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The Importance of Diagnostic Expectations in Open Economies

Selim Elekdag, Mananirina Razafitsiory, Luis-Felipe Zanna

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The Importance of Diagnostic Expectations in Open Economies

Prepared by Selim Elekdag, Mananirina Razafitsiory, and Luis-Felipe Zanna*

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ABSTRACT: We develop and estimate a parsimonious New-Keynesian small open-economy model that incorporates Diagnostic Expectations (DE)—a behavioral alternative to Rational Expectations (RE). Under DE, agents systematically overreact to new information, generating additional endogenous volatility. Our empirical analysis provides robust support for the DE framework: it fits Canadian data significantly better than the nested RE benchmark and improves forecasts of key macroeconomic variables, including real GDP growth, even during crises such as the Global Financial Crisis. These gains arise because DE reshapes the transmission of shocks, amplifying their effects and strengthening the exchange-rate channel of monetary policy. As a result, the relative importance of structural shocks shifts—with greater roles for supply shocks—and policymakers face a meaningfully worse inflation–output volatility trade-off. Taken together, our results highlight the relevance of behavioral expectations for open-economy dynamics and policy design.

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Author’s E-Mail Address:	SElekdag@imf.org; mananirina.razafitsiory.1@ulaval.ca; FZanna@imf.org

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WORKING PAPERS

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I. Introduction

Expectations shape macroeconomic dynamics, yet mounting evidence shows that the rational expectations (RE) hypothesis often fails to capture key empirical regularities. The recent behavioral economics literature has positioned Diagnostic Expectations (DE) as a compelling and empirically validated alternative (e.g., Bordalo and others, 2018, 2022). DE represents a simple, parsimonious, and micro-founded departure from RE, robust to the Lucas critique. Its core feature is to capture agents' systematic overreaction to news, thereby generating heightened endogenous volatility. Evidence from closed-economy settings shows that DE better reflects macroeconomic dynamics than RE (e.g., Bianchi and others, 2024; L'Huillier and others, 2024), while also helping explain asset-price puzzles such as bubbles and excess volatility (Bordalo and others, 2019; Bordalo and others, 2021).

This paper is the first to estimate a small open-economy (SOE) DSGE model with diagnostic expectations. Open economies provide an especially sharp test given the central role of the exchange rate in transmission. We ask three questions: (i) Does DE improve model fit and forecasting accuracy relative to RE? (ii) How does agents' overreaction reshape the nature of shocks and policy transmission? (iii) What are the implications for volatility trade-offs faced by policymakers?

To address these questions, we incorporate DE into a standard New Keynesian SOE model estimated on Canadian data, building on Justiniano and Preston (2010) and Galí and Monacelli (2005). The model features incomplete asset markets, nominal and real rigidities (habit formation, price stickiness, inflation indexation, imperfect pass-through), and key shocks needed for empirical validation. DE is explicitly integrated while nesting RE as a benchmark, enabling direct comparison between the two expectations frameworks.

Five main findings emerge.

First, DE fits the data better. The diagnosticity parameter that governs overreaction is robustly estimated to be greater than zero, providing empirical support for the DE framework in an open-economy context. Improvements in the log marginal likelihood further confirm the superior empirical performance of the DE specification.

Second, DE generates greater volatility and can exert more pronounced effects on both real and nominal exchange rates in response to different shocks. As a result, the exchange rate channel becomes a central mechanism for either amplifying or dampening shock transmission. For instance, monetary policy shocks yield larger real effects: a policy rate increase induces a stronger exchange rate appreciation, which reduces exports and contributes to a sharper output contraction. By contrast, the expansionary impact of higher government spending is partly offset, as the accompanying real appreciation crowds out exports and dampens the overall output response.

Third, DE shifts the importance of shocks. In Canadian data, the key driver of GDP switches from demand (e.g., government spending) shocks under RE to supply (e.g., productivity) shocks under DE. Cost-push shocks gain greater prominence for inflation, while risk-premium shocks matter more for the exchange rate—reflecting DE's stronger amplification of external volatility.

Fourth, DE worsens the policy trade-off. Inflation–output volatility frontiers shift outward, as DE induces greater endogenous volatility, and strengthens the role of supply shocks. Stabilizing inflation comes at the cost of larger output swings, leaving policymakers with a less favorable trade-off than under RE.

Fifth, DE improves forecasting performance. While both frameworks struggle with the magnitude of extreme shocks, DE better captures turning points—such as the output trough during the Global Financial Crisis—and provides earlier signals of economic distress.

Our contribution is twofold. First, we extend the literature on departures from RE—previously used to explain exchange-rate puzzles (Candian and De Leo, 2025; Chakraborty and Evans, 2008; Devereux and Engel, 2002; Du and others, 2021; Gourinchas and Tornell, 2004; Kolasa and others, 2022)—by incorporating DE into an estimated open-economy model.[1] The framework builds directly on Bordalo and others (2018), who formalize Tversky and Kahneman's (1983) representativeness heuristic: individuals overweight outcomes that appear more representative based on recent data, generating excessive optimism after good news and pessimism after bad news. Our results show that this behavioral channel matters quantitatively for open-economy dynamics.

Second, we contribute to the Bayesian estimation literature on SOE DSGE models (e.g., Smets and Wouters, 2002; Lubik and Schorfheide, 2003; Justiniano and Preston, 2010). Unlike prior studies, we demonstrate that even in a parsimonious framework without financial frictions, DE can enhance forecasting performance during downturns. This contrasts with much of the RE literature, which requires explicit financial frictions to explain such episodes (Del Negro and others, 2015; Kocherlakota, 2000; Christiano and others, 2018).
The rest of the paper is structured as follows. Section 2 introduces the SOE model with DE. Section 3 presents the Bayesian estimation. Section 4 analyzes model properties, contrasting DE and RE using impulse-responses, variance decompositions, and volatility trade-offs. Section 5 evaluates forecasting performance. Section 6 concludes.

II. An Open Economy Model with Diagnostic Expectations

This section begins with a primer on Diagnostic Expectations (DE), followed by a presentation of the model. We consider a relatively parsimonious New Keynesian DSGE model for a small open economy (SOE), building on the framework of Justiniano and Preston (2010). The model incorporates standard features such as two traded goods, incomplete asset markets, habit formation in consumption, price indexation to past inflation, and deviations from the law of one price (LOOP). Our key innovation is the integration of DE, which modifies the canonical equations of the standard model by introducing systematic belief distortions. As is typical in SOE

[1] Several departures from the RE benchmark have been proposed, often grounded in different notions of bounded rationality. A prominent strand is the literature on adaptive learning, with Evans and Honkapohja (2001) providing a comprehensive synthesis of the foundational contributions. Early applications of adaptive learning in open-economy settings explored the implications for expectational stability under alternative monetary and exchange rate rules. Examples include Llosa and Tuesta (2008), who examine interest rate rules, and Zanna (2009), who studies purchasing-power-parity-based exchange rate rules. Another strand departs from RE by introducing "cognitive discounting," as in Gabaix (2020), which allows for partial myopia toward atypical future events. Building on this approach, Kolasa and others (2022) apply cognitive discounting to an open-economy framework and propose it as a potential resolution to several exchange rate puzzles.

settings, the domestic economy (country H) is assumed to be too small to influence the rest of the world (country F), whereas foreign shocks can affect the domestic economy. Foreign variables are denoted with an asterisk (e.g., X^*). For an economic variable X_t, the steady state is denoted by $\bar{X}$, and $\hat{X}_t = \log(X_t/X)$ denotes its log deviation from its steady state. For variables that are assumed to have a steady-state value of zero, we linearize them directly.[2]

2.1 Diagnostic Expectations—A primer

Bordalo and others (2018, 2022) introduce DE into macroeconomics and finance as an alternative to the Rational Expectations (RE) hypothesis. DE represents a significant departure from RE, reflecting that agents tend to overreact to news and thereby generate greater macroeconomic volatility. This suggests that DE may play an important role in business cycle fluctuations.

Individuals often assess likelihood based on representativeness, and DE are grounded in the representative heuristic proposed by Kahneman and Tversky (1983). According to this heuristic, "an attribute is representative of a class if it is very diagnostic; that is, the relative frequency of this attribute is much higher in that class than in the relevant reference class". Bordalo and others (2018) illustrate this idea with a simple example: Consider an individual guessing the hair color (X) of an individual given data, $D = Irish$. The individual is likely to overestimate the probability of an Irish person having red hair, because red hair is representative of the Irish. In other words, relative to the rest of the world, the Irish have a higher likelihood of having red hair. Bordalo and others (2018) formalize this as:

$$\mathbb{E}^{\theta}[red\ hair|Irish] = \mathbb{E}[red\ hair|Irish] + \theta(\mathbb{E}[red\ hair|Irish] - \mathbb{E}[red\ hair|World]),$$

where $\mathbb{E}[\cdot]$ is the RE operator, $\mathbb{E}^{\theta}[\cdot]$ is the DE operator, and θ is the "diagnosticity" parameter indicating the strength of the DE—note that with $\theta = 0$ we revert to RE. The parameter θ therefore overweights the difference between the likelihood of Irish versus non-Irish people having red hair—that is, representativeness—when individuals form their beliefs.

Below we incorporate DE into our New Keynesian DSGE model, following Bianchi and others (2024) as well as L'Huillier and others (2024). This incorporation is somewhat straightforward and based on Bordalo and others (2018). Continuing with the previous example, we replace $X = hair\ color$ with a random variable one period ahead, x_{t+1}, and $D = Irish$ with the realization of that variable in the current period, x_t. We measure the representativeness of the realization of x_t using data up to period $t-1$ as the reference group. Then

$$\mathbb{E}_t^{\theta}[x_{t+1}] = \mathbb{E}_t[x_{t+1}] + \theta(\mathbb{E}_t[x_{t+1}] - \mathbb{E}_{t-1}[x_{t+1}]). \tag{1}$$

For example, if after observing x_t, an individual expects a higher x_{t+1} than they did before, they overweight that news when forming expectations.

We can interpret DE representativeness in a macroeconomic model as a surprise term:

$$\mathbb{E}_t^{\theta}[x_{t+1}] = \mathbb{E}_t[x_{t+1}] + \theta \underbrace{(\mathbb{E}_t[x_{t+1}] - \mathbb{E}_{t-1}[x_{t+1}])}_{\substack{\text{surprise at } t \text{ regarding} \\ \text{the expectation of } x_{t+1}}} = \mathbb{E}_t[x_{t+1}] + \theta \xi_{t+1}^x, \tag{2}$$

[2] Hereafter, we will refer informally to the linearized form of the model, acknowledging that some terms are, in fact, log-linearized.

where, with some abuse of notation, ξ_{t+1}^{x} represents the surprise associated with the expectation of x_{t+1} after receiving news at time t. In other words, it is the effect of today's news on tomorrow's expectations. The DE parameter θ then determines how strongly the agents react to the surprise term. When $\theta = 0$—the RE case—, agents do not overreact to news, and the DE operator is identical to the RE operator.[3]

We now outline the structure of the model. Given its largely standard formulation, we provide a general overview of the agents in the economy and their behavioral assumptions. Our focus is on the implications of DE for the key linearized behavioral equations, while relegating some technical details to Appendix II, including the full linearized model and steady state.

2.2 Households

The preferences of the representative household are given by:

$$U(C_t, N_t) + \mathbb{E}_t^{\theta}\left[\sum_{s=1}^{\infty} \beta^{t+s} U(C_{t+s}, N_{t+s})\right], \tag{3}$$

where the period utility function is defined as

$$U(C_t, N_t) = \frac{(C_t - h\, C_{t-1})^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi}, \tag{4}$$

and $\beta \in (0,1)$ is the discount factor. In this specification, C_t denotes aggregate consumption, N_t represents labor, $\sigma > 0$ is the coefficient of relative risk aversion (or the inverse of the intertemporal elasticity of substitution), and $\varphi > 0$ is the inverse of the Frisch elasticity of labor supply. The parameter $h > 0$ captures the degree of external habit formation in consumption.

Aggregate consumption is modeled as a constant elasticity of substitution (CES) composite of domestically produced goods $C_{H,t}$ and imported (foreign) goods $C_{F,t}$, which are purchased at prices $P_{H,t}$ and $P_{F,t}$, respectively. The optimal demand for each consumption component is given by:

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \quad \text{and} \quad C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t, \tag{5}$$

where $\eta > 0$ denotes the elasticity of substitution between domestic and foreign goods, and $\alpha \in (0,1)$ represents the share of imported goods in the household's consumption basket, capturing the degree of trade openness. The consumer price index (CPI) corresponds to $P_t = \left[(1-\alpha)P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}$. CPI inflation is

[3] For variables at time t, we have:

$$\mathbb{E}_t^{\theta}[x_t] = \mathbb{E}_t[x_t] + \theta \underbrace{(\mathbb{E}_t[x_t] - \mathbb{E}_{t-1}[x_t])}_{\substack{\text{surprise at } t \text{ regarding} \\ \text{the expectation of } x_t}} = x_t + \theta\, \xi_t^{x},$$

where, ξ_t^{x} is the surprise on x_t from news at time t, that is, the effect of today's news on the realization of x_t. Note that the DE operator differs from the RE operator: under RE case, $\mathbb{E}_t[x_t] = x_t$, whereas in the DE case, $\mathbb{E}_t^{\theta}[x_t] = x_t + \theta\, \xi_t^{x} \neq x_t$. Therefore, when working with DE, one needs to be careful when taking terms outside of the expectation operator. Note also, that DE has the property of strong additivity (see, L'Huillier and others, 2024): $\mathbb{E}_t^{\theta}[x_{t+r} + y_{t+s}] = \mathbb{E}_t^{\theta}[x_{t+r}] + \mathbb{E}_t^{\theta}[y_{t+s}],\ r, s \geq 0$.

defined as $\Pi_t = \frac{P_t}{P_{t-1}}$, while the inflation rates for domestic and imported goods are given by $\Pi_{H,t} = \frac{P_{H,t}}{P_{H,t-1}}$ and $\Pi_{F,t} = \frac{P_{F,t}}{P_{F,t-1}}$, respectively.

Given that $P_{H,t}C_{H,t} + P_{F,t}C_{F,t} = P_tC_t$, the representative household's nominal budget constraint can be written as:

$$P_tC_t + \frac{D_t}{R_t} + \frac{e_tB_t}{R_t^*\phi_t(A_t)} = D_{t-1} + e_tB_{t-1} + W_tN_t + F_{H,t} + F_{F,t} - T_t, \qquad \forall\, t > 0 \tag{6}$$

where D_t and B_t denote the household's holdings of one-period nominal domestic and foreign bonds, respectively, with gross nominal interest rates R_t and R_t^*. The term e_t represents the nominal exchange rate (expressed as domestic currency per unit of foreign currency). Households earn a nominal wage W_t, receive profits $F_{H,t}$ and $F_{F,t}$ from shareholdings in firms, respectively, and pay lump-sum taxes T_t. The term $\phi_t(.)$ captures a time-varying risk premium or financial friction associated with foreign borrowing:

$$\phi_t = \exp\{\chi[-A_t] - \varepsilon_{rp,t}\}, \tag{7}$$

where $-A_t = -\frac{e_tB_t}{P_t\bar{Y}}$ denotes the real quantity of outstanding foreign debt expressed in terms of domestic currency as a fraction of steady-state GDP $\bar{Y}$, and $\varepsilon_{rp,t}$ is a risk premium shock. This premium is specified to ensure stationarity in the linear approximation of the model around the steady state.[4] In the steady state, there is no risk premium, i.e., $\bar{\phi} = 1$.

