beta \mathbb{E}_t \left(\widehat{\pi}_{t+1}^*\right) + \left(\frac{(1-\alpha)(1-\beta\alpha)}{\alpha}\right) \left[\left(\left(1-\xi\right)\varphi + \left(1-\Theta\right)\gamma\right) \widehat{x}_t + \left(\xi\varphi + \Theta\gamma\right) \widehat{x}_t^*\right]$
Output gap	$\gamma \left(2\xi - 1\right) \left(\mathbb{E}_t \left[\widehat{x}_{t+1}^*\right] - \widehat{x}_t^*\right) \approx -\Gamma \left[\widehat{r}_t - \widehat{\overline{r}}_t\right] + \left(\left(2\xi - 1\right) + \Gamma\right) \left[\widehat{r}_t^* - \widehat{\overline{r}}_t^*\right]$
Monetary policy	$\widehat{i}_t^* \approx \left[\psi_\pi \widehat{\pi}_t^* + \psi_x \widehat{x}_t^*\right] + \widehat{m}_t^*$
Fisher equation	$\widehat{r}_t^* \equiv \widehat{i}_t^* - \mathbb{E}_t \left[\widehat{\pi}_{t+1}^*\right]$
Natural interest rate	$\widehat{\overline{r}}_t^* \approx \gamma \left[\left(1-\Theta\right) \left(\mathbb{E}_t \left[\widehat{\overline{y}}_{t+1}\right] - \widehat{\overline{y}}_t\right) + \Theta \left(\mathbb{E}_t \left[\widehat{\overline{y}}_{t+1}^*\right] - \widehat{\overline{y}}_t^*\right)\right]$
Potential output	$\widehat{\overline{y}}_t^* \approx \left(\frac{1+\varphi}{\gamma+\varphi}\right) \left[\left(1-\Lambda\right) \widehat{a}_t + \Lambda \widehat{a}_t^*\right]$
	Exogenous, Country-Specific Shocks
Productivity shock	$\begin{pmatrix} \widehat{a}_t \\ \widehat{a}_t^* \end{pmatrix} \approx \begin{pmatrix} \delta_a & \delta_{a,a^*} \\ \delta_{a,a^*} & \delta_a \end{pmatrix} \begin{pmatrix} \widehat{a}_{t-1} \\ \widehat{a}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \widehat{\varepsilon}_t^a \\ \widehat{\varepsilon}_t^{a*} \end{pmatrix}$
	$\begin{pmatrix} \widehat{\varepsilon}_t^a \\ \widehat{\varepsilon}_t^{a*} \end{pmatrix} \sim N \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_a^2 & \rho_{a,a^*}\sigma_a^2 \\ \rho_{a,a^*}\sigma_a^2 & \sigma_a^2 \end{pmatrix}\right)$
Monetary shock	$\begin{pmatrix} \widehat{m}_t \\ \widehat{m}_t^* \end{pmatrix} \approx \begin{pmatrix} \delta_m & 0 \\ 0 & \delta_m \end{pmatrix} \begin{pmatrix} \widehat{m}_{t-1} \\ \widehat{m}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \widehat{\varepsilon}_t^m \\ \widehat{\varepsilon}_t^{m*} \end{pmatrix}$
	$\begin{pmatrix} \widehat{\varepsilon}_t^m \\ \widehat{\varepsilon}_t^{m*} \end{pmatrix} \sim N \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_m^2 & \rho_{m,m^*}\sigma_m^2 \\ \rho_{m,m^*}\sigma_m^2 & \sigma_m^2 \end{pmatrix}\right)$
	Composite Parameters
	$\Theta \equiv \xi \left[\frac{\sigma\gamma - (\sigma\gamma-1)(2\xi-1)}{\sigma\gamma - (\sigma\gamma-1)(2\xi-1)^2}\right]$
	$\Lambda \equiv 1 + \left(\sigma\gamma - 1\right) \left[\frac{\gamma(1-\xi)(2\xi)}{\varphi\left(\sigma\gamma - (\sigma\gamma-1)(2\xi-1)^2\right) + \gamma}\right]$
	$\Gamma \equiv \left(1-\xi\right) \left[\sigma\gamma + \left(\sigma\gamma - 1\right)\left(2\xi - 1\right)\right]$

Table 2 - New Open-Economy Macro (NOEM) Model: Non-Core Equations	
	Home Economy
Output	$\widehat{y}_t = \widehat{\overline{y}}_t + \widehat{x}_t$
Consumption	$\widehat{c}_t \approx \Theta \widehat{y}_t + (1 - \Theta)\, \widehat{y}_t^*$
Employment	$\widehat{l}_t \approx \widehat{y}_t - \widehat{a}_t$
Real wages	$(\widehat{w}_t - \widehat{p}_t) \approx \gamma \widehat{c}_t + \varphi \widehat{l}_t \approx (\varphi + \gamma \Theta)\, \widehat{y}_t + \gamma\, (1 - \Theta)\, \widehat{y}_t^* - \varphi \widehat{a}_t$
	Foreign Economy
Output	$\widehat{y}_t^* = \widehat{\overline{y}}_t^* + \widehat{x}_t^*$
Consumption	$\widehat{c}_t^* \approx (1 - \Theta)\, \widehat{y}_t + \Theta \widehat{y}_t^*$
Employment	$\widehat{l}_t^* \approx \widehat{y}_t^* - \widehat{a}_t^*$
Real wages	$(\widehat{w}_t^* - \widehat{p}_t^*) \approx \gamma \widehat{c}_t^* + \varphi \widehat{l}_t^* \approx \gamma\, (1 - \Theta)\, \widehat{y}_t + (\varphi + \gamma \Theta)\, \widehat{y}_t^* - \varphi \widehat{a}_t^*$
	International Relative Prices and Trade
Real exchange rate	$\widehat{rs}_t \approx (2\xi - 1)\, \widehat{tot}_t$
Terms of trade	$\widehat{tot}_t \approx \left[\frac{\gamma}{\sigma\gamma - (\sigma\gamma - 1)(2\xi - 1)^2}\right] (\widehat{y}_t - \widehat{y}_t^*)$
Home real exports	$\widehat{exp}_t \approx \Xi \widehat{y}_t + (1 - \Xi)\, \widehat{y}_t^*$
Home real imports	$\widehat{imp}_t \approx -\,(1 - \Xi)\, \widehat{y}_t - \Xi \widehat{y}_t^*$
Home real trade balance	$\widehat{tb}_t \equiv \widehat{y}_t - \widehat{c}_t = (1 - \xi) \left(\widehat{exp}_t - \widehat{imp}_t\right) \approx (1 - \Theta)\, (\widehat{y}_t - \widehat{y}_t^*)$
	Composite Parameters
	$\Theta \equiv \xi \left[\frac{\sigma\gamma - (\sigma\gamma - 1)(2\xi - 1)}{\sigma\gamma - (\sigma\gamma - 1)(2\xi - 1)^2}\right]$
	$\Xi \equiv \left[\frac{\sigma\gamma + (\sigma\gamma - 1)(2\xi - 1)(1 - \xi)}{\sigma\gamma - (\sigma\gamma - 1)(2\xi - 1)^2}\right]$

Table 3 - Flexible Price (IRBC) Model: Core and Non-Core Equations

	Home Economy
Inflation	$\mathbb{E}_t\left[\widehat{\overline{\pi}}_{t+1}\right] \approx \psi_\pi \widehat{\overline{\pi}}_t + \widehat{m}_t - \widehat{\overline{r}}_t$
Output (potential)	$\widehat{\overline{y}}_t \approx \left(\frac{1+\varphi}{\gamma+\varphi}\right)\left[\Lambda \widehat{a}_t + (1-\Lambda)\,\widehat{a}_t^*\right]$
Monetary policy	$\widehat{\overline{i}}_t \approx \psi_\pi \widehat{\overline{\pi}}_t + \widehat{m}_t$
Fisher equation	$\widehat{\overline{r}}_t \equiv \widehat{\overline{i}}_t - \mathbb{E}_t\left[\widehat{\overline{\pi}}_{t+1}\right]$
Natural interest rate	$\widehat{\overline{r}}_t \approx \gamma\left[\Theta\left(\mathbb{E}_t\left[\widehat{\overline{y}}_{t+1}\right] - \widehat{\overline{y}}_t\right) + (1-\Theta)\left(\mathbb{E}_t\left[\widehat{\overline{y}}_{t+1}^*\right] - \widehat{\overline{y}}_t^*\right)\right]$
Consumption	$\widehat{\overline{c}}_t \approx \Theta \widehat{\overline{y}}_t + (1-\Theta)\,\widehat{\overline{y}}_t^*$
Employment	$\widehat{\overline{l}}_t \approx \widehat{\overline{y}}_t - \widehat{a}_t$
Real wages	$\left(\widehat{\overline{w}}_t - \widehat{\overline{p}}_t\right) \approx \gamma \widehat{\overline{c}}_t + \varphi \widehat{\overline{l}}_t \approx (\varphi + \gamma\Theta)\,\widehat{\overline{y}}_t + \gamma\,(1-\Theta)\,\widehat{\overline{y}}_t^* - \varphi \widehat{a}_t$
	Foreign Economy
Inflation	$\mathbb{E}_t\left[\widehat{\overline{\pi}}_{t+1}^*\right] \approx \psi_\pi \widehat{\overline{\pi}}_t^* + \widehat{m}_t^* - \widehat{\overline{r}}_t^*$
Output (potential)	$\widehat{\overline{y}}_t^* \approx \left(\frac{1+\varphi}{\gamma+\varphi}\right)\left[(1-\Lambda)\,\widehat{a}_t + \Lambda \widehat{a}_t^*\right]$
Monetary policy	$\widehat{\overline{i}}_t^* \approx \psi_\pi \widehat{\overline{\pi}}_t^* + \widehat{m}_t^*$
Fisher equation	$\widehat{\overline{r}}_t^* \equiv \widehat{\overline{i}}_t^* - \mathbb{E}_t\left[\widehat{\overline{\pi}}_{t+1}^*\right]$
Natural interest rate	$\widehat{\overline{r}}_t^* \approx \gamma\left[(1-\Theta)\left(\mathbb{E}_t\left[\widehat{\overline{y}}_{t+1}\right] - \widehat{\overline{y}}_t\right) + \Theta\left(\mathbb{E}_t\left[\widehat{\overline{y}}_{t+1}^*\right] - \widehat{\overline{y}}_t^*\right)\right]$
Consumption	$\widehat{\overline{c}}_t^* \approx (1-\Theta)\,\widehat{\overline{y}}_t + \Theta \widehat{\overline{y}}_t^*$
Employment	$\widehat{\overline{l}}_t^* \approx \widehat{\overline{y}}_t^* - \widehat{a}_t^*$
Real wages	$\left(\widehat{\overline{w}}_t^* - \widehat{\overline{p}}_t^*\right) \approx \gamma \widehat{\overline{c}}_t^* + \varphi \widehat{\overline{l}}_t^* \approx \gamma\,(1-\Theta)\,\widehat{\overline{y}}_t + (\varphi + \gamma\Theta)\,\widehat{\overline{y}}_t^* - \varphi \widehat{a}_t^*$
	International Relative Prices and Trade
Real exchange rate	$\widehat{\overline{rs}}_t \approx (2\xi - 1)\,\widehat{\overline{tot}}_t$
Terms of trade	$\widehat{\overline{tot}}_t \approx \left[\frac{\gamma}{\sigma\gamma-(\sigma\gamma-1)(2\xi-1)^2}\right]\left(\widehat{\overline{y}}_t - \widehat{\overline{y}}_t^*\right)$
Home real exports	$\widehat{\overline{exp}}_t \approx \Xi \widehat{\overline{y}}_t + (1-\Xi)\,\widehat{\overline{y}}_t^*$
Home real imports	$\widehat{\overline{imp}}_t \approx -(1-\Xi)\,\widehat{\overline{y}}_t - \Xi \widehat{\overline{y}}_t^*$
Home real trade balance	$\widehat{\overline{tb}}_t \equiv \widehat{\overline{y}}_t - \widehat{\overline{c}}_t = (1-\xi)\left(\widehat{\overline{exp}}_t - \widehat{\overline{imp}}_t\right) \approx (1-\Theta)\left(\widehat{\overline{y}}_t - \widehat{\overline{y}}_t^*\right)$
	Exogenous, Country-Specific Shocks
Productivity shock	$\begin{pmatrix} \widehat{a}_t \\ \widehat{a}_t^* \end{pmatrix} \approx \begin{pmatrix} \delta_a & \delta_{a,a^*} \\ \delta_{a,a^*} & \delta_a \end{pmatrix}\begin{pmatrix} \widehat{a}_{t-1} \\ \widehat{a}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \widehat{\varepsilon}_t^a \\ \widehat{\varepsilon}_t^{a*} \end{pmatrix}$ $\begin{pmatrix} \widehat{\varepsilon}_t^a \\ \widehat{\varepsilon}_t^{a*} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_a^2 & \rho_{a,a^*}\sigma_a^2 \\ \rho_{a,a^*}\sigma_a^2 & \sigma_a^2 \end{pmatrix}\right)$
Monetary shock	$\begin{pmatrix} \widehat{m}_t \\ \widehat{m}_t^* \end{pmatrix} \approx \begin{pmatrix} \delta_m & 0 \\ 0 & \delta_m \end{pmatrix}\begin{pmatrix} \widehat{m}_{t-1} \\ \widehat{m}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \widehat{\varepsilon}_t^m \\ \widehat{\varepsilon}_t^{m*} \end{pmatrix}$ $\begin{pmatrix} \widehat{\varepsilon}_t^m \\ \widehat{\varepsilon}_t^{m*} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_m^2 & \rho_{m,m^*}\sigma_m^2 \\ \rho_{m,m^*}\sigma_m^2 & \sigma_m^2 \end{pmatrix}\right)$
	Composite Parameters
	$\Theta \equiv \xi\left[\frac{\sigma\gamma-(\sigma\gamma-1)(2\xi-1)}{\sigma\gamma-(\sigma\gamma-1)(2\xi-1)^2}\right]$
	$\Lambda \equiv 1 + (\sigma\gamma - 1)\left[\frac{\gamma(1-\xi)(2\xi)}{\varphi\left(\sigma\gamma-(\sigma\gamma-1)(2\xi-1)^2\right)+\gamma}\right]$
	$\Xi \equiv \left[\frac{\sigma\gamma+(\sigma\gamma-1)(2\xi-1)(1-\xi)}{\sigma\gamma-(\sigma\gamma-1)(2\xi-1)^2}\right]$

Table 4 - New Open-Economy Macro (NOEM) and Flexible Price (IRBC) Models: Steady State

Home Economy	
Output	$\overline{Y} = \overline{Y}\left(h\right) = \overline{C}$
Consumption	$\overline{C} = \left(\frac{1}{\kappa}\right)^{\frac{1}{\gamma+\varphi}} \left(A\right)^{\frac{1+\varphi}{\gamma+\varphi}}$
	$\overline{C}\left(h\right) = 2\overline{C}^{H},\ \overline{C}\left(f\right) = 2\overline{C}^{F}, \overline{C}^{H} = \xi\overline{C},\ \overline{C}^{F} = \left(1-\xi\right)\overline{C}^{*}$
Employment	$\overline{L} = \overline{L}\left(h\right) = \frac{\overline{Y}}{A}$
Real wages	$\frac{\overline{W}}{\overline{P}} = A$
Prices	$\overline{P} = \overline{P}^{H} = \overline{\widetilde{P}}\left(h\right)$
Interest rates	$1 + \overline{i} = 1 + \overline{r} = \frac{1}{\beta}$
Foreign Economy	
Output	$\overline{Y}^{*} = \overline{Y}^{*}\left(f\right) = \overline{C}^{*}$
Consumption	$\overline{C}^{*} = \overline{C}$
	$\overline{C}^{*}\left(h\right) = 2\overline{C}^{H*},\ \overline{C}^{*}\left(f\right) = 2\overline{C}^{F*},\ \overline{C}^{H*} = \left(1-\xi\right)\overline{C}^{*},\ \overline{C}^{F*} = \xi\overline{C}^{*}$
Employment	$\overline{L}^{*} = \overline{L}^{*}\left(f\right) = \frac{\overline{Y}^{*}}{A}$
Real wages	$\frac{\overline{W}^{*}}{\overline{P}^{*}} = A$
Prices	$\overline{P}^{*} = \overline{P}^{F*} = \overline{\widetilde{P}}^{*}\left(f\right)$
Interest rates	$1 + \overline{i}^{*} = 1 + \overline{r}^{*} = \frac{1}{\beta}$
International Relative Prices and Trade	
Real exchange rate	$\overline{RS} \equiv \frac{\overline{SP}^{*}}{\overline{P}} = 1$
Terms of trade	$\overline{ToT} \equiv \frac{\overline{P}^{F}}{\overline{SP}^{H*}} = \frac{\overline{P}^{F}}{\overline{P}^{H}} = \frac{\overline{P}^{F*}}{\overline{P}^{H*}} = 1$
Home real exports	$\overline{EXP} = \overline{C}^{H*} = \left(1-\xi\right)\overline{C}^{*} = \left(1-\xi\right)\overline{C}$
Home real imports	$\overline{IMP} = \overline{C}^{F} = \left(1-\xi\right)\overline{C}$
Home real trade balance	$\overline{TB} = \overline{EXP} - \overline{IMP} = 0$