Appendix II presents the first-order conditions and their economic interpretation in solving the household's optimization problem—see equations (A1)–(A3). Here, we focus on the implications of DE for the linearized versions of two key equilibrium conditions: the Euler equation for consumption and the uncovered interest parity (UIP) condition. Particular attention is given to the role of DE in the transmission mechanism of monetary policy—specifically, how changes in the policy rate R_t propagate through the economy, as elaborated below. In linearized terms, the Euler equation for consumption becomes:

$$\hat{C}_t = \frac{h}{1+h}\left(\hat{C}_{t-1} - \theta\xi_t^C\right) + \frac{h}{1+h}\left\{\mathbb{E}_t\left[\hat{C}_{t+1}\right] + \theta\xi_{t+1}^C\right\} - \frac{1}{\sigma(1+h)}\left\{\hat{R}_t - \mathbb{E}_t\left[\hat{\Pi}_{t+1}\right] - \theta(\xi_{t+1}^\pi + \xi_t^\pi)\right\}, \tag{8}$$

where $\xi_{t+j}^x = \mathbb{E}_t\left[\hat{x}_{t+j}\right] - \mathbb{E}_{t-1}\left[\hat{x}_{t+j}\right]$ for $j = 0{,}1$ and $\mathbb{E}_t[.]$ denotes the RE operator. DE affects this equation through three distinct channels. First, the surprise term for current consumption, ξ_t^C , negatively affects current consumption, $\hat{C}_t$. Second, the surprise term for future consumption, ξ_{t+1}^C, amplifies the reaction of current consumption, $\hat{C}_t$, to the expected consumption, $\mathbb{E}_t\left[\hat{C}_{t+1}\right]$. Third, the surprise terms related to inflation expectations, ξ_{t+1}^π and ξ_t^π, cause the representative household to overreact to news about expected future and current inflation. This overreaction distorts the real interest rate—$\hat{R}_t - \mathbb{E}_t\left[\hat{\Pi}_{t+1}\right] - \theta(\xi_{t+1}^\pi + \xi_t^\pi)$—, which is directly influenced by monetary policy and, in turn, affects intertemporal consumption decisions.[5]

[4] See Schmitt-Grohe and Uribe (2003).

[5] The two surprise terms arise because DE introduces behavioral inattention whereby predetermined variables are observed with a lag, implying that they cannot be treated as constants as in the case of RE. See, for instance, Bounader and Elekdag (2024) for further intuition.

DE also affects the UIP condition, which equates the expected returns on domestic and foreign bonds after accounting for expected exchange rate depreciation and country-specific risk premia. In linearized terms, the UIP condition under DE can be written as:

$$\hat{e}_t = \hat{R}_t^* - \hat{R}_t + \hat{\phi}_t + \mathbb{E}_t[\hat{e}_{t+1}] + \theta[\xi_{t+1}^{\Delta e} + \xi_t^{\Delta e}], \tag{9}$$

which illustrates that the nominal exchange rate is driven not only by interest rate differentials ($\hat{R}_t^* - \hat{R}_t$), the risk premium ($\hat{\phi}$), and the expected exchange rate ($\mathbb{E}_t[\hat{e}_{t+1}]$)—as in the case of RE—but also by surprise components in exchange rate expectations captured by the term $\theta[\xi_{t+1}^{\Delta e} + \xi_t^{\Delta e}]$, with Δe denoting the change in the linearized exchange rate. These expectation surprises can amplify exchange rate volatility, with important implications for monetary policy transmission and the stability of capital flows.

The LOOP is assumed not to hold in this framework. A price gap, denoted by $\Gamma_{F,t}$, exists between the foreign CPI, P_t^*, and the domestic currency price of imported goods, $P_{F,t}$. This gap is defined as $\Gamma_{F,t} = \frac{e_t P_t^*}{P_{F,t}}$. Moreover, the CPI-based real exchange is defined as $q_t = \frac{e_t P_t^*}{P_t}$ and the terms of trade (TOT) are defined as the relative price of foreign goods in terms of domestic goods, $S_t = \frac{P_{F,t}}{P_{H,t}}$. Given these definitions and the departure from LOOP, the linearized real exchange rate can be expressed as: $\hat{q}_t = \hat{\Gamma}_{F,t} + (1-\alpha)\hat{S}_t$. This expression implies that real exchange rate fluctuations are driven by deviations from the LOOP (i.e., the price gap) and movements in TOT.

2.3 Firms

There are three types of firms in the model: final domestic goods firms, intermediate goods firms, and retail import firms.

Final domestic goods firms. These firms operate in a setting of perfect competition and aggregate a continuum of intermediate goods, indexed by $i \in [0,1]$, into a composite good $Y_{H,t}$, using a Dixit-Stiglitz aggregator. The intermediate goods $Y_{H,t}(i)$ are supplied by monopolistically competitive intermediate firms which charge prices $P_{H,t}(i)$. Solving the firm's cost minimization problem subject to the aggregator constraint yields the following demand function for each variety i:

$$Y_{H,t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\epsilon_H} Y_{H,t}, \tag{10}$$

where $\epsilon_H > 1$ denotes the elasticity of substitution across domestic varieties of intermediate goods.

Intermediate goods firms. Each intermediate goods producer i in the continuum of monopolistically competitive firms supplies a differentiated variety, $Y_{H,t}(i)$, using a linear production technology:

$$Y_{H,t}(i) = \varepsilon_{a,t} N_t(i), \tag{11}$$

where $\varepsilon_{a,t}$ represents total factor productivity (TFP), which is common across firms and subject to exogenous productivity shocks. Production is demand-determined, as each firm faces a downward-sloping demand curve given by equation (10) from final goods producers.

Intermediate firms also face nominal rigidities in the form of sticky prices. Price adjustment costs are modeled à la Rotemberg (1982), through a quadratic cost function:

$$AC_{H,t}(i) = \frac{\psi_H}{2}\left(\frac{P_{H,t}(i)}{\Pi_{H,t-1}^{\delta_H} P_{H,t-1}(i)} - 1\right)^2 P_{H,t}Y_{H,t}, \tag{12}$$

where $\psi_H \geq 0$ captures the degree of price stickiness and $\delta_H \geq 0$ reflects the extent of indexation to past domestic inflation.

Each intermediate firm sets its price $P_{H,t}(i)$ to maximize expected discounted profits:

$$\frac{F_{H,t}(i)}{P_{H,t}} + \mathbb{E}_t^{\theta}\left[\sum_{s=1}^{\infty} \Lambda_{t,t+s}\frac{F_{H,t+s}(i)}{P_{H,t+s}}\right], \tag{13}$$

where real profits are defined as:

$$\frac{F_{H,t}(i)}{P_{H,t}} = \frac{P_{H.t}(i)}{P_{H,t}}\left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\epsilon_H} Y_{H,t} - (1-\iota_H)MC_t\left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\epsilon_H} Y_{H,t} - \frac{AC_{H,t}(i)}{P_{H,t}}, \tag{14}$$

and the real marginal cost $MC_t = \frac{W_t}{P_{H,t}\,\varepsilon_{a,t}}$, which is not firm-specific. The subsidy ι_F is calibrated such that $\overline{MC} = 1$ in steady state. The stochastic discount factor $\Lambda_{t,t+s}$ is defined as: $\Lambda_{t,t+s} = \beta^s \frac{(C_{t+s}-hC_{t+s-1})^{-\sigma}}{(C_t-hC_{t-1})^{-\sigma}}$.
Appendix II presents the first-order conditions derived from this optimization problem of the intermediate firms. Assuming symmetry across firms—i.e., $P_{H,t}(i)$= $P_{H,t}$, $\forall\, i \in [0,1]$—, the resulting New Keynesian Phillips Curve (NKPC), in linearized form, is given by:

$$(1+\beta\delta_H)\widehat{\Pi}_{H,t} = \delta_H\,\widehat{\Pi}_{H,t-1} + \beta\mathbb{E}_t\left[\widehat{\Pi}_{H,t+1}\right] + \frac{\epsilon_H - 1}{\psi_H}\widehat{MC}_t + \beta\theta\left[\,\xi_{t+1}^{\Pi_H} - \delta_H\xi_t^{\Pi_H}\right] \tag{14}$$

where $\widehat{\Pi}_{H,t}$ is the log-deviation of domestic inflation, $\xi_{t+1}^{\Pi_H}$ and $\xi_t^{\Pi_H}$ are inflation expectation surprises, and the marginal cost in log-deviations is given by: $\widehat{MC}_t = \alpha\hat{S}_t + \varphi\,\hat{Y}_{H,t} + \frac{\sigma}{1-h}\,(\hat{C}_t - h\hat{C}_{t-1}) - (1+\varphi)\,\hat{\varepsilon}_{a,t}$.

Equation (15) illustrates that, relative to the standard NKPC under RE—where current domestic inflation depends on lagged inflation, expected future inflation, and real marginal costs—the DE framework introduces an additional term, $\beta\theta\left[\,\xi_{t+1}^{\Pi_H} - \delta_H\xi_t^{\Pi_H}\right]$. This term captures the effect of surprises in inflation expectations, implying that DE can generate additional volatility and overreaction in domestic inflation dynamics. For example, a positive surprise in expected future inflation—i.e., $\xi_{t+1}^{\Pi_H} > 0$—adds to current inflationary pressures beyond those implied by the standard RE channel, represented by the forward-looking term $\beta\mathbb{E}_t\left[\widehat{\Pi}_{H,t+1}\right]$ in equation (15).

Retail import firms. There is also a continuum of retail firms, indexed by $i \in [0,1]$, which import differentiated foreign goods. These firms, like the domestic intermediate firms, operate under monopolistic competition. Each domestic retailer i purchases a quantity $C_{F,t}(i)$ of the imported goods at the price $e_tP_t^*$—recall that $e_tP_t^* = \Gamma_{F,t}P_{F,t}$, since the LOOP does not hold. Retailers then differentiate the imported good and resell it to households at the retail price $P_{F,t}(i)$, facing a similar downward-sloping demand curve as in equation (10) with one important difference: the elasticity of substitution between imported varieties, $\epsilon_{F,t} > 1$, is time-variant to introduce cost-push shocks, as in Justiniano and Preston (2010). Additionally, they face price adjustment costs $AC_{F,t}(i)$ à la Rotemberg (1982), like the ones described in equation (12), with $\psi_F \geq 0$ capturing the degree of nominal price rigidity and $\delta_F \geq 0$ reflecting the degree of indexation to past imported goods inflation. Appendix II presents the first-order conditions associated with this optimization problem.

In a symmetric equilibrium—i.e., $P_{F,t}(i)= P_{F,t}, \ \forall\, i \in [0,1]$—, the resulting NKPC for imports inflation, in linearized form, is given by:[6]

$$(1+\beta\delta_F)\widehat{\Pi}_{F,t} = \delta_F\, \widehat{\Pi}_{F,t-1} + \beta \mathbb{E}_t\big[\widehat{\Pi}_{F,t+1}\big] + \frac{(\epsilon_F-1)\alpha}{\psi_F}\widehat{\Gamma}_{F,t} + \beta\theta\big[\, \xi_{t+1}^{\Pi_F} - \delta_F \xi_t^{\Pi_F}\big] + \hat{\varepsilon}_{cp,t}. \quad (16)$$

Like equation (15) for domestic inflation, equation (16) shows that DE introduces an additional term, $\beta\theta\big[\, \xi_{t+1}^{\Pi_F} - \delta_F \xi_t^{\Pi_F}\big]$, which captures inflation expectation surprises. This term implies that DE can amplify volatility and induce overreactions in the inflation dynamics of imported goods.

2.4 The Government

Monetary policy is assumed to follow a Taylor-type rule, expressed in linearized form as:

$$\hat{R}_t = \rho \hat{R}_{t-1} + \psi_\pi \widehat{\Pi}_{H,t} + \psi_y \widehat{\mathrm{Y}}_t + \psi_{\Delta e}\Delta\hat{e}_t + \hat{\varepsilon}_{m,t}, \quad (17)$$

where the nominal interest rate responds to its own lag, domestic inflation, output, and the change in the nominal exchange rate. The term $\hat{\varepsilon}_{m,t}$ represents a monetary policy shock. Fiscal policy, on the other hand, is modeled as a zero-debt regime, wherein lump-sum taxes, T_t, adjust each period to ensure that the government's budget constraint, $T_t = P_{H,t}G_{H,t} + \iota_H P_{H,t} MC_t Y_{H,t} + \iota_F \Gamma_{F,t} P_{F,t} C_{F,t}$, is always satisfied. Government expenditures consist of subsidies, $\iota_H P_{H,t} MC_t Y_{H,t}$ and $\iota_F \Gamma_{F,t} P_{F,t} C_{F,t}$, as well as public consumption of domestic goods, $G_{H,t}$, which follows an AR(1) process subject to shocks.[7]

2.5 Market Clearing Conditions

In the domestic economy, market clearing for domestic goods—in a symmetric equilibrium—requires that aggregate output equals aggregate demand:

$$Y_{H,t} = C_{H,t} + C_{H,t}^* + G_{H,t} + \frac{AC_{H,t}}{P_{H,t}}, \quad (18)$$

where the foreign demand for domestic goods is specified as: $C_{H,t}^* = \left(\Gamma_{F,t} S_t\right)^\eta Y_t^*$ and Y_t^* denotes foreign output. By combining the budget constraints of households and the government, along with the definition of firm profits and the market-clearing condition (18), we can derive the economy-wide budget constraint:

$$\frac{e_t B_t}{R_t^* \phi_t(A_t)} - e_t B_{t-1} = P_{H.t} C_{H,t}^* - \Gamma_{F,t} \mathrm{P}_{F,t} C_{F,t} - AC_{F,t}, \quad (19)$$

[6] As in L'Huillier and others (2024), $\hat{\varepsilon}_{F,t}^{n}$ is a normalized price-markup shock process defined as $\hat{\boldsymbol{\varepsilon}}_{\boldsymbol{cp,t}} = \frac{\epsilon_F - 1}{\psi_F}\hat{\varepsilon}_{F,t}$, with $\varepsilon_{cp} = \frac{\epsilon_F}{\epsilon_F - 1}$ in steady state.

[7] In line with the terminology of Woodford (2003), fiscal policy is therefore Ricardian. Consequently, the government budget constraint does not need to be explicitly included among the equilibrium conditions used to solve the model.

which implies that the accumulation of net foreign assets, along with the associated interest income—the left-hand side of equation (19)—must equal net exports, as shown on the right-hand side of the same equation.

2.6 The Foreign Economy

The foreign economy is treated as exogenous to the domestic economy. We assume that the paths of foreign output (Y_t^*), foreign interest rate (R_t^*), and foreign inflation (Π_t^*) follow a second-order vector autoregressive process—VAR (2) process. The corresponding equations are provided in Appendix II.

III. Model Estimations

This section covers the data used, the estimation strategy, choice of prior distributions, the estimation results, and their robustness.

3.1 Data

We employ quarterly macroeconomic data for Canada (the home country) over the period 1992–2023, with the starting point corresponding to the Bank of Canada's formal adoption of inflation targeting. For the foreign economy, we use data from the United States (US). The dataset includes output, inflation, and short-term interest rates for both countries, as well as measures of the terms of trade (TOT) and the real exchange rate. The output gap is computed as the deviation of the logarithm of real GDP from its trend, estimated using the Hodrick-Prescott (HP) filter with a smoothing parameter of 6400. Inflation is measured as the annualized quarterly log-difference of the Consumer Price Index (CPI). Interest rates refer to the respective monetary policy rates of Canada and the U.S., expressed in annualized percentage terms. The real exchange rate is constructed using Canadian and U.S. core CPI data and the bilateral nominal exchange rate; for estimation purposes, it is expressed in log-differences. The terms of trade are calculated as the ratio of import to export prices, using the corresponding price deflators and are also expressed in log-differences. A detailed description of the data and sources is provided in **Figure 1** and **Appendix I Table AI.1**.