Table 5 - Structural and Shock Parameters: Prior Distributions

		Prior Distributions			
Structural parameters		**Domain**	**Density**	**Mean**	**Std. Dev.**
Non-policy parameters					
β	Intertemporal discount factor	$(0,1)$	Fixed	0.99	–
γ	Inverse intertemporal elasticity of substitution	$\mathbb{R}^+$	Gamma	5	1
φ	Inverse Frisch elasticity of labor supply	$\mathbb{R}^+$	Gamma	$\varphi = \gamma$	–
σ	Elasticity of substitution btw. Home and Foreign varieties	$\mathbb{R}^+$	Gamma	1.5	1
$2\xi - 1$	(Transformed) Share of local goods in consumption basket	$(0,1)$	Beta	0.88	0.01
α	Calvo (1983) price stickiness parameter	$(0,1)$	Beta	0.75	0.02
Policy parameters					
$\psi_\pi - 1$	(Transformed) Policy response to inflation	$\mathbb{R}^+$	InvGamma	0.24	2
ψ_x	Policy response to the output gap	$\mathbb{R}^+$	InvGamma	0.33	2
Shock parameters					
δ_a	Persistence parameter in productivity	$(0,1)$	Beta	0.97	0.02
$\frac{1}{2} + \frac{1}{2}\frac{\delta_{a,a^*}}{0.03}$	(Transformed) Spillover parameter in productivity	$(0,1)$	Beta	0.91667	0.05
σ_a	Std. deviation of productivity innovations	$\mathbb{R}^+$	InvGamma	0.73	3
ρ_{a,a^*}	Cross-correlation of productivity innovations	$(0,1)$	Beta	0.29	0.18
δ_m	Persistence parameter in the monetary shock	$(0,1)$	Beta	0.92	0.09
σ_m	Std. deviation of monetary shock innovations	$\mathbb{R}^+$	InvGamma	0.36	5
ρ_{m,m^*}	Cross-correlation of monetary shock innovations	$(0,1)$	Beta	0.50	0.2

Note: The share of locally-produced goods ξ and the spillovers between Home and Foreign productivity shocks δ_{a,a^*} are transformed to adjust their range to the domain of the Beta distribution. I also transform the sensitivity of monetary policy to deviations from the inflation target ψ_π to adjust its range (set above one to satisfy the Taylor principle) to the domain of the Gamma distribution. The existence and uniqueness of a solution for the NOEM model requires the policy parameter ψ_π to be slightly above 1 for very low values of the policy parameter ψ_x but is consistent with a threshold slightly below 1 at high values of ψ_x. Hence, restricting the policy parameter ψ_π to satisfy the Taylor principle for the NOEM model is neither necessary nor sufficient to ensure determinacy but is a conventional practice that ensures most draws from these prior distributions will fall in a region of the parameter space for which a unique solution exists. Similarly, the priors on the parameters of the shock processes are chosen to ensure that both productivity and monetary shocks are well-behaved and stationary processes under almost any draw generated by them.

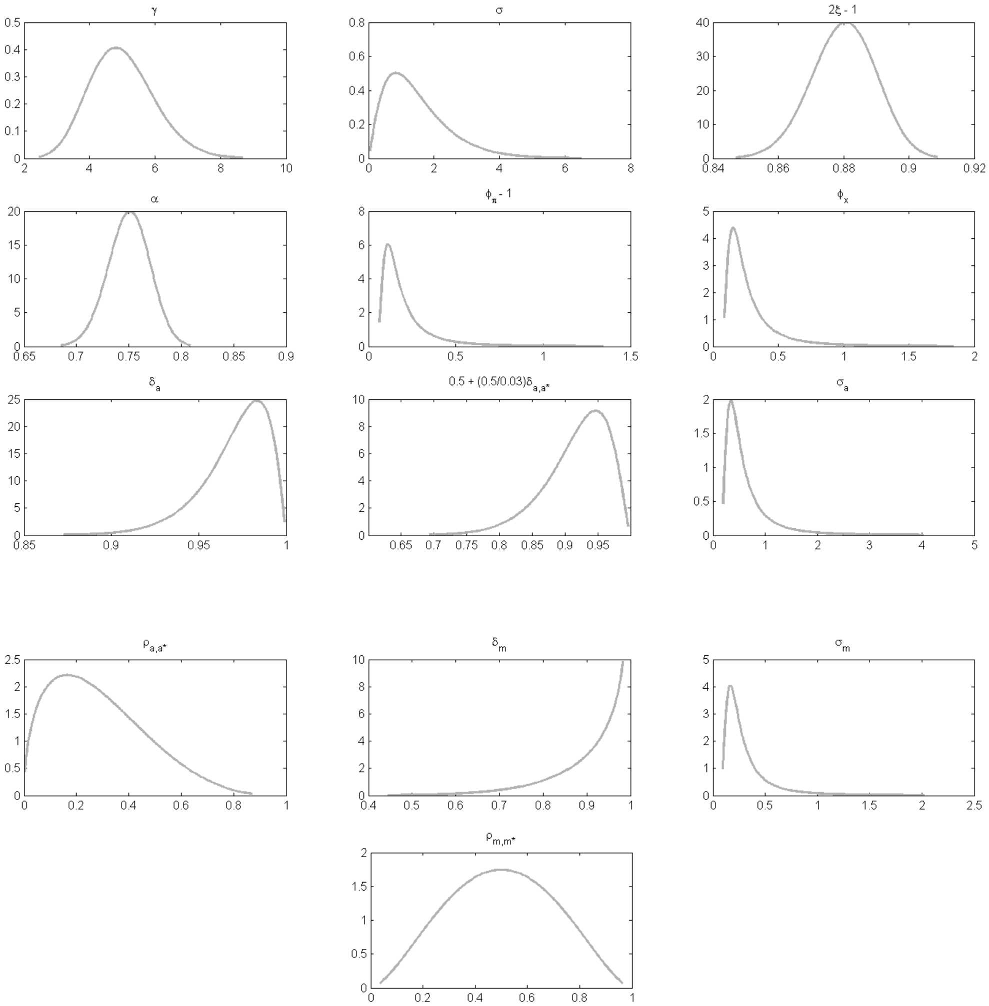
Note: This table reports only the prior mean and prior standard deviation for each model parameter. Each one of the prior distributions considered can be fully characterized with two parameters v and s. For any plausible choice of the prior mean and the prior standard deviation there is a one-to-one mapping that uniquely determines parameters v and s and fully characterizes the prior distribution. For the Normal distribution, the mean is $\mu{=}v$ and the variance is $\sigma^2{=}s^2$. For the Beta distribution, the mean is $\mu{=}v/(v+s)$ and the variance is $\sigma^2{=}vs/((v+s)^2(v+s+1))$. For the Gamma distribution, the mean is $\mu{=}vs$ and the variance is $\sigma^2{=}vs^2$. For the Uniform distribution, the upper and lower bound of the support are v and s respectively, while the mean is $\mu{=}(v+s)/2$ and the variance is $\sigma^2{=}(v-s)^2/12$. For the Inverse Gamma distribution, the mean is $\mu{=}s/(v-1)$ and the variance is $\sigma^2{=}s^2/((v-1)^2(v-2))$.

Table 6 - Structural and Shock Parameters: Posterior Distributions

		Prior	Posterior	
			Mean	**90%-CI**
Structural parameters				
Non-policy parameters				
β	Intertemporal discount factor	0.99	0.99	–
γ	Inverse intertemporal elasticity of substitution	5	4.9332	$[4.2680, 5.5490]$
φ	Inverse Frisch elasticity of labor supply	$\varphi = \gamma$	$\varphi = \gamma$	–
σ	Elasticity of substitution btw. Home and Foreign varieties	1.5	1.6137	$[0.0942, 3.2349]$
$2\xi - 1$	(Transformed) Share of local goods in consumption basket	0.88	0.8810	$[0.8640, 0.8974]$
α	Calvo (1983) price stickiness parameter	0.75	0.7450	$[0.7161, 0.7732]$
Policy parameters				
$\psi_{\pi}-1$	(Transformed) Policy response to inflation	0.24	0.1640	$[0.0667, 0.2685]$
ψ_x	Policy response to the output gap	0.33	0.1554	$[0.0794, 0.2315]$
Shock parameters				
δ_a	Persistence parameter in productivity	0.97	0.9659	$[0.9588, 0.9732]$
$\frac{1}{2}+\frac{1}{2}\frac{\delta_{a,a^*}}{0.03}$	(Transformed) Spillover parameter in productivity	0.91667	0.9069	$[0.8198, 0.9894]$
σ_a	Std. deviation of productivity innovations	0.73	0.6991	$[0.1997, 1.2853]$
ρ_{a,a^*}	Cross-correlation of productivity innovations	0.29	0.2806	$[0.0093, 0.5401]$
δ_m	Persistence parameter in the monetary shock	0.92	0.7941	$[0.7667, 0.8225]$
σ_m	Std. deviation of monetary shock innovations	0.36	0.2816	$[0.0940, 0.4799]$
ρ_{m,m^*}	Cross-correlation of monetary shock innovations	0.50	0.5027	$[0.1823, 0.8242]$

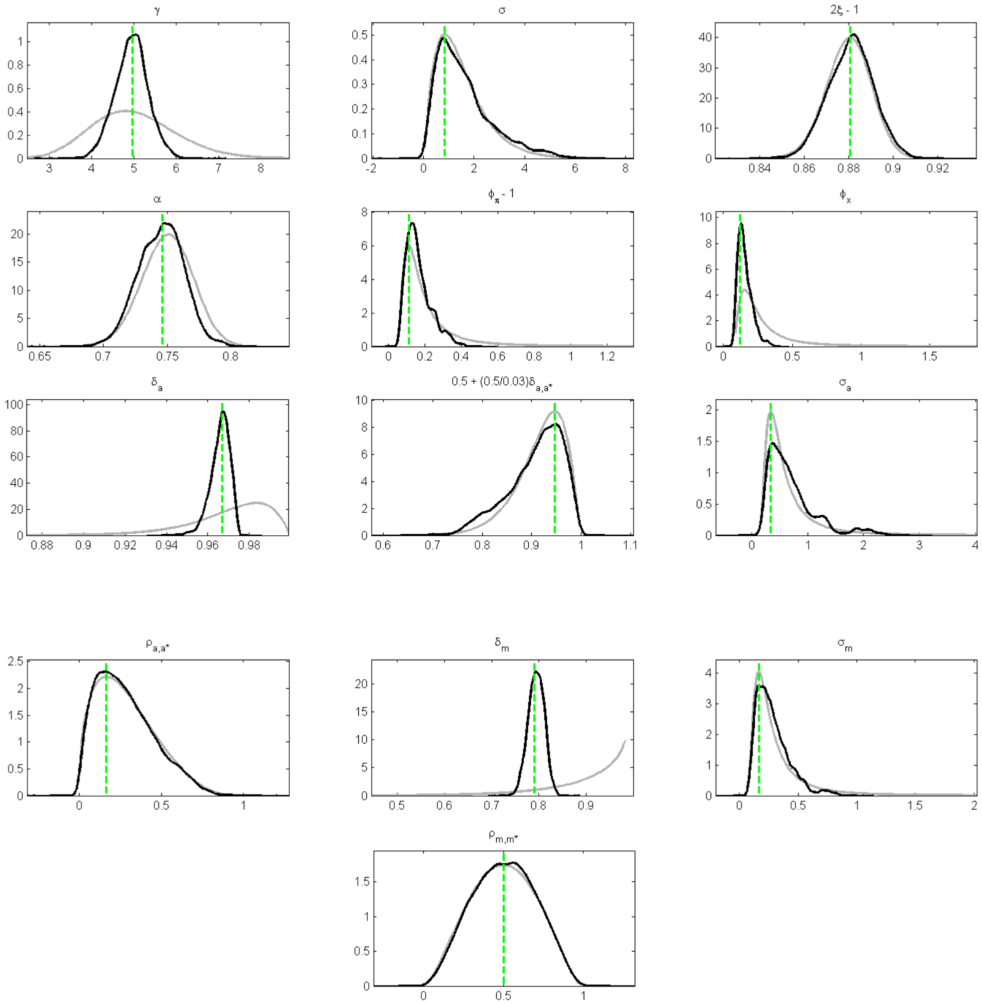
This table reports the prior mean, and the posterior point estimates and 90 percent confidence intervals for each one of the 13 structural (policy and non-policy) and shock parameters of the NOEM model that do not receive a degenerate prior distribution. The table reports the Bayesian estimates after pre-filtering the data using the one-sided Hodrick-Prescott Filter with parameter set at 1600. I estimate the NOEM model for a time series of 128 observations from 1980Q1 until 2011Q4 for the U.S. and a foreign aggregate composed of the 38 largest trading partners of the U.S. The estimation is based on four observables: Home and Foreign output, Home and Foreign CPI inflation. The code for the Bayesian estimation is written for Matlab version 8.3.0.532 and Dynare version 4.3.2, and it is available upon request from the author.

Figure 1. Prior Distributions



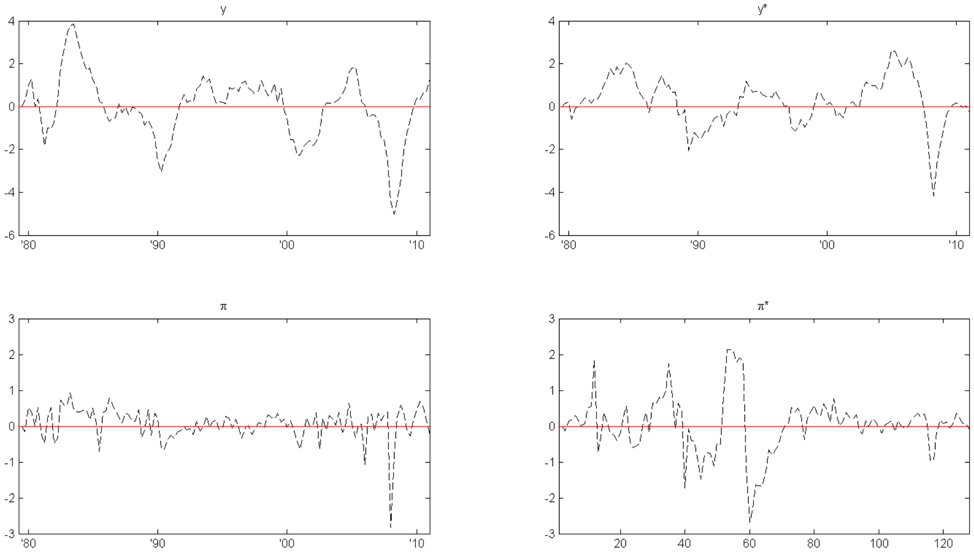
Note: The code is written for Matlab version 8.3.0.532 and Dynare version 4.3.2. This figure plots the prior distributions of all 13 structural (policy and non-policy) and shock parameters that do not receive a degenerate prior distribution. The code for this figure is available upon request from the author.

Figure 2. Priors and Posteriors



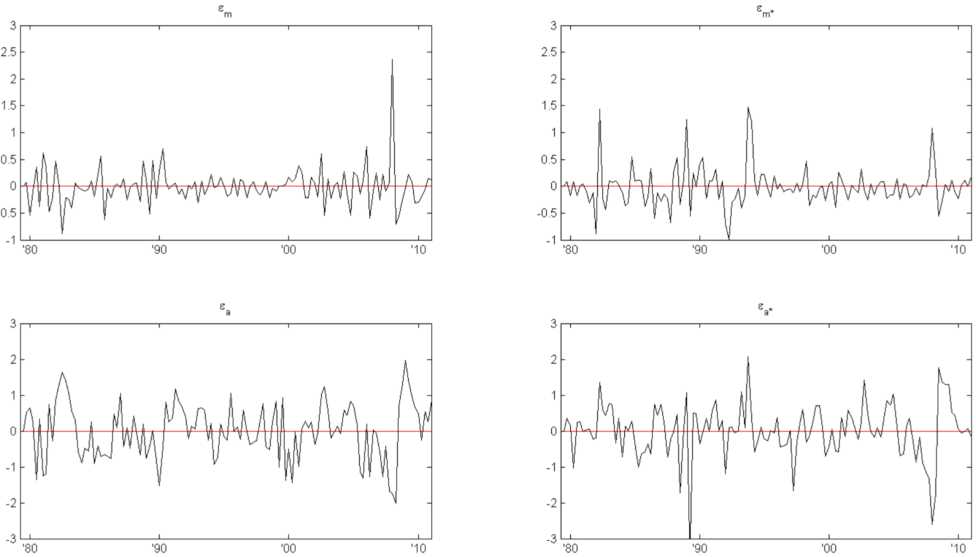
Note: The code is written for Matlab version 8.3.0.532 and Dynare version 4.3.2. This figure plots the prior distributions of all 13 structural (policy and non-policy) and shock parameters that do not receive a degenerate prior distribution. It also includes the posterior distribution estimated from the sample of 128 quarterly observations for the U.S. and a foreign aggregate composed of the 38 largest trading partners of the U.S. The estimation is based on four observables: Home and Foreign output, Home and Foreign CPI inflation. The code for this figure is available upon request from the author.