In summary, the model is estimated using eight observable time series: output, inflation, and short-term interest rates for both Canada and the US, along with the terms of trade and the real exchange rate. The number of structural shocks identified in the model matches the number of observables. These include monetary policy, government spending, risk premium, cost-push, and productivity shocks, as well as the foreign shocks arising from a VAR(2) representation of U.S. output, interest rates, and CPI inflation.

3.2 Bayesian Estimation

The estimation strategy follows a Bayesian approach. We choose prior distributions for the parameters and then estimate their posterior distribution using the Metropolis-Hastings algorithm in line with An and Schorfheide (2007). Following standard practice in the estimation of structural models as in Christiano and others (2005), Smets and Wouters (2003, 2007), and, for open economies, Adolfson and others (2007) as well as Justiniano and Preston (2010), we estimate the parameters that we think are well-identified by the observable series, and calibrate (that is, impose strict priors) for parameters that we believe are either not well-identified or would just capture the sample means of certain series had they been included.[8] The calibrated parameters are shown in **Table 1** are in line with the literature. For example, the intertemporal elasticity of substitution in consumption is set to 1, the Frisch elasticity of labor supply is fixed at 0.5, and the elasticity of substitution between home and foreign goods is calibrated to be 0.8, as in Chen and others (2023).

3.3 Prior Distributions

The prior distributions are presented in the first three columns of **Table 2**. The parameter of greatest interest is theta (θ). Recall that this parameter determines the degree of diagnosticity. Because its value is theoretically greater than zero, we initially choose a truncated normal distribution with a positive support. Based on the work of Bianchi and others (2024), who find a value of 1.97 in a closed economy setting, we choose a prior mean of 2.0 with a standard deviation of 0.2. Given the importance of this parameter, we conduct an array of sensitivity tests as discussed below.

The remaining parameters have prior distributions that are consistent with the literature. We use the beta distribution for all parameters bounded between 0 and 1. Such parameters include the degree of habit formation, price indexation, interest rate smoothing, and the persistence of the exogenous shock processes. Likewise, the standard deviations of these shocks are assumed to be positive and captured using the inverse gamma distribution. For the interest rate rule, we use fairly loose Gamma distributions pinned at mean values that are common in many other studies. Following L’Huillier and others (2024), a Normal distribution with the same parameterization is used for the priors guiding the price adjustment cost parameters à la Rotemberg (1982).

3.4 Estimation Results

Table 2 also reports the estimation results for two models: the benchmark RE model and our preferred DE model. The most important parameter of the paper, θ, is estimated at 1.96, with a 5-95 percent probability band ranging from 1.87 to 2.07. This estimate is remarkably close to the value of 1.97 estimated by Bianchi and others (2024), and notably above the value of 0.97 found in L'Huillier and others (2024).

In addition, **Table 2** presents the log marginal likelihood (LML) values of each model to assess fit. Recall that the data favors the model with a lower LML. Based on the comparison of the LMLs, the findings indicate that the DE outperforms its RE counterpart. Given the importance of this result for the paper, the next section discusses its robustness. Overall, we interpret these findings as strong evidence supporting DE in an open-economy setting.

Model estimates point to significant differences across models in their other structural characteristics. For instance, nominal rigidities differ: Under DE, the domestic price adjustment cost parameter is lower relative to the RE model. This indicates a steeper NKPC, implying that domestic inflation will be more sensitive to marginal cost fluctuations. By contrast, the NKPC for imported goods is flatter. Likewise, domestic and import price indexation is lower in the DE model. This suggests a greater role for inflation expectations, which can strengthen the role of the inflation surprise terms in the NKPC.

[8] See also Charalampidis and Razafitsiory (2025).

There are notable differences in the estimated interest rate reaction functions across models. In particular, the higher coefficient on inflation suggests a more aggressive response to deviations of inflation from target in the case of DE. The coefficient on the output gap is modestly higher under DE as well. The parameters dictating the response to the rate of nominal exchange rate depreciation and the degree of interest rate smoothing are broadly similar. The degree of habit formation also shows resemblance across models, whereas the persistence and standard deviations of the shock processes are mixed. For example, while the persistence for the TFP shock increases in the DE model, its standard deviation decreases; the opposite is true for demand shocks.

3.5 Robustness

Given the centrality of the estimate for θ, we conduct several sensitivity tests. **Table 3** summarizes the robustness analysis and displays the posterior distributions for three alternative models. For reference, the prior distributions, our preferred DE model, and the LML metrics are included. The main difference across these models is the prior distribution for θ. For instance, while the baseline DE model used a truncated Normal distribution with mean 2 and standard deviation 0.2, we consider a variant with a looser prior by setting the standard deviation to 0.4. The other two models use an inverse gamma distribution—recall that this distribution is used to model the standard deviations of the exogenous shock processes because of its positive support. As mentioned before, the shapes of these distributions are similar, but the inverse gamma has a lower mode of 1.86 (versus the value of 2 for the truncated normal). The final variant considers an inverse gamma with a lower mean.

Overall, the analysis indicates the robustness of the baseline model. First, note that the estimate of θ ranges from 0.37 to 0.59. In all cases, however, the lower end of the probability bands is always greater than zero. Second, the LML metrics suggest that the DE models are favored relative to the RE benchmark. Moreover, based on the guidance in Kass and Raftery (1995) and the implementation in Chen and others (2023), there seems to be strong evidence supporting the DE model given that the difference between the RE model and the alternative models' LMLs exceeds 10 in several cases. In what follows, we focus on the DE model with an estimated value for θ of 1.96. This is to more effectively highlight the differences between the RE and DE models. However, for completeness, we include the results from the best performing model (with an estimated value for θ of 0.59).

IV. Model Properties

In this section, we examine the properties of the estimated model, beginning with impulse response function (IRF) analysis to understand and quantify the transmission channels of various shocks, with particular attention to the implications of DE. A common feature across the DE shock analysis is the larger initial impact on the exchange rate and its volatility. This, combined with the prominent role of the exchange rate mechanism, implies that DE can either amplify or dampen shock transmission and the effects on real output.

4.1 Impulse Responses

The analysis of the Impulse Response Functions (IRFs) considers the benchmark RE model (shown using black dashed lines), along with two versions of the estimation DE model: our preferred model ($\theta = 1.96$)—red lines—and the version the fits the data the best ($\theta = 0.59$)—blue lines.

Monetary policy shock. Under RE, a contractionary monetary policy shock yields familiar dynamic responses, as illustrated in **Figure 2** for selected macroeconomic variables. A one-standard deviation increase in the policy rate results in a higher real interest rate, which dampens aggregate demand and lowers both domestic and CPI inflation. At the same time, the tighter monetary stance induces a nominal and real exchange rate appreciation which has two effects. First, the real appreciation reduces exports, as implied by the expenditure-switching mechanism, thereby exerting a negative effect on domestic output (equation 18). Second, it produces a negative LOOP deviation—i.e., a decline in the price gap that reflects the marginal cost of imported goods—, thereby reducing imported goods inflation and, in turn, CPI inflation. As the monetary impulse dissipates, monetary policy gradually steers the economy back to its steady state.

Under DE, the qualitative responses remain broadly similar to those under RE, but important quantitative differences emerge, driven by three interrelated mechanisms. First, the nominal—and consequently real—exchange rate appreciation is much stronger owing to the exchange rate depreciation surprise terms, as implied by the UIP condition (equation 9). The strength of the exchange rate channel implies that exports fall more sharply, amplifying the contraction in output and the decline in domestic inflation.[9] Second, the reduction in domestic activity is also more pronounced due to the consumption surprise terms in the Euler equation (8). Despite a smaller increase in nominal interest rates, households cut consumption disproportionately, overreacting to the perceived deterioration in the economic outlook. Third, the decline in domestic inflation is larger because the domestic NKPC is steeper under DE—see equation (15)—making domestic inflation more responsive to changes in domestic activity (captured by the marginal cost term). Moreover, the domestic surprise terms further exacerbate the disinflationary effects.[10]

Government spending shock. Higher government spending stimulates economic activity, pushing up marginal costs, and consequently domestic inflation in the RE model (**Figure 3**). The resulting overheating of the economy prompts a tightening of the monetary policy stance, which raises real interest rates. At the same time, the tighter stance induces a nominal and real exchange rate appreciation, which reduces foreign demand for domestic goods and thereby lowers exports. Over time, the restrictive monetary conditions cool off the economy.

Notable quantitative differences arise in the exchange rate dynamics between the RE and DE models. Under DE, the nominal exchange rate appreciates more sharply due to the UIP-related surprise terms, leading to a stronger real appreciation that reduces exports and dampens the increase in domestic output relative to RE. This effect is further reinforced by consumption surprise terms. Despite the stronger real appreciation, imported goods inflation falls less than under RE because the related NKPC is flatter—see equation (16). The smaller decline in imported inflation, together with similar domestic inflation dynamics, results in higher CPI inflation under DE, prompting a larger policy rate increase than in the RE case.

[9] Appendix III Figures 1-5 consider unit shocks to complement the analysis shown here that illustrates one standard deviation shocks. The appendix figures of the IRFs also present a counterfactual scenario in which all parameters take their Rational Expectations (RE) estimates, except for $\theta = 1.96$, thereby illustrating how the overreaction parameter influences model dynamics independently. Overall, even in the case of RE parameters, setting $\theta = 1.96$ leads to heightened volatility and more pronounced effects on both real and nominal exchange rates in response to different shocks. As a result, the exchange rate channel becomes a central mechanism for either amplifying or dampening shock transmission.

[10] By contrast, imported goods inflation declines less under DE because the associated NKPC is flatter, making it less responsive to changes in the price gap. This dampening effect dominates the influence of the larger negative price gaps and the expectation-surprise terms, which on their own would have pushed imported goods inflation further down.

Importantly, the sharper initial real appreciation under DE dampens the output response to the demand shock. Unlike other shocks, a government spending impulse raises output less under DE than under RE. Compared with a closed-economy framework, this dampening is primarily driven by DE's effects on the exchange rate transmission.

Risk premium shock. As illustrated in **Figure 4**, under RE, a one-standard-deviation increase in the country risk premium triggers a nominal and real depreciation, and consequently a positive LOOP deviation—i.e., an increase in the price gap. Since this gap reflects the marginal cost of imported goods, inflation of these goods rises, pushing up CPI inflation. The real depreciation also raises foreign demand for domestic goods, stimulating exports, and generating additional domestic inflationary pressures. With both domestic and imported inflation increasing, CPI inflation rises. In response to inflationary pressures, a widening output gap, and nominal depreciation, the central bank tightens monetary policy—raising real interest rates after a few quarters—while allowing the economy to gradually converge to its steady state.

Under DE, the risk premium also triggers a nominal and real depreciation, but these effects are considerably larger due to the depreciation surprise terms in the UIP condition. The initial sharp real depreciation further stimulates economic activity relative to RE through its stronger impact on exports. However, the imported goods NKPC is significantly flatter under DE, limiting the pass-through of the larger depreciation to imported goods inflation. Moreover, although domestic output increases more and the real exchange rate appreciates further, domestic inflation remains lower than under the RE scenario. This reflects relative price adjustments, particularly a smaller impact on imported goods inflation.[11] With smaller increases in both domestic and imported inflation, CPI inflation is lower under DE. Nevertheless, the larger output increase and depreciation prompt the monetary authority to raise initially the policy rate more than under RE.

Note that the output response aligns broadly with Adrian and others (2021), who examine a similar shock across several advanced economies, including Canada. A key distinction is the initial spike in output under DE, driven by a stronger exchange rate channel due to the depreciation surprise terms.

Cost-push shock. A cost-push shock increases imported goods inflation and necessitates a relative price adjustment that also raises domestic inflation (**Figure 5**). As a result, CPI inflation rises, prompting the central bank to raise the nominal interest rate. The tighter monetary stance induces both nominal and real appreciations, which mitigate the inflationary impact of the shock by generating a negative deviation in the price gap—i.e., the marginal cost of imported goods. However, the real appreciation depresses exports, and together with the contractionary effect of higher interest rates on consumption, leads to a decline in domestic output. Under DE, several differences emerge. First, the impact of the cost-push shock on imported goods inflation is amplified by the inflation surprise terms, as reflected in the imported-goods NKPC. Similarly, the stronger increase in domestic inflation is explained by the surprise terms in the domestic NKPC. These magnified effects result in a larger initial increase in CPI inflation under DE, which in turn triggers a stronger monetary tightening and a sharper contraction in consumption. Second, the tighter policy stance generates a more pronounced initial real appreciation. Third, the decline in economic activity is more severe on impact, reflecting the stronger exchange rate channel under DE, the higher interest rate response, and the consumption surprise terms in the Euler equation.

[11] More specifically, note that the marginal cost for domestic goods is given by $\widehat{MC}_t = \alpha \hat{S}_t + \varphi \, \hat{Y}_{H,t} \; + \frac{\sigma}{1-h} \, (\hat{C}_t - h\hat{C}_{t-1}) - \; (1+\varphi) \, \hat{\varepsilon}_{a,t}$. Therefore, under DE, a more pronounced decline in TOT ($\hat{S}_t$)—a relative price adjustment which is not shown in the figure—helps dampen the domestic inflationary pressures.

Productivity shock. A temporary increase in total factor productivity raises domestic output and lowers domestic inflation, irrespective of the expectations formation assumption (**Figure 6**). Higher productivity reduces marginal costs, thereby pushing down both domestic and CPI inflation. In response, the central bank cuts the policy rate, which stimulates consumption and induces both nominal and real depreciation. The real depreciation raises the price gap of imported goods, pushing imported goods inflation upward and partially offsetting domestic disinflationary pressures. At the same time, the depreciation strengthens exports, which, together with higher consumption, further boosts domestic output.

Under DE, the stronger real exchange rate response—driven by the depreciation surprise terms in the UIP condition—plays a central role. It generates an additional spike in output by amplifying the export response, which in turn dampens the initial decline in domestic inflation. Moreover, amid brighter economic prospects, households overreact by increasing consumption more strongly than under RE, further reinforcing the output expansion.

4.2 Variance Decompositions

To help understand the drivers of key macroeconomic variables, we turn to variance decomposition (VD) analysis. **Table 4** presents the results for the RE and DE models (for further details see **Appendix I Table AI.2**). **Figure 7** summarizes the results by visualizing how DE changes the VDs. It focuses on a subset of variables (output, inflation, domestic inflation, real interest rate, real exchange rate) and combines the contributions of the three foreign shocks.

The relative importance of structural shocks driving key macroeconomic variables changes under DE. For example, under RE, while the government spending shock explains most of the variability in GDP, whereas under DE, TFP becomes more prominent. Recall that the countercyclicality of net exports is amplified under DE—owing to a greater real exchange rate volatility—which helps stabilize output. The role of cost-push shocks becomes even more prominent for headline inflation and the real interest rate under DE. Likewise, monetary policy shocks are more influential for domestic inflation volatility in the DE model. Greater inflation volatility—especially from inflation surprise shocks—requires a more active monetary policy response. Risk premium shocks gain more traction under DE for the real exchange rate. The greater role of the cost-push and risk premium shocks likely reflects the greater role of exchange rate fluctuations in the DE model.

The prominence of supply shocks (TFP, cost push) in the case of DE is not too surprising given the importance of commodities for the Canadian economy. Canada is one of the few advanced economies that are net exporters of energy. Canada possesses vast offshore deposits of natural gas and oil reserves (including oil sands). The country is also a leading exporter of metals (including zinc, gold, nickel, aluminum, and steel) and agricultural products (such as wheat). These sectors are not modeled in our parsimonious setup, but are captured by the exogenous shocks. The fact that the role of supply shocks is more pronounced could be a factor explaining why DE improves model fit in the case of Canada.