Figure 3. Time Series of Observable Variables



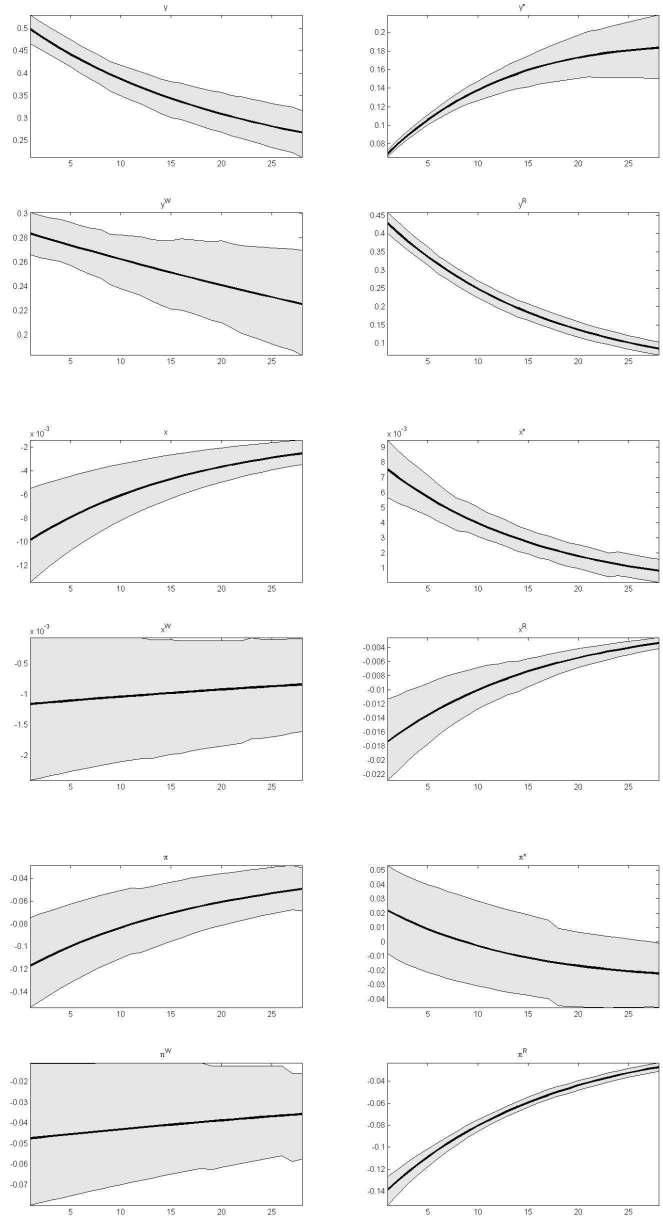
Note: The code is written for Matlab version 8.3.0.532 and Dynare version 4.3.2. This figure plots the time series for the observables used to estimate the NOEM model: Home and Foreign output, Home and Foreign CPI inflation. The observable data distinguishes between the U.S. and a foreign aggregate composed of the 38 largest trading partners of the U.S. The estimation sample includes 128 quarterly observations from 1980Q1 until 2011Q4. The code for this figure is available upon request from the author.

Figure 4. Smoothed Shock Innovations



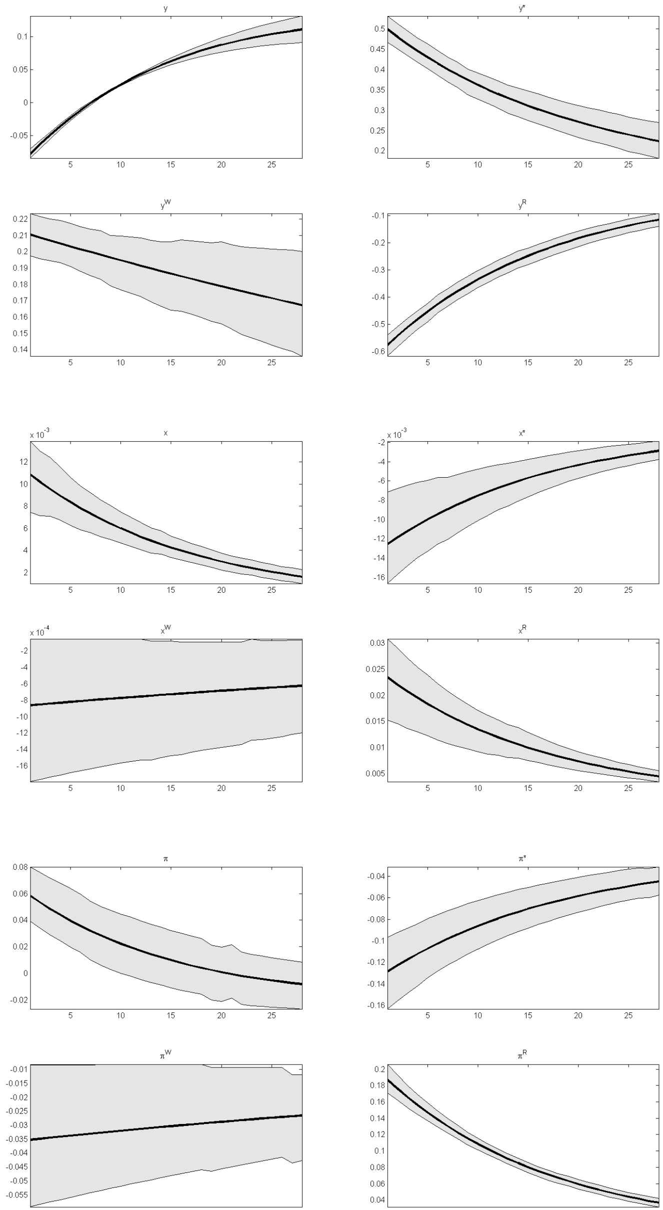
Note: The code is written for Matlab version 8.3.0.532 and Dynare version 4.3.2. This figure plots the smoothed innovations of the monetary and productivity shocks inferred from the estimated NOEM model for the U.S. and a foreign aggregate composed of the 38 largest trading partners of the U.S. The estimation sample includes 128 quarterly observations and is based on four observables: Home and Foreign output, Home and Foreign CPI inflation. The code for this figure is available upon request from the author.

Figures 5.A Bayesian IRFs in Response to a Home Productivity Shock



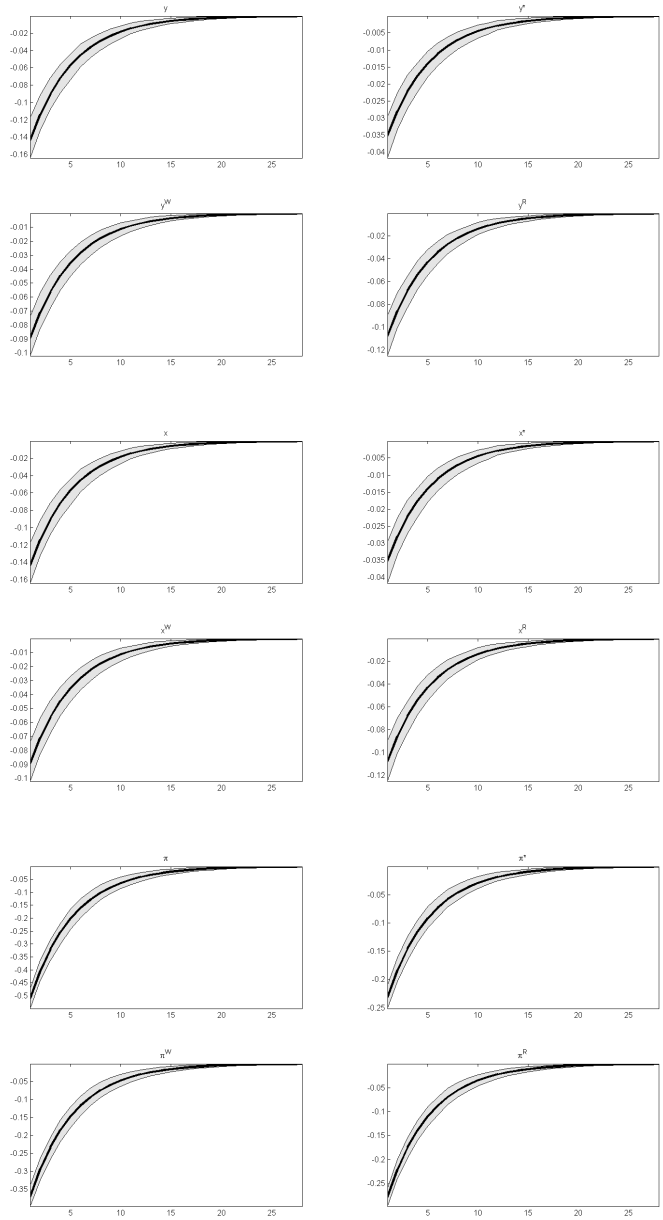
Note: The code is written for Matlab version 8.3.0.532 and Dynare version 4.3.2. This figure plots the Bayesian impulse response functions (IRFs) for output, the output gap and inflation distinguishing between the U.S. (H), the foreign aggregate (F), global (W) and the U.S. differential with respect to the foreign aggregate (R) in response to U.S. productivity shock innovations. The Bayesian IRFs are estimated from a sample of 128 quarterly observations using data for the U.S. and an aggregate of 38 of the largest trading partners of the U.S. on four observables: Home and Foreign output, Home and Foreign inflation. The code for this figure is available upon request from the author.