4.3 Output-Inflation Volatility Trade-Offs

To further illustrate the policy implications of DE, we construct standard inflation-output volatility frontiers.[12] Relative to the RE case, note that the volatility of output and inflation is always higher for the corresponding DE models. That is, the DE model results in a worse inflation-output volatility trade-off relative to RE, including because of the greater prominence of supply shocks. **Figure 8** traces out the inflation-output volatility policy frontiers for three models: RE, DE ($\theta = 0.59$ and $\theta = 1.96$). All three frontiers clearly illustrate the non-linear inverse relationship between output and inflation volatility. Importantly, the DE models present a worse policy trade-off since their frontiers are further away from the origin. An increasing degree of diagnosticity results in a less favorable trade-off.

4.4 Forecasting Properties—An Initial Assessment

In this section, we explore the forecasting properties of DE in our modeling framework. Importantly, this exercise should be considered a first pass to assess its potential, given the streamlined model and parsimonious DE specification. An avenue for future research would be to relax this assumption and consider distant memory models similar to those used in Bianchi and others (2024) in their closed-economy model. Accordingly, we consider a targeted forecasting evaluation exercise. We consider five macroeconomic variables—the output (gap), CPI and (domestic) core inflation, and output and real exchange rate (RER) growth—over three horizons (one, two, and four-quarters). The analysis cover a relatively tranquil period (2016) and a turbulent period (the Global Financial Crisis). Given the feature of greater endogenous volatility generation, we conjecture that the DE models can be informative amid the turbulent period.

Table 5 displays our metric of forecast accuracy, the root mean squared error (RMSE), for the selected macroeconomic variables during the tranquil and turbulent periods.[13] Consider first 2016. Note that the DE model with $\theta = 1.96$ outperforms the RE model for the output gap, core inflation, and real GDP and RER growth in the near term ($h = 1$). Likewise, the DE models are better at forecasting the real exchange rate at all horizons. This is likely because of the surprise terms DE introduces into the UIP conditions which can capture a broader array of RER dynamics than those found in the data. (Recall from the discussion of model properties that DE strengthens the exchange rate channel.) These findings are visually summarized in **Figure 9** (which for brevity only displays the growth of output and the real exchange rate). Note that the DE model ($\theta = 1.96$) better forecasts the dip in output growth in the second quarter of 2016 more accurately than the competing specifications. One reason for this is the near-term overreaction that DE imbues in the model at shorter horizons (again, recall the discussion of model properties). While the RER appreciation is approximately twice that with DE ($\theta = 1.96$) relative to the RE model, all models struggle to capture the full extent of the data. Before discussing the forecasting properties during the turbulent period, it is worth recognizing that it's a tall order for any model to accurately replicate the dynamics in these episodes of global economic dislocation. Nonetheless, we are still curious to see how DE can add insights to the forecasts during these episodes. Starting with the GFC, notice that DE model ($\theta = 1.96$) displays superior performance the output and inflation variables when considering six-month ahead forecasts. DE's potential for more accurate forecasts is visually

[12] As is standard in the literature, we compute inflation–output volatility frontiers for the alternative estimated models. These frontiers are derived from the minimum weighted unconditional variances of output and domestic inflation, evaluated at different relative preferences for inflation versus output stabilization. In a companion paper, Bounader et al. (2025), we address the question of optimal monetary and exchange rate policies by deriving a social welfare function as a second-order approximation to households' utility, following Benigno and Woodford (2004).

[13] Specifically, we use $RMSE = \sqrt{\frac{1}{H}\sum_{h=1}^{H}(y_{t+h} - \hat{y}_{t+h})^2}$ for h=1 and h=4 for the one-quarter- and one-year-ahead calculations.

clear in the context of output growth as shown in **Figure 9**. Notice how the DE model is best at capturing the trough in the context of output growth.

While some papers have argued that DSGE models (under RE) can perform reasonably well during such turbulent periods (see Del Negro and others, 2015), these models typically rely on the inclusion of financial frictions. In contrast, we demonstrate that even in the absence of such frictions, and within a parsimonious DSGE framework, DE—a behavioral friction—has the potential to enhance the forecasting performance of key macroeconomic variables during such episodes. Turning to the RER, again, owing to the surprise terms embedded in the UIP, the inclusion of DE helps improve forecast accuracy. However, while the DE models signal the ensuing RER depreciation, they fall short relative to the data in terms of capturing the magnitude of the relative price shift.[14]

Overall, while the introduction of DE holds promise in improving the forecasting properties of structural models, caution is warranted given the stylized nature of the current framework. Future research should extend the model to incorporate features such as investment, capital accumulation, sticky wages, and a richer supply side (Christiano and others, 2005; Smets and Wouters, 2007; Adolfson and others, 2007), as well as explore more general DE specifications. To our knowledge, this is the first paper to introduce DE into an estimated open-economy structural model, and we see ample scope for further extensions along these lines.

V. Conclusion

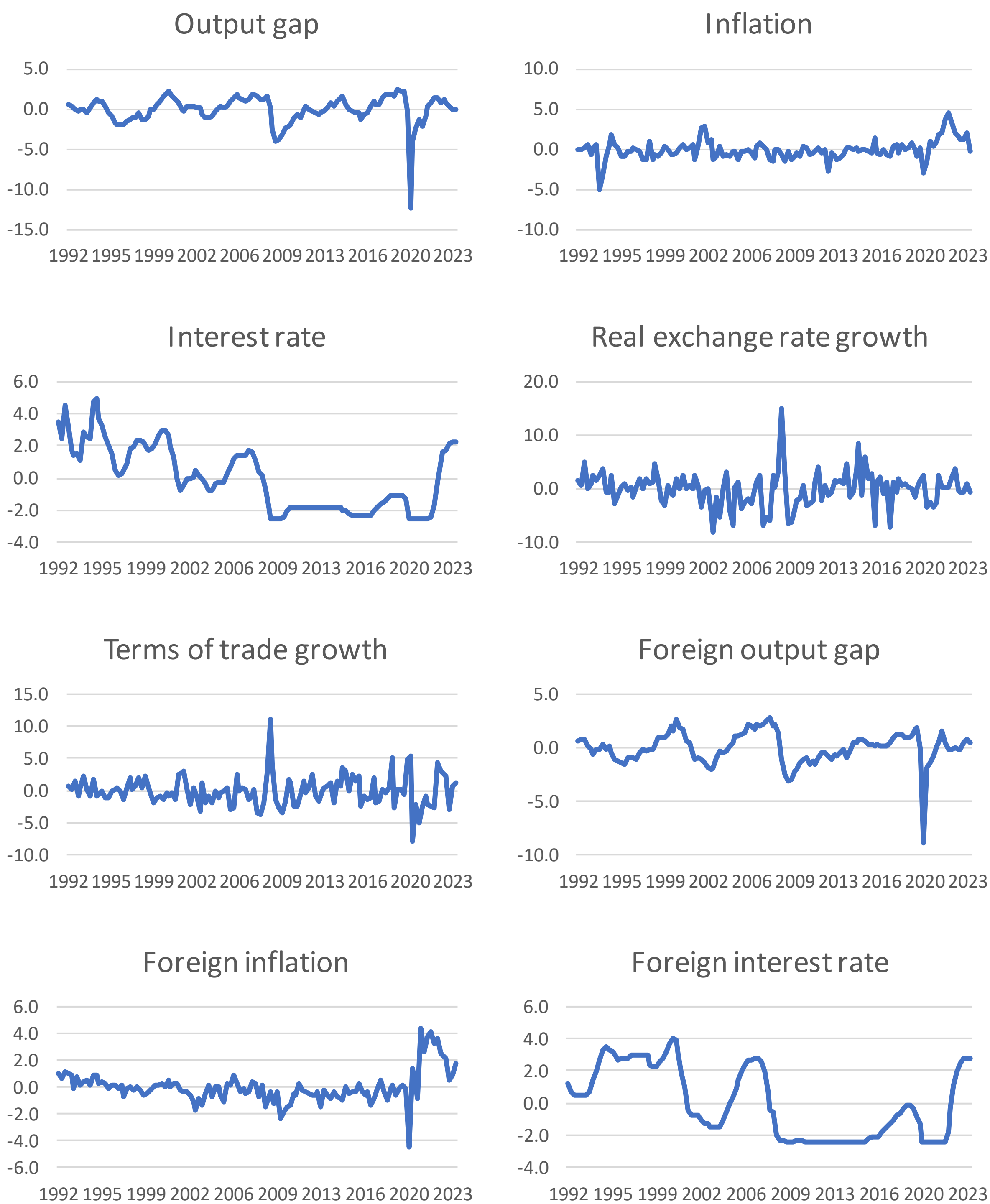
We introduce Diagnostic Expectations (DE) into a small open economy model. DE is a departure from the Rational Expectations (RE) hypothesis which, through agents' systematic overreaction, generates additional endogenous macroeconomic volatility. We estimate this model and find robust evidence in favor of DE, as it provides a better fit to the data than the nested RE alternative. Likewise, on a first pass, we show that DE models can outperform RE frameworks when forecasting selected macroeconomic variables, such as real GDP growth, including during major disruptions like the Global Financial Crisis. Their ability to respond rapidly to initial shocks underscores the potential of DE models as a valuable complement to standard forecasting methods.

The incorporation of DE alters the nature and strength of underlying economic channels, partly because it amplifies shocks, thereby improving the model's ability to track macroeconomic fluctuations. For instance, the exchange rate channel of monetary policy is more powerful under DE, with direct implications for policy design. A rise in the policy rate under DE results in a larger real appreciation, and thus tighter monetary conditions, leading to a larger economic contraction. In the case of fiscal policy, however, DE dampens the output response: the stronger real appreciation overwhelms the aggregate demand stimulus through an outsized contraction of the trade balance. Moreover, we show that DE worsens the inflation–output volatility trade-off confronted by policymakers.

[14] We also considered 2017 and the COVID episode as additional tranquil and turbulent periods, respectively. The results for the former were broadly consistent with those for 2016, whereas for the latter, inflation forecasts performed well but the outcomes for other macroeconomic variables were more mixed.

Future research should extend the model to emerging market economies and incorporate additional features such as sticky wages and selected financial frictions. A related avenue is to explore distant memory variants of DE, which may further improve model fit and enhance forecast accuracy.

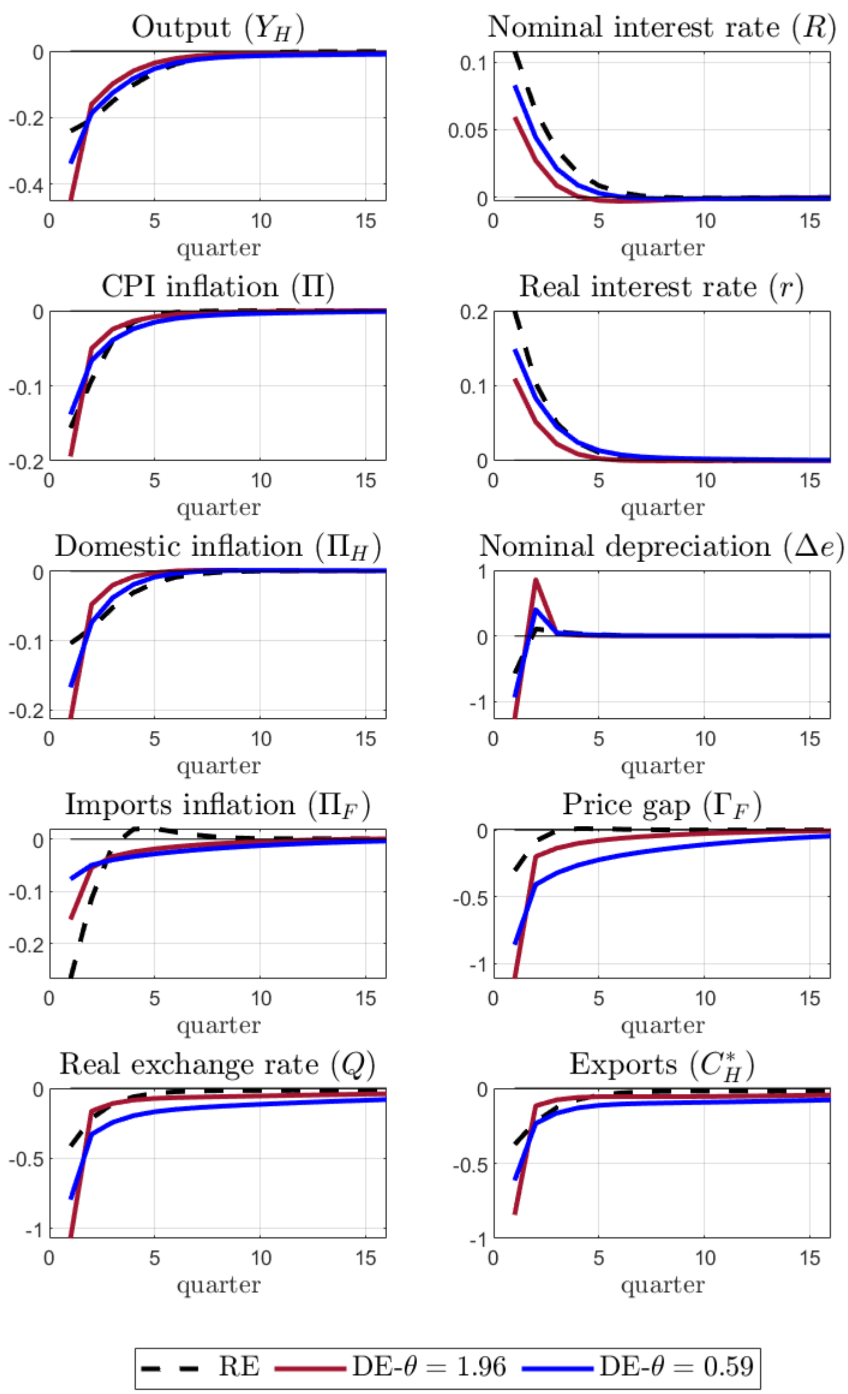
Figure 1. Data



Source: Authors calculations and Haver Analytics.

Notes: All variable in percent; see Appendix I Table AI.1 for details.

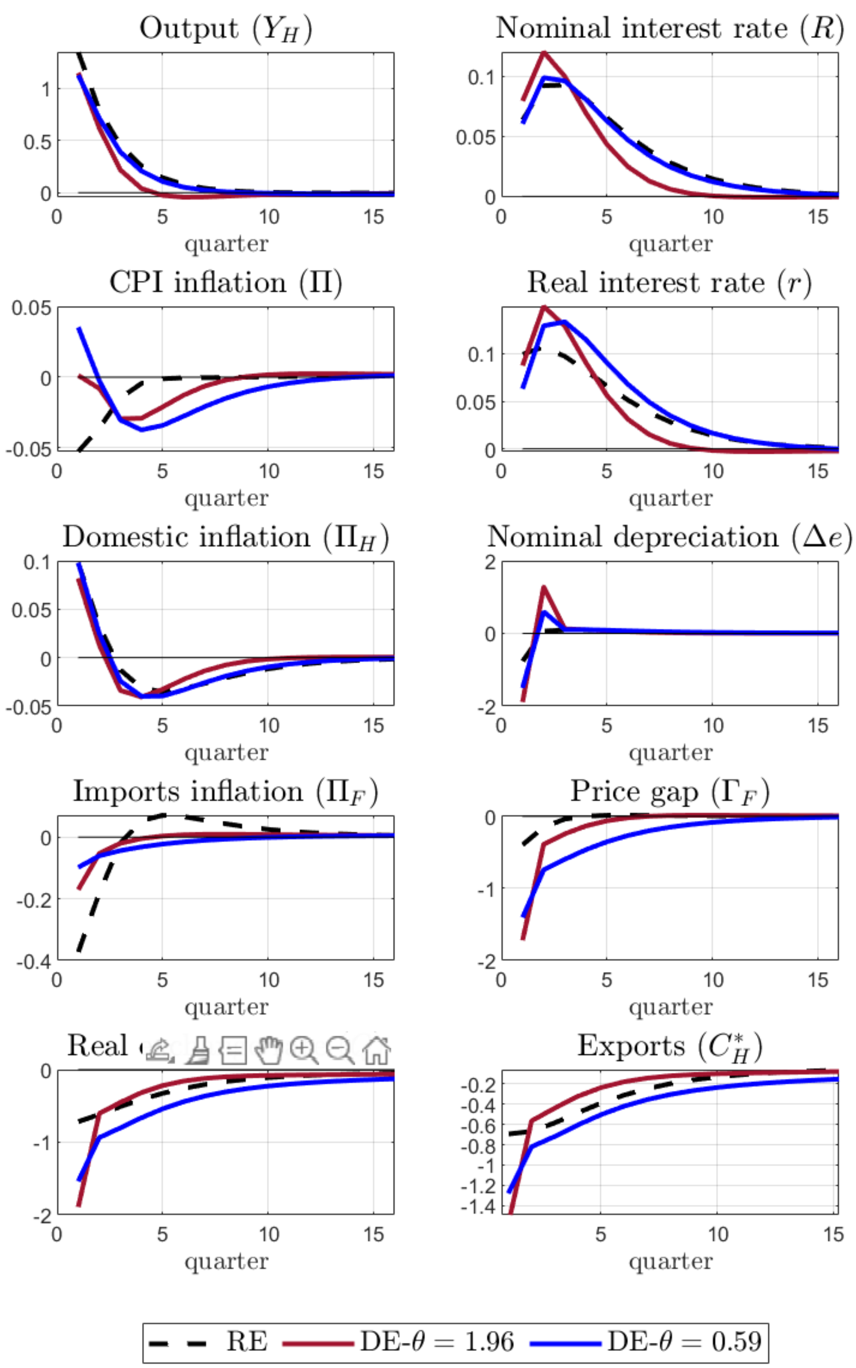
Figure 2. Impulse Responses: Monetary Policy Shock (μ_m)



Source: Authors calculations.

Notes: Percent deviations from steady state. The shock is a one-standard-deviation increase.

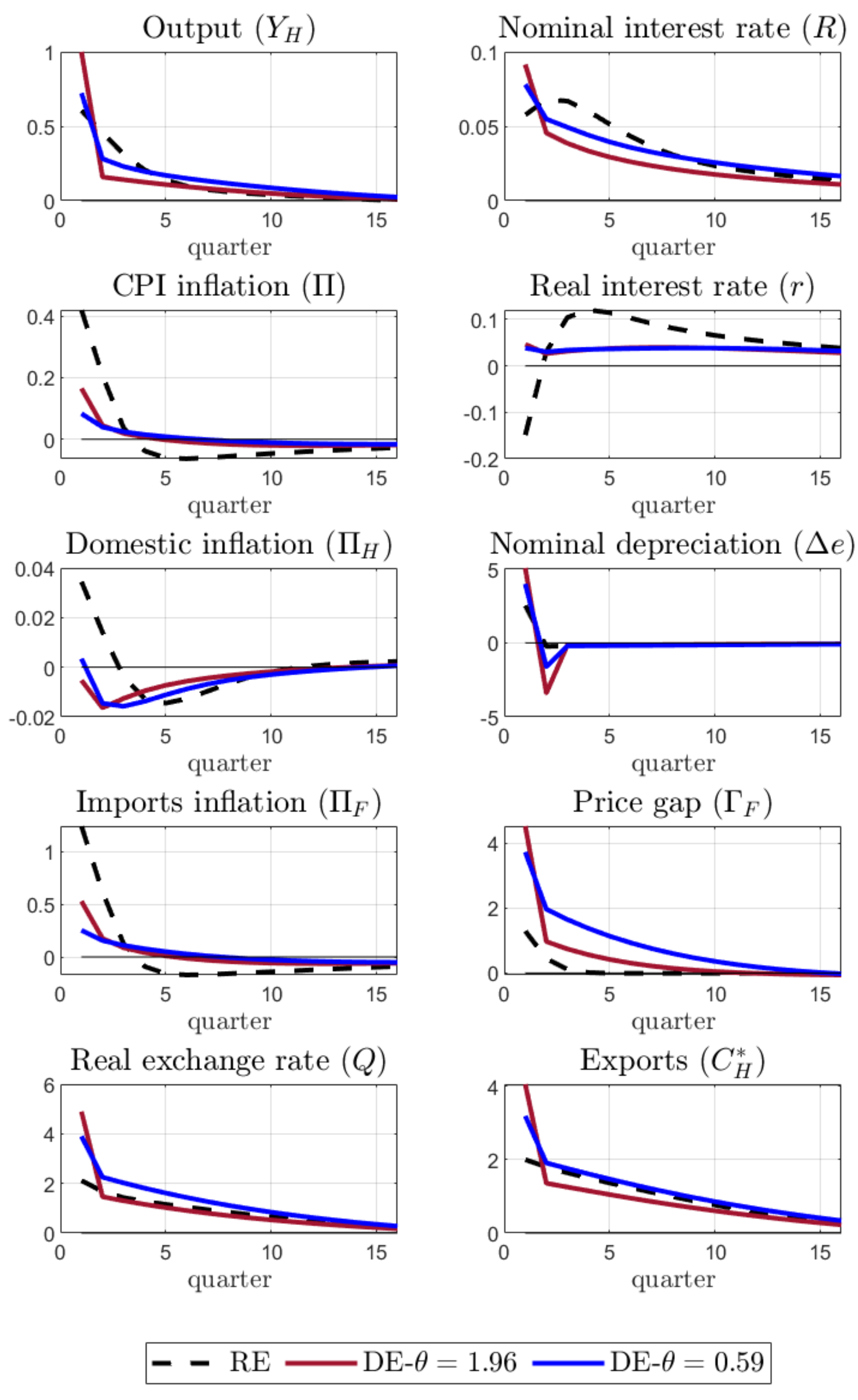
Figure 3. Impulse Responses: Government Spending Shock (μ_g)



Source: Authors calculations.

Notes: Percent deviations from steady state. The shock is a one-standard-deviation increase.

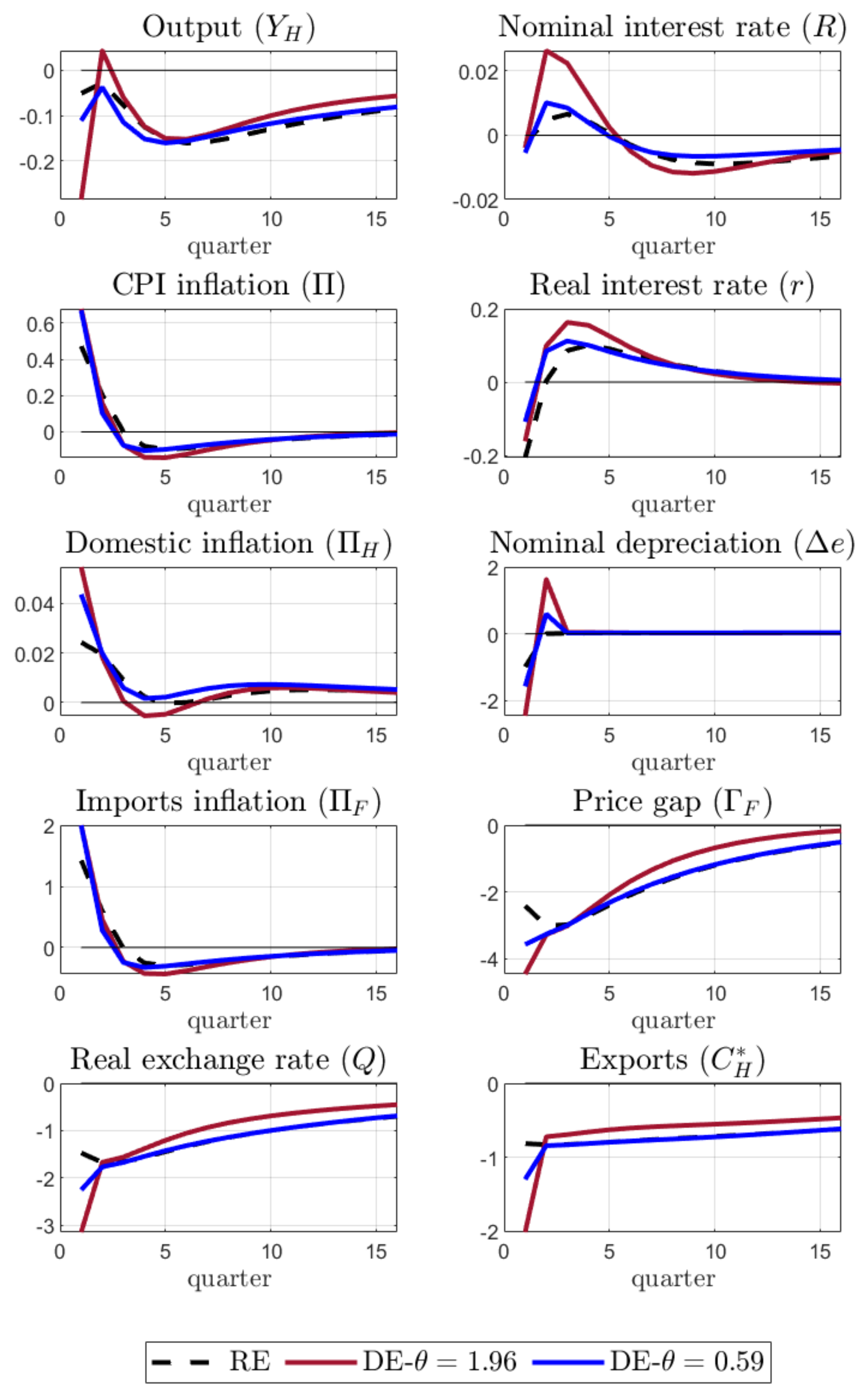
Figure 4. Impulse Responses: Risk Premium Shock (μ_{rp})



Source: Authors calculations.

Notes: Percent deviations from steady state. The shock is a one-standard-deviation increase.

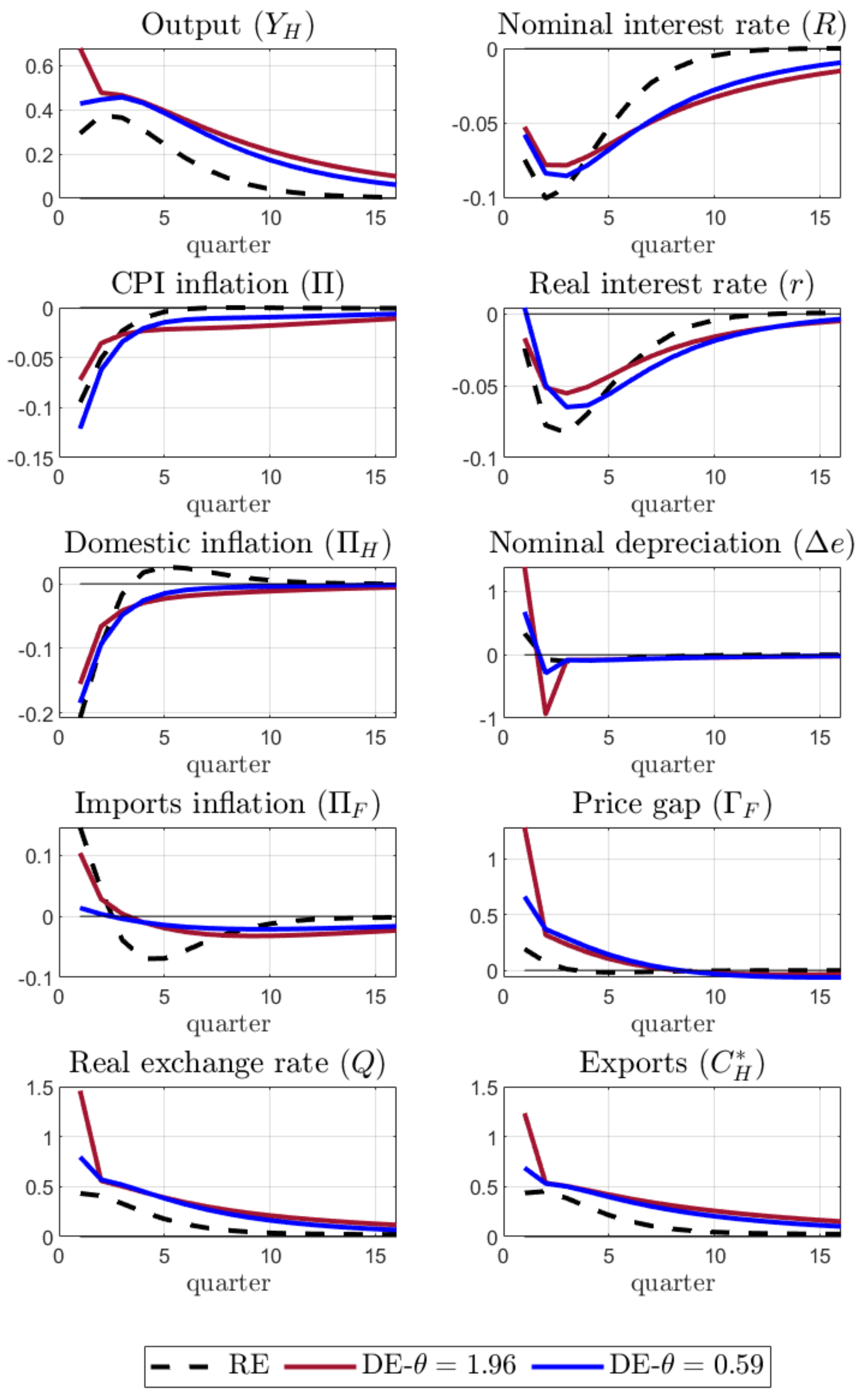
Figure 5. Impulse Responses: Imports Cost-Push Shock (μ_{cp})



Source: Authors calculations.

Notes: Percent deviations from steady state. The shock is a one-standard-deviation increase.