Figures 5.B Bayesian IRFs in Response to a Foreign Productivity Shock



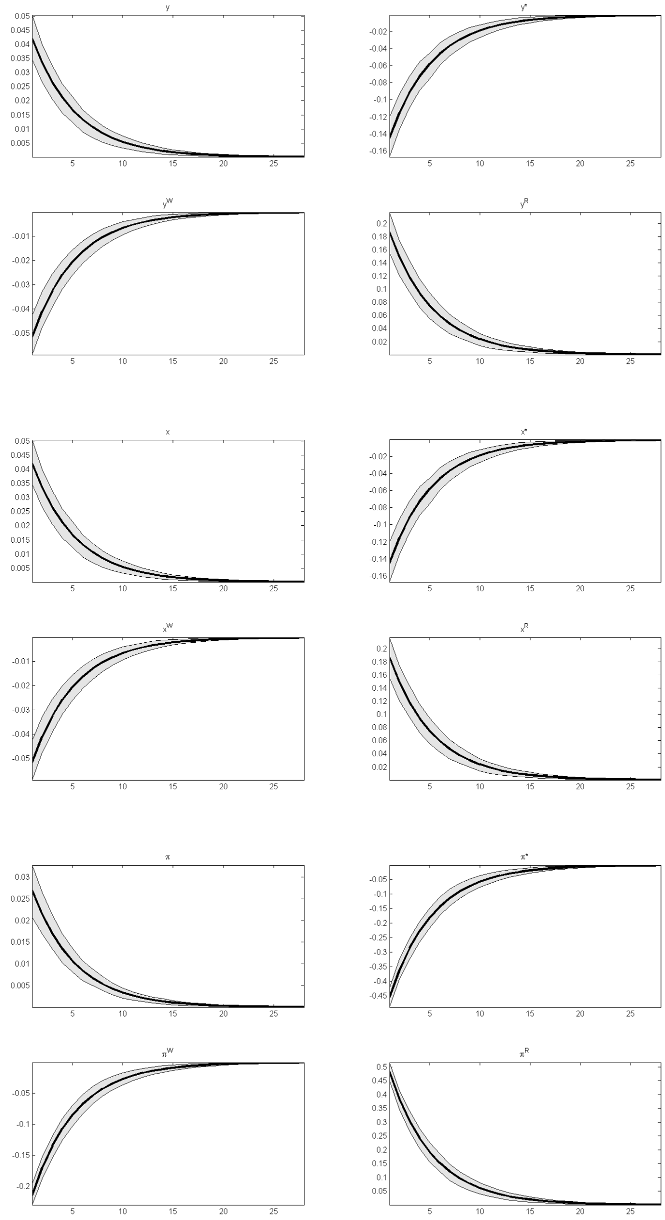
Note: The code is written for Matlab version 8.3.0.532 and Dynare version 4.3.2. This figure plots the Bayesian impulse response functions (IRFs) for output, the output gap and inflation distinguishing between the U.S. (H), the foreign aggregate (F), global (W) and the U.S. differential with respect to the foreign aggregate (R) in response to Foreign productivity shock innovations. The Bayesian IRFs are estimated from a sample of 128 quarterly observations using data for the U.S. and an aggregate of 38 of the largest trading partners of the U.S. on four observables: Home and Foreign output, Home and Foreign inflation. The code for this figure is available upon request from the author.

Figures 6.A Bayesian IRFs in Response to a Home Monetary Shock



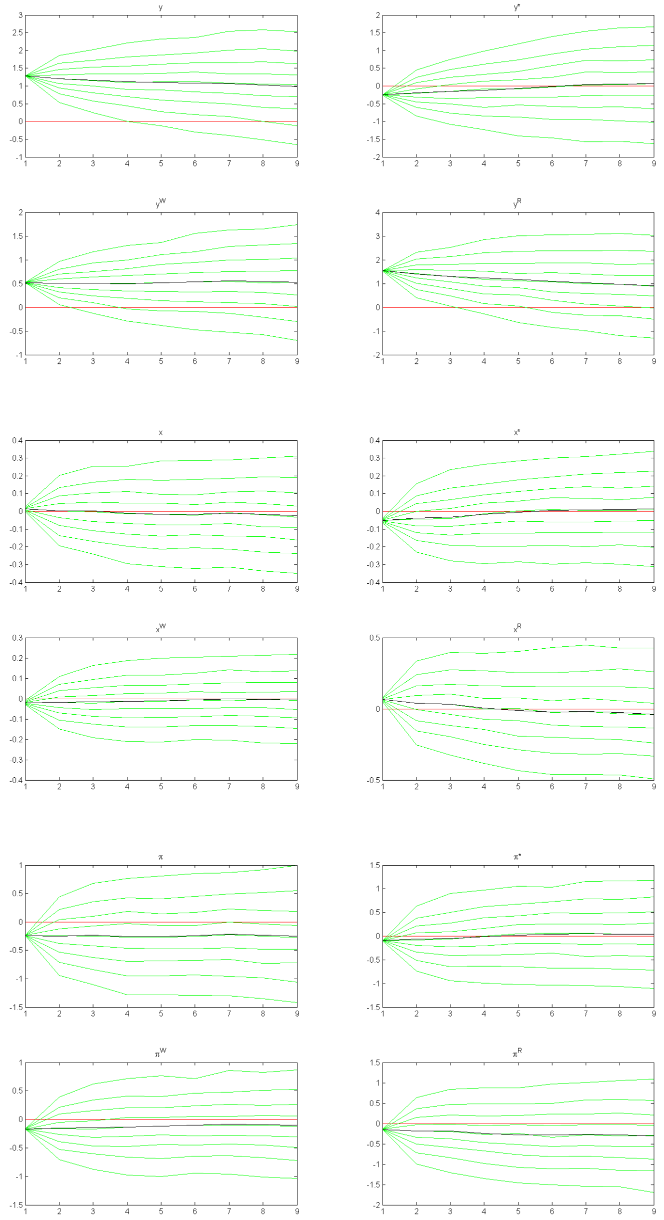
Note: The code is written for Matlab version 8.3.0.532 and Dynare version 4.3.2. This figure plots the Bayesian impulse response functions (IRFs) for output, the output gap and inflation distinguishing between the U.S. (H), the foreign aggregate (F), global (W) and the U.S. differential with respect to the foreign aggregate (R) in response to U.S. monetary shock innovations. The Bayesian IRFs are estimated from a sample of 128 quarterly observations using data for the U.S. and an aggregate of 38 of the largest trading partners of the U.S. on four observables: Home and Foreign output, Home and Foreign inflation. The code for this figure is available upon request from the author.

Figures 6.B Bayesian IRFs in Response to a Foreign Monetary Shock



Note: The code is written for Matlab version 8.3.0.532 and Dynare version 4.3.2. This figure plots the Bayesian impulse response functions (IRFs) for output, the output gap and inflation distinguishing between the U.S. (H), the foreign aggregate (F), global (W) and the U.S. differential with respect to the foreign aggregate (R) in response to Foreign monetary shock innovations. The Bayesian IRFs are estimated from a sample of 128 quarterly observations using data for the U.S. and an aggregate of 38 of the largest trading partners of the U.S. on four observables: Home and Foreign output, Home and Foreign inflation. The code for this figure is available upon request from the author.

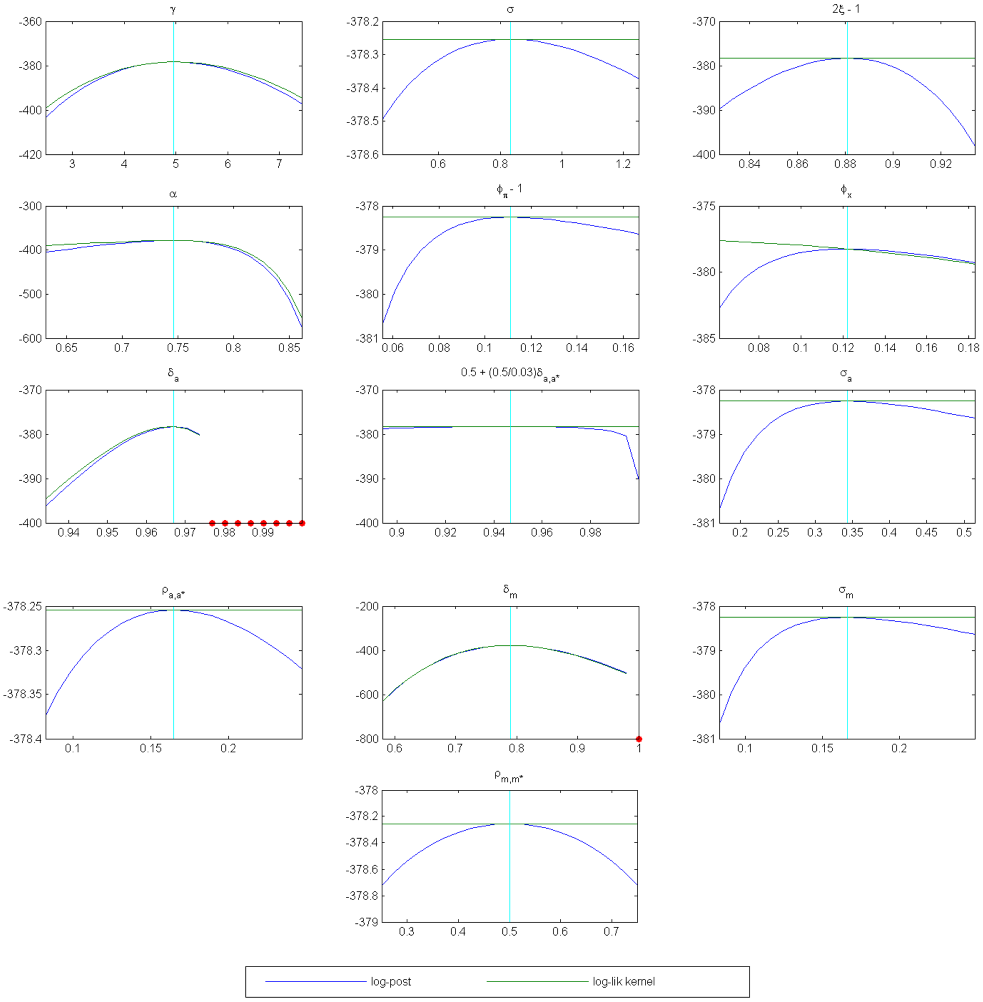
Figure 7. Forecasted Variables Over the Period 2012Q1-2014Q1