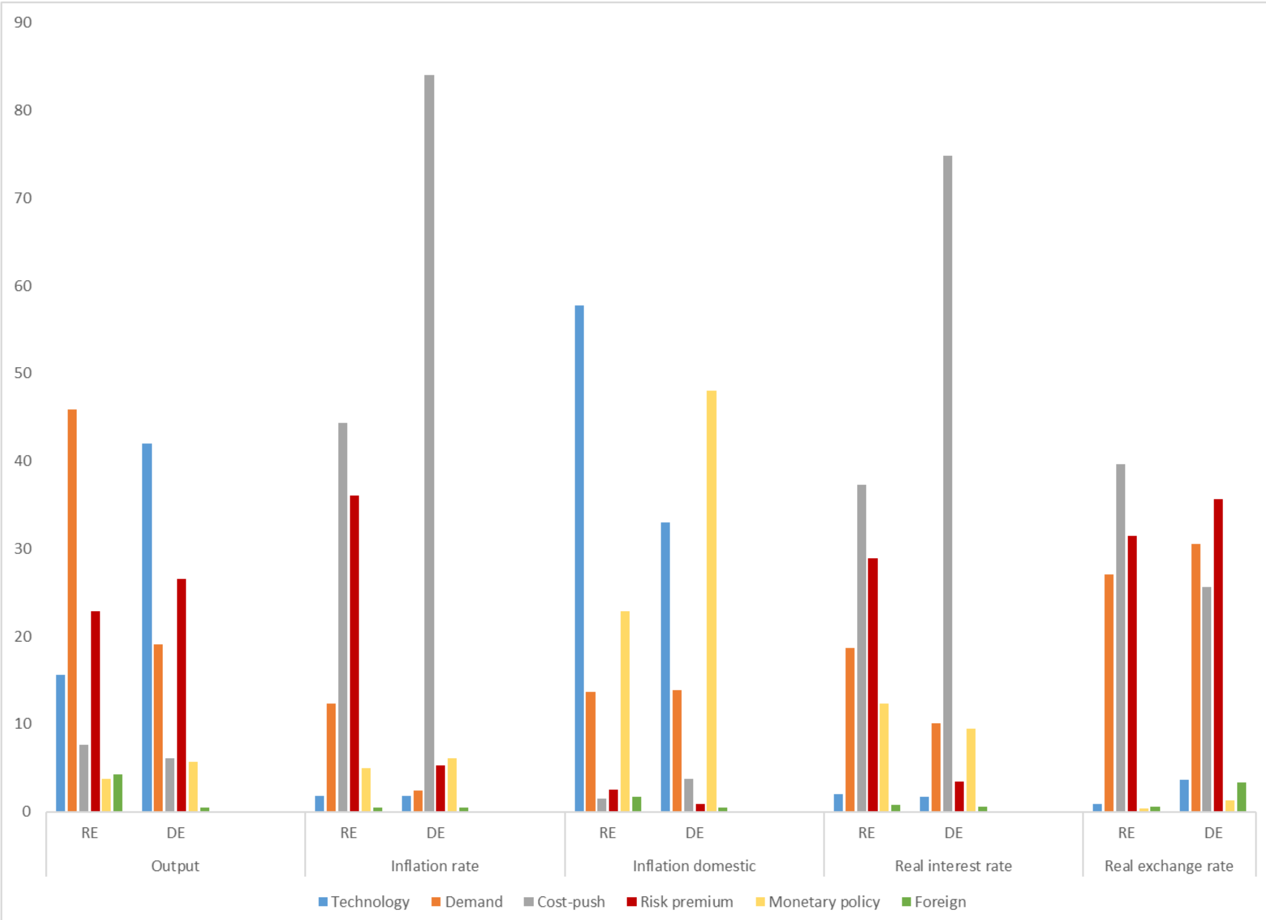
Figure 6. Impulse Responses: Productivity Shock (μ_a)



Source: Authors calculations.

Notes: Percent deviations from steady state. The shock is a one-standard-deviation increase.

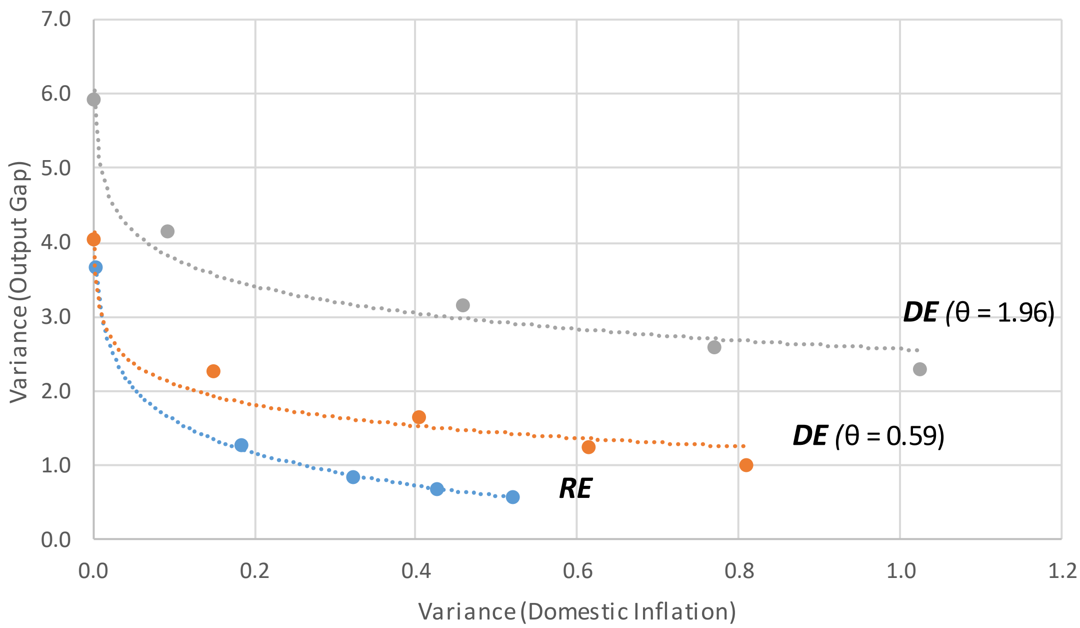
Figure 7. Variance Decompositions



Source: Authors calculations.

Notes: In percent.

Figure 8. Policy Frontiers

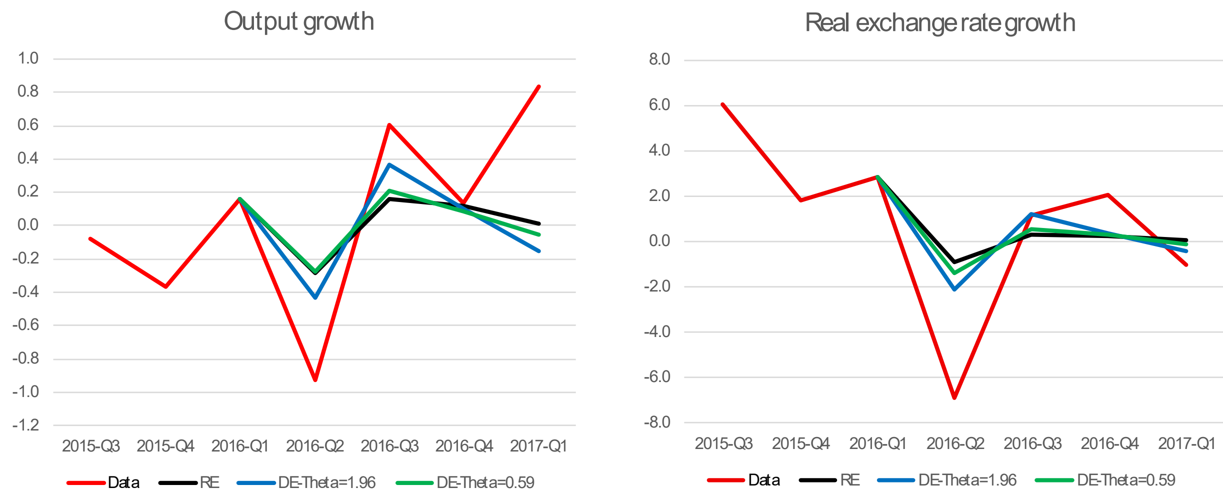


Source: Authors calculations.

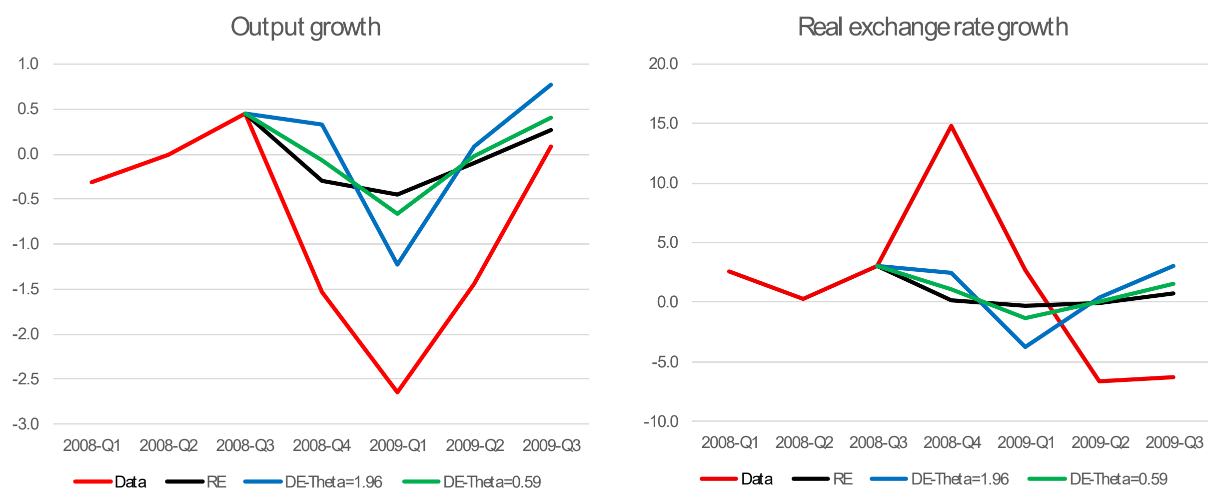
Notes: The horizontal axis represents the optimized variance (in percent) of domestic inflation, while the vertical axis represents the optimized variance (in percent) of the output gap under different weights of monetary policy. The rational expectations (RE) model is depicted in blue, while the diagnostic expectations models with ($\theta = 0.59$ and $\theta = 1.96$) are shown in orange and grey, respectively.

Figure 9. Selected Forecast Comparisons

Tranquil period: 2016 Q1



Turbulent period: 2008 Q3 (GFC)



Source: See Appendix I Table A.1 for details.

Notes: Forecasts display output and real exchange rate growth (percent) for the Rational expectations (RE) and two Diagnostic expectations (DE) models along with the actual data.

Table 1. Calibrated Parameters

Parameter	Description	Value
β	Discount factor	0.99
σ	Inverse intertemporal elasticity	1
φ	Inverse Frisch elasticity	2
χ	Debt premium elasticity	0.01
ϵ_H	Elasticity of substitution: domestic goods	6
ϵ_F	Elasticity of substitution: imported goods	6
α	Share of for foreign goods	0.32
η	Elasticity of substitution between domestic and imported goods	0.8
ρ_m	Persistence of monetary policy shock	0

Source: Authors calculations.

Notes: See main text for details.

Table 2. Prior Densities and Posterior Estimates

Parameters		**Prior distribution**			**Posterior distributions**							
					Rational expectations				**Diagnostic expectations**			
		Type	Mean	Std	Mean	Std	5	95	Mean	Std	5	95
Diagnostic expectation	θ	TN	2	0.2	—	—	—	—	1.96	0.07	1.87	2.07
External habit formation	h	B	0.5	0.25	0.64	0.06	0.54	0.74	0.62	0.05	0.53	0.70
Nominal rigidities												
Domestic price adjustment cost	ψ_H	N	100	25	120.59	4.51	113.07	127.62	82.76	8.74	69.23	97.44
Foreign price adjustment cost	ψ_F	N	100	25	2.17	0.41	1.58	2.85	34.64	6.01	25.07	44.92
Indexation: domestic	δ_H	B	0.5	0.25	0.15	0.03	0.09	0.20	0.04	0.02	0.01	0.07
Indexation: foreign	δ_F	B	0.5	0.25	0.26	0.05	0.18	0.34	0.13	0.08	0.01	0.25
Interest rate rule												
Interest rate smoothing	ρ	B	0.5	0.25	0.93	0.02	0.89	0.97	0.92	0.03	0.88	0.96
Inflation	ψ_π	G	1.5	0.3	0.41	0.03	0.36	0.46	0.62	0.05	0.52	0.70
Output	ψ_y	G	0.25	0.13	0.02	0.01	0.01	0.04	0.04	0.01	0.03	0.06
Exchange rate depreciation	$\psi_{\Delta e}$	G	0.25	0.13	0.01	0.00	0.01	0.02	0.01	0.00	0.01	0.02
Shock persistence												
Technology	ρ_a	B	0.8	0.1	0.61	0.02	0.58	0.63	0.88	0.02	0.84	0.92
Demand	ρ_g	B	0.8	0.1	0.75	0.02	0.72	0.77	0.58	0.02	0.54	0.62
Risk premium	ρ_{rp}	B	0.8	0.1	0.96	0.01	0.94	0.97	0.96	0.01	0.94	0.98
Cost-push	ρ_{cp}	B	0.5	0.25	0.87	0.03	0.83	0.92	0.39	0.05	0.32	0.46
Shock standard deviations												
Technology		IG	0.5	Inf	1.52	0.11	1.34	1.69	0.68	0.07	0.54	0.79
Monetary policy		IG	0.5	Inf	0.16	0.01	0.15	0.18	0.22	0.02	0.19	0.26
Demand		IG	0.5	Inf	1.80	0.12	1.61	2.00	2.05	0.13	1.84	2.27
Risk premium		IG	0.5	Inf	0.29	0.04	0.23	0.35	0.20	0.03	0.15	0.24
Cost-push		IG	0.5	Inf	2.99	0.23	2.65	3.40	1.63	0.27	1.25	2.10
Foreign inflation		IG	0.5	Inf	0.11	0.01	0.09	0.12	0.09	0.01	0.08	0.09
Foreign demand		IG	0.5	Inf	1.13	0.06	1.04	1.22	1.10	0.07	0.98	1.21
Foreign interest rate		IG	0.5	Inf	0.10	0.01	0.09	0.11	0.08	0.01	0.08	0.09
Log marginal likelihood					-1615				-1608			

Source: See Appendix I Table A.1 for details.

Notes: B, G, IG, N, and TN, denote beta, gamma, inverse gamma, normal, and truncated normal distributions.

Table 3. Robustness: Prior Densities and Posterior Estimates

Parameters		Prior distribution			Posterior distributions															
					Model prior: TN(2, 0.2, 0)				Model prior: TN(2, 0.4, 0)				Model prior: IG(2, 0.4, 0)				Model prior: IG(1, 0.2, 0)			
		Type	Mean	Std	Mean	Std	5	95	Mean	Std	5	95	Mean	Std	5	95	Mean	Std	5	95
Diagnostic expectation	θ	TN	2	0.2	1.96	0.07	1.87	2.07	0.37	0.08	0.24	0.52	0.52	0.05	0.82	0.96	0.59	0.04	0.52	0.67
External habit formation	h	B	0.5	0.25	0.62	0.05	0.53	0.70	0.18	0.05	0.08	0.27	0.27	0.05	0.76	0.91	0.54	0.07	0.43	0.68
Nominal rigidities																				
Domestic price adjustment cost	ψ_H	N	100	25	82.76	8.74	69.23	97.44	94.69	0.01	86.65	102.12	102.12	5.72	99.57	117.67	83.30	11.32	63.10	100.97
Foreign price adjustment cost	ψ_F	N	100	25	34.64	6.01	25.07	44.92	41.48	0.04	30.89	51.19	51.19	4.66	12.42	27.59	96.19	5.87	86.56	106.17
Indexation: domestic	δ_H	B	0.5	0.25	0.04	0.02	0.01	0.07	0.28	0.01	0.18	0.38	0.38	0.03	0.00	0.10	0.07	0.05	0.00	0.14
Indexation: foreign	δ_F	B	0.5	0.25	0.13	0.08	0.01	0.25	0.03	0.01	0.00	0.06	0.06	0.06	0.00	0.17	0.13	0.06	0.04	0.24
Interest rate rule																				
Interest rate smoothing	ρ	B	0.5	0.25	0.92	0.03	0.88	0.96	0.94	0.06	0.89	0.98	0.98	0.02	0.92	0.99	0.94	0.02	0.90	0.97
Inflation	ψ_π	G	1.5	0.3	0.62	0.05	0.52	0.70	0.50	0.03	0.40	0.59	0.59	0.03	0.45	0.56	0.44	0.05	0.36	0.51
Output	ψ_y	G	0.25	0.13	0.04	0.01	0.03	0.06	0.03	0.02	0.01	0.04	0.04	0.01	0.01	0.03	0.03	0.01	0.02	0.04
Exchange rate depreciation	$\psi_{\Delta e}$	G	0.25	0.13	0.01	0.00	0.01	0.02	0.02	0.06	0.01	0.03	0.03	0.00	0.01	0.02	0.01	0.00	0.01	0.02
Shock persistence																				
Technology	ρ_a	B	0.8	0.1	0.88	0.02	0.84	0.92	0.44	0.06	0.35	0.50	0.50	0.03	0.72	0.81	0.84	0.04	0.78	0.90
Demand	ρ_g	B	0.8	0.1	0.58	0.02	0.54	0.62	0.59	6.46	0.54	0.65	0.65	0.02	0.75	0.81	0.73	0.02	0.70	0.77
Risk premium	ρ_{rp}	B	0.8	0.1	0.96	0.01	0.94	0.98	0.95	4.71	0.94	0.97	0.97	0.02	0.87	0.95	0.95	0.01	0.93	0.97
Cost-push	ρ_{cp}	B	0.5	0.25	0.39	0.05	0.32	0.46	0.36	0.09	0.23	0.48	0.48	0.07	0.49	0.71	0.17	0.06	0.07	0.26
Shock standard deviations																				
Technology		IG	0.5	Inf	0.68	0.07	0.54	0.79	1.56	0.17	1.29	1.83	1.83	0.08	0.86	1.13	0.82	0.09	0.67	0.97
Monetary policy		IG	0.5	Inf	0.22	0.02	0.19	0.26	0.20	0.02	0.16	0.22	0.22	0.02	0.16	0.21	0.18	0.02	0.15	0.21
Demand		IG	0.5	Inf	2.05	0.13	1.84	2.27	1.95	0.12	1.77	2.14	2.14	0.13	1.73	2.17	1.89	0.11	1.71	2.07
Risk premium		IG	0.5	Inf	0.20	0.03	0.15	0.24	0.30	0.04	0.24	0.36	0.36	0.06	0.23	0.42	0.28	0.04	0.21	0.34
Cost-push		IG	0.5	Inf	1.63	0.27	1.25	2.10	1.73	0.21	1.35	2.03	2.03	0.22	1.07	1.76	2.04	0.24	1.66	2.45
Foreign inflation		IG	0.5	Inf	0.09	0.01	0.08	0.09	0.08	0.01	0.08	0.09	0.09	0.01	0.08	0.10	0.08	0.01	0.08	0.09
Foreign demand		IG	0.5	Inf	1.10	0.07	0.98	1.21	1.11	0.07	1.00	1.23	1.23	0.08	1.00	1.26	1.07	0.07	0.95	1.19
Foreign interest rate		IG	0.5	Inf	0.08	0.01	0.08	0.09	0.09	0.01	0.08	0.10	0.10	0.01	0.08	0.09	0.08	0.01	0.07	0.09
Log marginal likelihood					-1608				-1588				-1601				-1547			