Note: The code is written for Matlab version 8.3.0.532 and Dynare version 4.3.2. This figure plots the Bayesian unconditional forecasts (point forecasts) for output, the output gap and inflation distinguishing between the U.S. (H), the foreign aggregate (F), global (W) and the U.S. differential with respect to the foreign aggregate (R). The black line depicts the point forecasts for the corresponding variable starting from the last observation of the sample (2011Q4). The green lines depict the point forecast deciles taking into account both the parameter uncertainty as well as the uncertainty about future shocks. The Bayesian forecasts are inferred from a sample of 128 quarterly observations using data for the U.S. and an aggregate of 38 of the largest trading partners of the U.S. on four observables: Home and Foreign output, Home and Foreign inflation. The code for this figure is available upon request from the author.

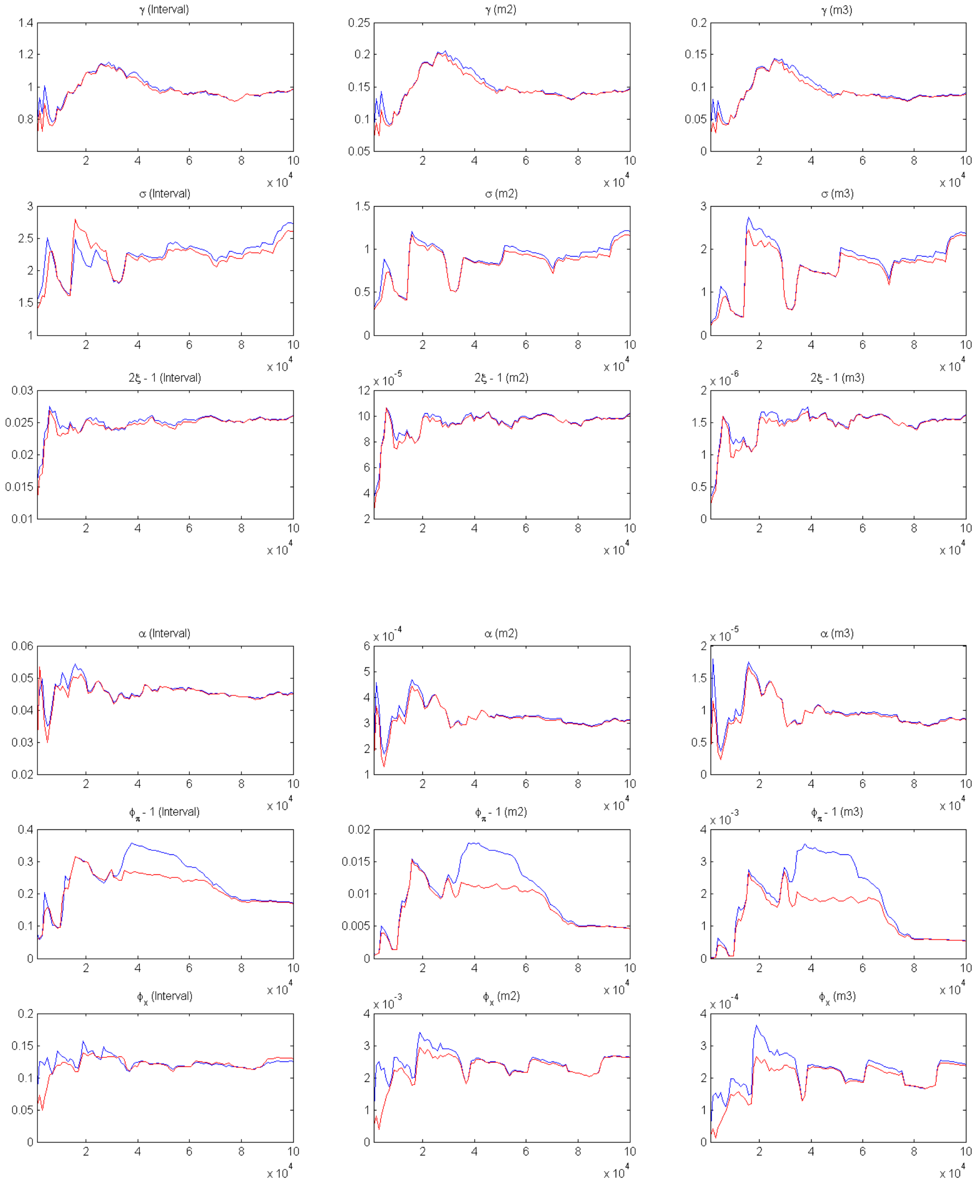
C Diagnostic Figures on Bayesian Estimation

Figure I. Check Plots on the Estimated Parameters

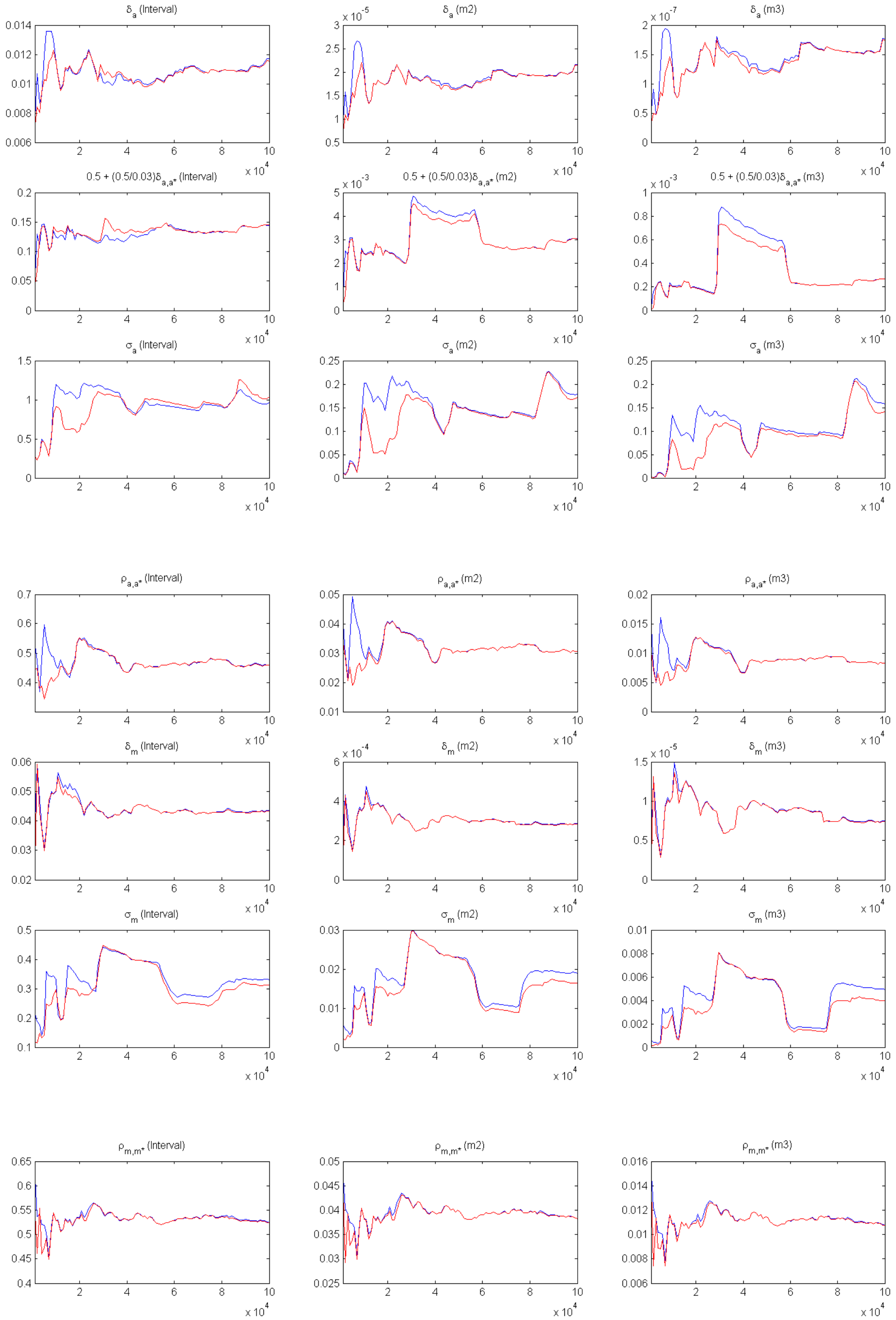


Note: The code is written for Matlab version 8.3.0.532 and Dynare version 4.3.2. This figure includes the mode check plots for all 13 structural (policy and non-policy) and shock parameters that do not receive a degenerate prior distribution in the estimation. The code for this figure is available upon request from the author.