Source: See Appendix I Table A.1 for details.

Notes: B, G, IG, N, and TN, denote beta, gamma, inverse gamma, normal, and truncated normal distributions

Table 4. Variance Decompositions

Rational Expections

	Technology	Demand	Cost-push	Risk premium	Monetary policy	Foreign
Output	16	46	8	23	4	4
Real interest rate	2	19	37	29	12	1
Nominal Interest rate	33	21	1	26	17	2
CPI inflation	2	12	44	36	5	1
Domestic inflation	58	14	1	3	23	2
Import inflation	1	20	44	34	1	1
Real exchange rate	1	27	40	32	0	1
Terms of trade	1	36	23	39	0	1
Nominal depreciation	1	30	8	55	3	3
Terms of trade growth	3	23	42	31	1	1

Diagnostic Expections (theta = 1.96)

	Technology	Demand	Import cost-push	Risk premium	Monetary policy	Foreign
Output	42	19	6	27	6	0
Real interest rate	2	10	75	3	9	1
Nominal Interest rate	41	30	3	20	5	1
CPI inflation	2	2	84	5	6	0
Domestic inflation	33	14	4	1	48	0
Import inflation	0	5	87	6	1	1
Real exchange rate	4	31	26	36	1	3
Terms of trade	4	26	43	22	0	6
Nominal depreciation	3	36	10	45	3	3
Terms of trade growth	1	7	84	7	0	1

Source: Authors calculations.

Notes: In percent.

Table 5. Forecasts Evaluations

Root Mean Squared Errors (RMSE)										
	Output (gap)	Domestic (core) inflaton	Real GDP growth	CPI inflation	Real exchange rate growth	Output (gap)	Domestic (core) inflaton	Real GDP growth	CPI inflation	Real exchange rate growth
	Tranquil periods					***Turbulent periods***				
	2016 Q1					2008 Q3				
	h=1					*h=1*				
RE	0.954	0.399	0.644	0.224	5.995	0.487	0.088	1.240	3.446	14.627
DE(θ =1.96)	0.802	0.394	0.493	0.330	4.763	0.130	0.089	1.857	3.417	12.344
DE(θ =0.59)	0.958	0.401	0.649	0.353	5.529	0.267	0.072	1.460	3.472	13.728
	h=2					*h=2*				
RE	0.509	0.065	0.444	0.275	0.842	1.705	0.296	2.192	1.030	3.007
DE(θ =1.96)	0.560	0.084	0.242	0.324	0.060	1.544	0.291	1.414	1.017	6.462
DE(θ =0.59)	0.560	0.074	0.398	0.322	0.616	1.712	0.286	1.978	1.008	4.124
	h=4					*h=4*				
RE	0.333	0.011	0.821	0.370	1.105	3.253	0.272	0.191	1.240	6.994
DE(θ =1.96)	0.464	0.010	0.985	0.328	0.591	3.765	0.284	0.695	1.211	9.366
DE(θ =0.59)	0.382	0.012	0.886	0.337	0.938	3.460	0.273	0.325	1.176	7.856

Source: Authors calculations.

Notes: Root mean square error (RMSE) shown for one-, two-, and four-quarter-ahead forecasts for selected macroeconomic variables (as discussed in the main text) . RE and DE denoted the Rational expectations and Diagnostic expectations models.

Appendix I: Data

Appendix Table AI. 1. Data and Transformation

	HAVER code	HAVER descriptor
Canada		
Real GDP	V6E05752@CANADA	Gross Domestic Product at Market Prices (SAAR, Mil.Chn.2017.C$)
Core CPI	V4C91233@CANADAR	CPI: All Items ex Food and Energy [V41691233] (NSA, 2002=100)
Nominal interest rate	B156RDV@CANADA	Target Rate (AVG, %)
Export price deflator	V6E07276@CANADA	Implicit Price Index: Exports of Goods and Svcs(SA, 2017=100)
Import price deflator	V6E07279@CANADA	Implicit Price Index: Imports of Goods and Svcs(SA, 2017=100)
Nominal exchange rate (C$/US$)	V37426@CANADA	U.S. Dollar Exchange Rate (Avg, C$/US$)
United States		
Real GDP	GDPH@USECON	Real Gross Domestic Product (SAAR, Bil.Chn.2017$)
Core CPI	PCUSLFE@USECON	CPI-U: All Items Less Food and Energy (SA, 1982-84=100)
Nominal interest rate	FFED@USECON	Federal Funds [effective] Rate (% p.a.)

Data transformations

Output gaps
CAN and USA: log (real) GDP was detrended using the Hodrick-Prescott filter (lambda = 6400) (percent)

Inflation
CAN: CORE CPI was seasonally adjusted (X-13)
CAN and USA: Core inflation: annualized, quarterly log difference (percent); demeaned

Real exchange rate (RER)
RER calculated as the nominal exchange rate, multiplied by USA (core) CPI divided by CAN (core) CPI
After taking the log difference, the series is demeaned (percent)

Terms of trade (TOT)
TOT is calculated as the ratio of the price of imports to the price of exports
After taking the log difference, the series is demeaned (percent)

Source: Authors calculations.

Table AI. 2. Variance Decompositions—Details

Rational Expections

	Technology	Demand	Cost-push	Risk premium	Monetary policy	Foreign output	Foreign interest rate	Foreign inflation
Output	15.6	45.9	7.6	22.9	3.8	4.0	0.1	0.2
Real interest rate	2.0	18.7	37.3	28.9	12.3	0.4	0.1	0.2
Nominal Interest rate	33.3	21.1	0.9	26.0	16.7	1.5	0.2	0.2
CPI inflation	1.8	12.3	44.4	36.1	5.0	0.1	0.1	0.3
Domestic inflation	57.8	13.7	1.4	2.6	22.9	1.4	0.1	0.2
Import inflation	0.6	19.8	43.8	33.9	1.3	0.2	0.1	0.3
Real exchange rate	0.9	27.0	39.6	31.5	0.4	0.2	0.1	0.3
Terms of trade	1.0	36.1	23.4	38.6	0.1	0.3	0.1	0.3
Nominal depreciation	1.2	29.8	8.2	55.2	2.8	0.3	0.6	1.9
Terms of trade growth	2.6	23.1	41.7	31.5	0.5	0.3	0.1	0.2

Diagnostic Expections (theta = 0.59)

	Technology	Demand	Cost-push	Risk premium	Monetary policy	Foreign output	Foreign interest rate	Foreign inflation
Output	34.5	29.5	7.3	22.4	4.7	1.4	0.0	0.1
Real interest rate	2.7	10.9	73.2	3.4	9.5	0.3	0.0	0.0
Nominal Interest rate	39.0	26.4	0.7	23.6	9.3	0.9	0.1	0.1
CPI inflation	3.7	2.6	86.9	2.3	4.4	0.1	0.0	0.0
Domestic inflation	43.3	18.7	2.8	1.2	33.1	0.7	0.1	0.1
Import inflation	0.1	3.9	92.6	3.0	0.3	0.1	0.0	0.0
Real exchange rate	1.6	40.1	23.8	33.0	0.9	0.6	0.0	0.0
Terms of trade	2.3	43.2	36.5	17.1	0.2	0.6	0.1	0.0
Nominal depreciation	1.5	40.3	7.2	47.2	2.6	0.7	0.2	0.4
Terms of trade growth	1.1	5.6	89.6	3.3	0.2	0.1	0.0	0.0

Diagnostic Expections (theta = 1.96)

	Technology	Demand	Cost-push	Risk premium	Monetary policy	Foreign output	Foreign interest rate	Foreign inflation
Output	42.0	19.1	6.1	26.6	5.7	0.4	0.1	0.1
Real interest rate	1.7	10.0	74.9	3.4	9.4	0.5	0.0	0.0
Nominal Interest rate	41.4	30.2	2.5	19.8	4.8	0.8	0.4	0.1
CPI inflation	1.8	2.4	84.1	5.2	6.1	0.3	0.1	0.0
Domestic inflation	33.0	13.9	3.7	0.9	48.1	0.4	0.1	0.0
Import inflation	0.4	5.2	86.9	6.4	0.5	0.5	0.1	0.0
Real exchange rate	3.6	30.5	25.6	35.6	1.2	2.6	0.6	0.1
Terms of trade	3.9	25.6	42.7	22.2	0.1	3.7	1.7	0.3
Nominal depreciation	3.4	35.7	10.5	44.7	2.8	2.4	0.4	0.1
Terms of trade growth	1.5	7.1	83.8	6.8	0.1	0.6	0.1	0.0

Source: Authors calculations.

Notes: Variances decompositions in percent.

Appendix II: Microeconomic Foundations, the Steady State and the Linearized Model

A. Microeconomic Foundations

A.1 Households

The representative household chooses the sequences for C_t, N_t, D_t, and B_t to maximize expected discounted utility as defined in equations (3) and (4), subject to the period-by-period budget constraint in equation (6), as well as a standard transversality condition on bond holdings to ensure solvency. By deriving and manipulating the first-order conditions associated with this optimization problem, the following optimality conditions, which characterize the household's behavior in equilibrium, can be obtained:

$$\frac{W_t}{P_t} = (C_t - h\, C_{t-1})^{-\sigma} N_t^{\varphi}, \tag{A1}$$

$$\frac{(C_t - h\, C_{t-1})^{-\sigma}}{\Pi_t R_t} = \beta \mathbb{E}_t^{\theta}\left[\frac{(C_{t+1} - h\, C_t)^{-\sigma}}{\Pi_{t+1}\Pi_t}\right], \tag{A2}$$

$$R_t\, \mathbb{E}_t^{\theta}\left[\frac{(C_{t+1} - h\, C_t)^{-\sigma}}{\Pi_{t+1}\Pi_t}\right] = \frac{R_t^{*}\phi_t}{\left(\frac{e_t}{e_{t-1}}\right)} \mathbb{E}_t^{\theta}\left[\frac{(C_{t+1} - h\, C_t)^{-\sigma}}{\Pi_{t+1}\Pi_t}\left(\frac{e_{t+1}}{e_t}\right)\left(\frac{e_t}{e_{t-1}}\right)\right]. \tag{A3}$$

The interpretation of these conditions is straightforward. Equation (A1) represents the optimal intra-temporal trade-off between labor and consumption, implicitly defining the household's labor supply decision. Equation (A2), commonly referred to as the Euler equation, characterizes the optimal intertemporal allocation of consumption. It reflects the representative household's preference for smoothing consumption over time through the accumulation and decumulation of domestic bonds. Finally, equation (A3) captures the uncovered interest parity (UIP) condition, which equates the expected returns on domestic and foreign bonds, adjusted for expected exchange rate depreciation and country-specific risk premia.

A.2 Firms

Final goods firms. These firms operate under perfect competition and aggregate a continuum of intermediate goods indexed by $i \in [0,1]$ using the Dixit-Stiglitz aggregator:

$$Y_{H,t} \equiv \left(\int_0^1 Y_{H,t}(i)^{\frac{\epsilon_H - 1}{\epsilon_H}} di\right)^{\frac{\epsilon_H}{\epsilon_H - 1}}. \tag{A4}$$

Solving the final goods firm's cost minimization problem yields the demand function for retail variety *i*, priced at $P_{H,t}(i)$:

$$Y_{H,t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\epsilon_H} Y_{H,t}, \tag{A5}$$

where the corresponding price index for domestic goods is given by:

$$P_{H,t} = \left(\int_0^1 P_{H,t}(i)^{1-\epsilon_H} di\right)^{\frac{1}{1-\epsilon_H}}. \tag{A6}$$

Intermediate domestic firms. They operate under monopolistic competition and face nominal price rigidities. As described in the main text, each firm chooses its price $P_{H,t}(i)$ to maximize expected discounted profits described by equations (13) and (14). The first-order condition for this problem yields the non-linear New Keynesian Phillips Curve (NKPC) for domestic inflation:

$$\psi_H \left(\frac{\Pi_{H,t}}{\Pi_{H,t-1}^{\delta_H}} - 1\right) \frac{\Pi_{H,t}}{\Pi_{H,t-1}^{\delta_H}} = (1 - \epsilon_H) + \epsilon_H MC_t + \beta \psi_H \frac{\Pi_{H,t}}{\Lambda_t Y_{H,t}} \mathbb{E}_t^\theta \left[\Lambda_{t+1} \left(\frac{\Pi_{H,t+1}}{\Pi_{H,t}^{\delta_H}} - 1\right) \frac{\Pi_{H,t+1}}{\Pi_{H,t}^{\delta_H}} \frac{Y_{H,t+1}}{\Pi_{H,t}}\right], \tag{A7}$$

whose linearized approximation yields equation (15) in the main text.

Optimality also implies the following expression for the marginal cost:

$$MC_t = \frac{W_t}{P_{H,t}\, \varepsilon_{a,t}}, \tag{A8}$$

which, in conjunction with equations (11), (A1), the CPI (P_t) definition, and the TOT definition $S_t = \frac{P_{F,t}}{P_{H,t}}$, allows us to derive the following expression in a symmetric equilibrium:

$$MC_t = \left[(1 - \alpha) + \alpha S_t^{1-\eta}\right]^{\frac{1}{1-\eta}} \frac{\left(Y_{H,t}\right)^{\varphi}}{\left(\varepsilon_{a,t}\right)^{1+\varphi} (C_t - hC_{t-1})^{-\sigma}}. \tag{A9}$$

Retail import firms. There is also a continuum of retail firms, indexed by $i \in [0,1]$, which import differentiated foreign goods. These firms operate under monopolistic competition and face nominal price rigidities à la Rotemberg (1982). The price adjustment cost for each firm is given by

$$AC_{F,t}(i) = \frac{\psi_F}{2} \left(\frac{P_{F,t}(i)}{\Pi_{F,t-1}^{\delta_F} P_{F,t-1}(i)} - 1\right)^2 P_{F,t} C_{F,t}, \tag{A10}$$

where $\psi_F \geq 0$ captures the degree of nominal price rigidity and $\delta_F \geq 0$ reflects the degree of indexation to past imported goods inflation.