Figure II. MCMC Univariate Diagnostic on the Estimated Parameters

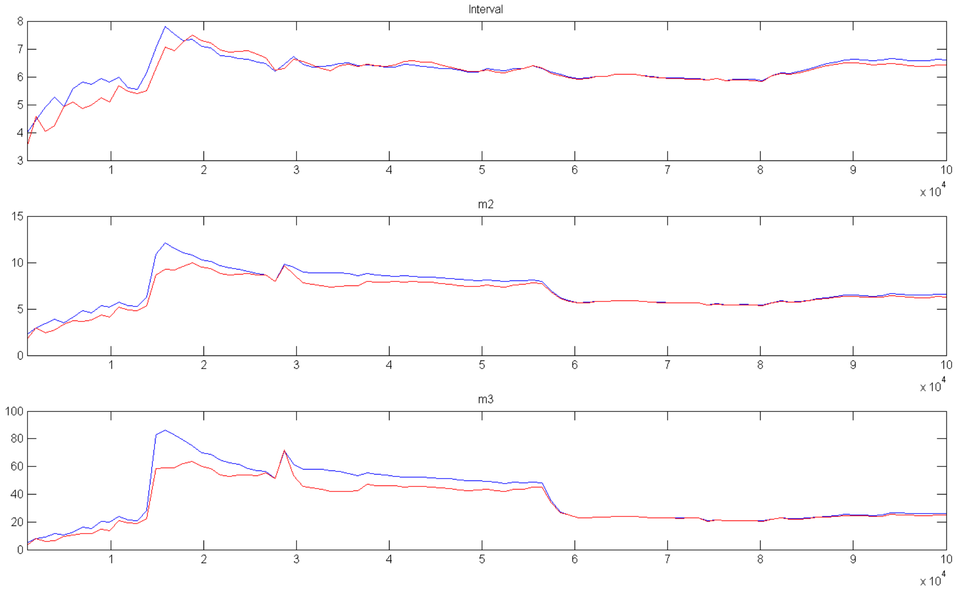


Note: The code is written for Matlab version 8.3.0.532 and Dynare version 4.3.2. This figure includes the univariate convergence plots for 6 out of the 13 structural (policy and non-policy) and shock parameters that do not receive a degenerate prior distribution in the estimation. The code for this figure is available upon request from the author.



Note: The code is written for Matlab version 8.3.0.532 and Dynare version 4.3.2. This figure includes the univariate convergence plots for 7 out of the 13 structural (policy and non-policy) and shock parameters that do not receive a degenerate prior distribution in the estimation. The code for this figure is available upon request from the author.

Figure III. Multivariate Diagnostics on the Estimated Model



Note: The code is written for Matlab version 8.3.0.532 and Dynare version 4.3.2. This figure includes the multivariate convergence statistics plots on all 13 structural (policy and non-policy) and shock parameters that do not receive a degenerate prior distribution in the estimation. The code for this figure is available upon request from the author.

References

Adolfson, M., S. Laséen, J. Lindé, and M. Villani (2005). The Role of Sticky Prices in an Open Economy DSGE Model: A Bayesian Investigation. *Journal of the European Economic Association 3*(2-3), 444–457.

Adolfson, M., S. Laséen, J. Lindé, and M. Villani (2007). Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-Through. *Journal of International Economics 72*(2), 481–511.

Adolfson, M., S. Laséen, J. Lindé, and M. Villani (2008). Evaluating an Estimated New Keynesian Small Open Economy Model. *Journal of Economic Dynamics 32*(8), 2690–2721.

An, S. and F. Schorfheide (2007). Bayesian Analysis of DSGE Models. *Econometric Reviews 26*(2-4), 113–172.

Aoki, M. (1981). *Dynamic Analysis of Open Economies.* New York, NY: Academic Press.

Borio, C. E. V. and A. Filardo (2007). Globalisation and Inflation: New Cross-country Evidence on the Global Determinants of Domestic Inflation. *BIS Working Paper no. 227*(Basel, SUI, Bank for International Settlements, May). May.

Calvo, G. A. (1983). Staggered Prices in a Utility-Maximizing Framework. *Journal of Monetary Economics 12*(3), 383–398.

Clarida, R., J. Galí, and M. Gertler (2002). A Simple Framework for International Monetary Policy Analysis. *Journal of Monetary Economics 49*(5), 879–904.

Engel, C. (2009). Currency Misalignments and Optimal Monetary Policy: A Reexamination. *NBER Working Paper no. 14829*(Cambridge, Mass., National Bureau of Economic Research, April).

Fernández-Villaverde, J. (2010). The Econometrics of DSGE Models. *SERIEs 1*(1-2), 3–49.

Ferroni, F. (2011). Trend Agnostic One-Step Estimation of DSGE Models. *B.E. Journal of Macroeconomics, Advances 11: Iss. 1*(25).

Fukuda, S.-i. (1993). International Transmission of Monetary and Fiscal Policy. A Symmetric N-Country Analysis with Union. *Journal of Economic Dynamics and Control 17*(4), 589–620.

Guerron-Quintana, P. A. (2010). What You Match Does Matter: The Effects of Data on DSGE Estimation. *Journal of Applied Econometrics 25*(5), 774–804.

Heathcote, J. and F. Perri (2002). Financial Autarky and International Business Cycles. *Journal of Monetary Economics 49*(3), 601–627.

Ihrig, J., S. B. Kamin, D. Lindner, and J. Marquez (2007). Some Simple Tests of the Globalization and Inflation Hypothesis. *Federal Reserve Board, International Finance Discussion Paper no. 891*(Washington, D.C., April). April.

Martínez-García, E. (2008). Globalization and Monetary Policy: An Introduction. *Federal Reserve Bank of Dallas, Globalization and Monetary Policy Institute Working Paper no. 11*(April).

Martínez-García, E. (2011). A Redux of the Workhorse NOEM Model with Capital Accumulation and Incomplete Asset Markets. *Federal Reserve Bank of Dallas, Globalization and Monetary Policy Institute Working Paper no. 74*(February).

Martínez-García, E. and J. Søndergaard (2009). Investment and Trade Patterns in a Sticky-Price, Open-Economy Model. In G. Calcagnini and E. Saltari (Eds.), *The Economics of Imperfect Markets. The Effect of Market Imperfections on Economic Decision-Making*, Series: Contributions to Economics. Heidelberg: Springer (Physica-Verlag). December.

Martínez-García, E. and J. Søndergaard (2013). Investment and Real Exchange Rates in Sticky Price Models. *Macroeconomic Dynamics 17*(2), 195–234.

Martínez-García, E., D. Vilán, and M. A. Wynne (2012). Bayesian Estimation of NOEM Models: Identification and Inference in Small Samples. *Advances in Econometrics 28*, 137–199.

Martínez-García, E. and M. A. Wynne (2010). The Global Slack Hypothesis. Federal Reserve Bank of Dallas *Staff Papers, 10*. September.

Martínez-García, E. and M. A. Wynne (2013). Global Slack as a Determinant of U.S. Inflation. In A. Filardo and A. Mehrotra (Eds.), *Globalisation and Inflation Dynamics in Asia and the Pacific*, Volume BIS Papers No. 70, pp. 93–98. Bank for International Settlements.

Martínez-García, E. and M. A. Wynne (2014). Assessing Bayesian Model Comparison in Small Samples. *Advances in Econometrics 34*, 71–115.

Rudebusch, G. D. (2006). Monetary Policy Inertia: Fact or Fiction? *International Journal of Central Banking 2*(4), 85–135.

Ríos-Rull, J.-V., F. Schorfheide, C. Fuentes-Albero, M. Kryshko, and R. Santaeulàlia-Llopis (2012). Methods versus Substance: Measuring the Effects of Technology Shocks. *Journal of Monetary Economics 59*(8), 826–846.

Stock, J. H. and M. W. Watson (1999). Forecasting Inflation. *Journal of Monetary Economics 44*(2), 293–335.

Taylor, J. B. (1993). Discretion versus Policy Rules in Practice. *Carnegie-Rochester Conference Series on Public Policy 39*, 195–214.

Woodford, M. (2003). *Interest and Prices. Foundations of a Theory of Monetary Policy.* Princeton, New Jersey: Princeton University Press.

Zellner, A. (1971). *An Introduction to Bayesian Inference in Econometrics.* John Wiley & Sons.