Each domestic retailer i purchases a quantity $C_{F,t}(i)$ of the imported goods at the price $e_t P_t^*$—recall that $e_t P_t^* = \Gamma_{F,t} P_{F,t}$. Retailers then differentiate the imported good and resell it to households at the retail price $P_{F,t}(i)$, facing the following demand function:

$$C_{F,t}(i) = \left(\frac{P_{F,t}(i)}{P_{F,t}}\right)^{-\epsilon_{F,t}} C_{F,t}, \tag{A11}$$

where $\epsilon_{F,t} > 1$ denotes the elasticity of substitution between imported varieties. It is time-variant to introduce cost-push shocks, as in Justiniano and Preston (2010).

Each retailer sets its price $P_{F,t}(i)$ to maximize expected discounted profits:

$$\frac{F_{F,t}(i)}{P_{F,t}} + \mathbb{E}_t^{\theta}\left[\sum_{s=1}^{\infty} \Lambda_{t,t+s} \frac{F_{F,t+s}(i)}{P_{F,t+s}}\right], \tag{A12}$$

where real profits are defined as:

$$\frac{F_{F,t}(i)}{P_{F,t}} = \frac{P_{F.t}(i)}{P_{F,t}}\left(\frac{P_{F,t}(i)}{P_{F,t}}\right)^{-\epsilon_{F,t}} C_{F,t}, -(1-\iota_F)\Gamma_{F,t}\left(\frac{P_{F,t}(i)}{P_{F,t}}\right)^{-\epsilon_{F,t}} C_{F,t}, - \frac{AC_{F,t}(i)}{P_{F,t}}, \tag{A13}$$

with ι_F denoting a subsidy that ensures $\bar{\Gamma}_F = 1$ in steady state.

Each firm sets its price $P_{F,t}(i)$ to maximize expected discounted profits, as formalized in equations (A12) and (A13). The corresponding first-order condition gives rise to a NKPC for imported goods inflation:

$$\psi_F\left(\frac{\Pi_{F,t}}{\Pi_{F,t-1}^{\delta_F}} - 1\right)\frac{\Pi_{F,t}}{\Pi_{F,t-1}^{\delta_F}} = \left(1-\epsilon_{F,t}\right) + \epsilon_{F,t}\Gamma_{F,t} + \beta\psi_F \frac{\Pi_{F,t}}{\Lambda_t C_{F,t}} \mathbb{E}_t^{\theta}\left[\Lambda_{t+1}\left(\frac{\Pi_{F,t+1}}{\Pi_{F,t}^{\delta_F}} - 1\right)\frac{\Pi_{F,t+1}}{\Pi_{F,t}^{\delta_F}}\frac{C_{F,t+1}}{\Pi_{F,t}}\right]. \tag{A14}$$

This expression corresponds to the non-linear NKPC, whose linearized approximation yields equation (16) in the main text.

B. Steady State

We characterize the steady state of the model under a set of simplifying assumptions. Specifically, we assume that net foreign assets are zero, i.e., $\overline{A} = 0$, and normalize the terms of trade, domestic output, and (gross) inflation rates—domestic, imported, and CPI—to unity: $\bar{S} = \bar{\Pi}_F = \bar{\Pi}_H = \bar{\Pi} = \bar{Y}_H = 1$. By construction, the subsidies ι_H and ι_F ensure that the steady-state marginal cost and price gap are also normalized: $\overline{MC} = \bar{\Gamma}_F = 1$. Given these assumptions and the model's nonlinear equilibrium conditions, it follows that the risk premium, relative prices—including the real exchange rate—and aggregate consumption satisfy $\bar{\phi} = \bar{Q} = \frac{\bar{P}}{\bar{P}_H} = \frac{\bar{P}}{\bar{P}_F} = \bar{C} = 1$. The steady-state nominal interest rates, both domestic and foreign, satisfy $\bar{R} = \bar{R}^* = \frac{1}{\beta}$. Consumption allocations imply $\bar{C}_H = 1 - \alpha$ and $\bar{C}_F = \alpha$, while the foreign economy's output and consumption are given by $\bar{Y}^* = \bar{C}_H^* = \alpha$.

C. Linearized Model

Structural behavioral equations of the domestic economy

Recall that for a linearized variable $\hat{x}$, we have that $\xi_{t+j}^{x} = \mathbb{E}_t\left[\hat{x}_{t+j}\right] - \mathbb{E}_{t-1}\left[\hat{x}_{t+j}\right]$ for $j = 0,1$.

Euler equation for consumption

$$\hat{C}_t = \frac{h}{1+h}\left(\hat{C}_{t-1} - \theta\xi_t^C\right) + \frac{h}{1+h}\left\{\mathbb{E}_t\left[\hat{C}_{t+1}\right] + \theta\xi_{t+1}^C\right\} - \frac{1}{\sigma(1+h)}\left\{\hat{R}_t - \mathbb{E}_t\left[\widehat{\Pi}_{t+1}\right] - \theta(\xi_{t+1}^\pi + \xi_t^\pi)\right\}$$

Uncovered interest parity (UIP) condition

$$\hat{e}_t = \hat{R}_t^* - \hat{R}_t + \hat{\phi}_t + \mathbb{E}_t[\hat{e}_{t+1}] + \theta[\xi_{t+1}^{\Delta e} + \xi_t^{\Delta e}]$$

Country-risk premium

$$\hat{\phi}_t = -\chi\hat{A}_t - \hat{\varepsilon}_{rp,t}$$

New Keynesian Phillips curve (NKPC) for domestic inflation

$$(1+\beta\delta_H)\widehat{\Pi}_{H,t} = \delta_H\,\widehat{\Pi}_{H,t-1} + \beta\mathbb{E}_t\left[\widehat{\Pi}_{H,t+1}\right] + \frac{\epsilon_H - 1}{\psi_H}\widehat{MC}_t + \beta\theta\left[\xi_{t+1}^{\Pi_H} - \delta_H\xi_t^{\Pi_H}\right]$$

Real marginal cost for domestic goods firms

$$\widehat{MC}_t = \alpha\hat{S}_t + \varphi\,\hat{Y}_{H,t} + \frac{\sigma}{1-h}\left(\hat{C}_t - h\hat{C}_{t-1}\right) - (1+\varphi)\,\hat{\varepsilon}_{a,t}$$

NKPC for imports inflation

$$(1+\beta\delta_F)\widehat{\Pi}_{F,t} = \delta_F\,\widehat{\Pi}_{F,t-1} + \beta\mathbb{E}_t\left[\widehat{\Pi}_{F,t+1}\right] + \frac{(\epsilon_F - 1)\alpha}{\psi_F}\hat{\Gamma}_{F,t} + \beta\theta\left[\xi_{t+1}^{\Pi_F} - \delta_F\xi_t^{\Pi_F}\right] + \hat{\varepsilon}_{cp,t}$$

Price gap

$$\hat{\Gamma}_{F,t} = \hat{q}_t - (1-\alpha)\hat{S}_t$$

Taylor rule

$$\hat{R}_t = \rho\hat{R}_{t-1} + \psi_\pi\widehat{\Pi}_{H,t} + \psi_y\hat{Y}_t + \psi_{\Delta e}\Delta\hat{e}_t + \hat{\varepsilon}_{M,t}$$

Government spending

$$\hat{G}_{H,t} = \hat{\varepsilon}_{g,t}$$

Market clearing condition for domestic goods

$$\hat{Y}_{H,t} = (1-\alpha)\hat{C}_t + \hat{G}_{H,t} + \eta\alpha(2-\alpha)\hat{S}_t + \alpha\eta\,\hat{\Gamma}_{F,t} + \alpha\hat{Y}_t^*$$

Budget constraint for the domestic economy

$$\beta\hat{A}_t - \hat{A}_{t-1} = \widehat{NX}_t = \hat{Y}_{H,t} - \hat{C}_t - \hat{G}_{H,t} - \alpha\left(\hat{S}_t + \hat{\Gamma}_{F,t}\right)$$

Definitions and Additional Dynamic Equations

Real interest rate

$$\hat{r}_t = \hat{R}_t - \mathbb{E}_t\left[\widehat{\Pi}_{H,t+1}\right]$$

Change of the terms of trade (TOT)

$$\Delta\hat{S}_t = \hat{S}_t - \hat{S}_{t-1}$$

Change of the real exchange (rer)

$$\Delta\hat{q}_t = \hat{q}_t - \hat{q}_{t-1}$$

Relationship between the change of rer, nominal depreciation, and foreign and domestic inflation

$$\Delta\hat{q}_t = \Delta\hat{e}_t + \hat{\Pi}_t^* - \hat{\Pi}_t$$

Relationship between TOT change and imports and domestic inflation

$$\Delta\hat{S}_t = \hat{\Pi}_{F,t} - \hat{\Pi}_{H,t}$$

Relationship between CPI inflation, TOT change, and domestic inflation

$$\hat{\Pi}_t = \alpha\Delta\hat{S}_t + \hat{\Pi}_{H,t}$$

The Foreign Sector VAR(2)

Foreign output

$$\hat{Y}_t^* = \rho_{yy,1}\hat{Y}_{t-1}^* + \rho_{yr,1}\hat{R}_{t-1}^* + \rho_{y\pi,1}\hat{\Pi}_{t-1}^* + \rho_{yy,2}\hat{Y}_{t-2}^* + \rho_{yr,2}\hat{R}_{t-2}^* + \rho_{y\pi,2}\hat{\Pi}_{t-2}^* + \mu_{y^*,t}$$

Foreign interest rate

$$\hat{R}_t^* = \rho_{ry,1}\hat{Y}_{t-1}^* + \rho_{rr,1}\hat{R}_{t-1}^* + \rho_{r\pi,1}\hat{\Pi}_{t-1}^* + \rho_{ry,2}\hat{Y}_{t-2}^* + \rho_{rr,2}\hat{R}_{t-2}^* + \rho_{r\pi,2}\hat{\Pi}_{t-2}^* + \mu_{r^*,t}$$

Foreign inflation rate

$$\hat{\Pi}_t^* = \rho_{\pi y,1}\hat{Y}_{t-1}^* + \rho_{\pi r,1}\hat{R}_{t-1}^* + \rho_{\pi\pi,1}\hat{\Pi}_{t-1}^* + \rho_{\pi y,2}\hat{Y}_{t-2}^* + \rho_{\pi r,2}\hat{R}_{t-2}^* + \rho_{\pi\pi,2}\hat{\Pi}_{t-2}^* + \mu_{\pi^*,t}$$

Shocks

1. Technology

$$\hat{\varepsilon}_{a,t} = \rho_a\hat{\varepsilon}_{a,t-1} + \mu_{a,t}$$

2. Government spending

$$\hat{\varepsilon}_{g,t} = \rho_g\hat{\varepsilon}_{g,t-1} + \mu_{g,t}$$

3. Risk premium

$$\hat{\varepsilon}_{rp,t} = \rho_{rp}\hat{\varepsilon}_{rp,t-1} + \mu_{rp,t}$$

4. Cost-push

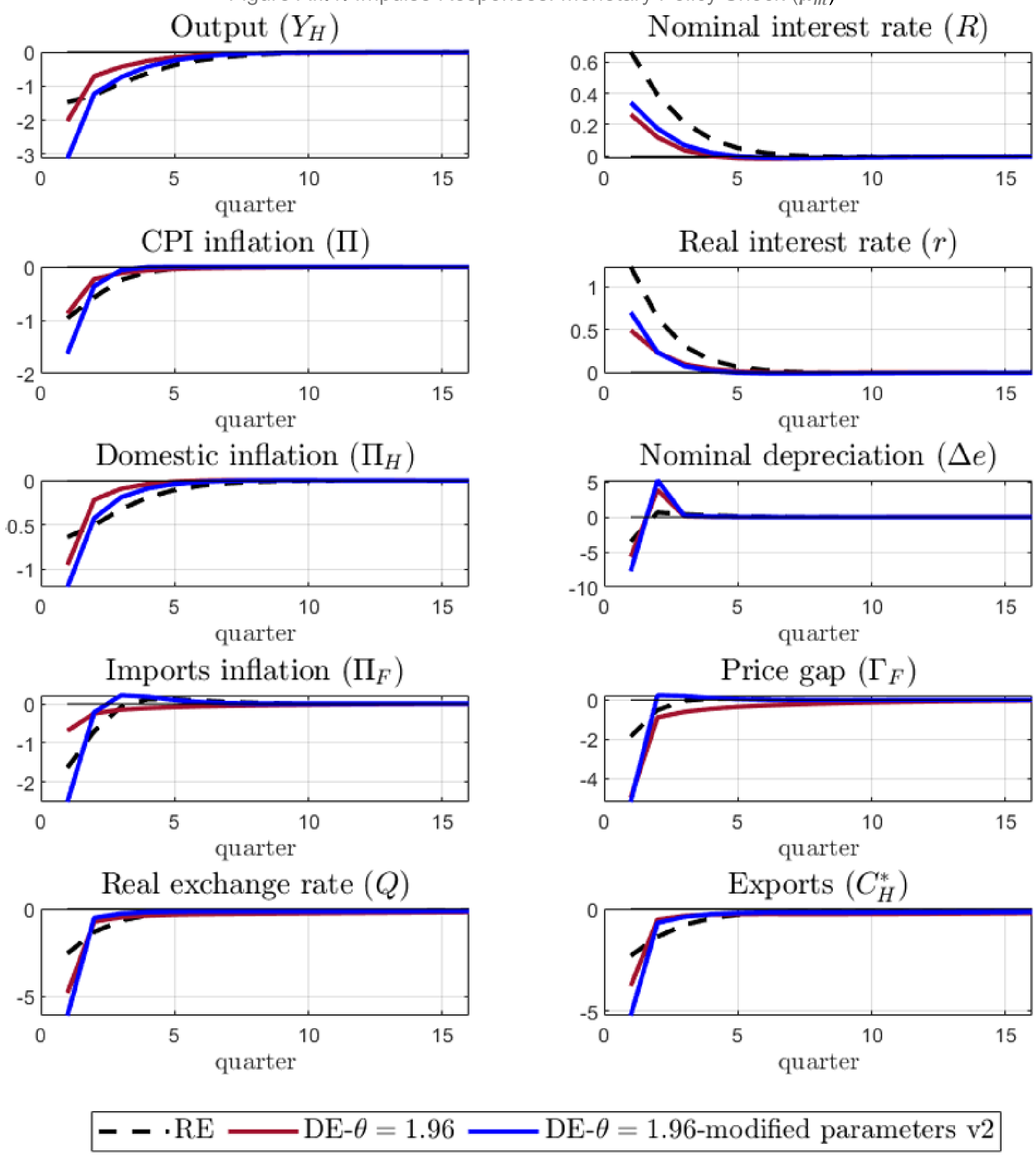
$$\hat{\varepsilon}_{cp,t} = \rho_{cp}\hat{\varepsilon}_{cp,t-1} + \mu_{cp,t}$$

5. Monetary Policy

$$\hat{\varepsilon}_{m,t} = \rho_m\hat{\varepsilon}_{m,t-1} + \mu_{m,t}$$

Appendix III: Supplementary IRF Analysis

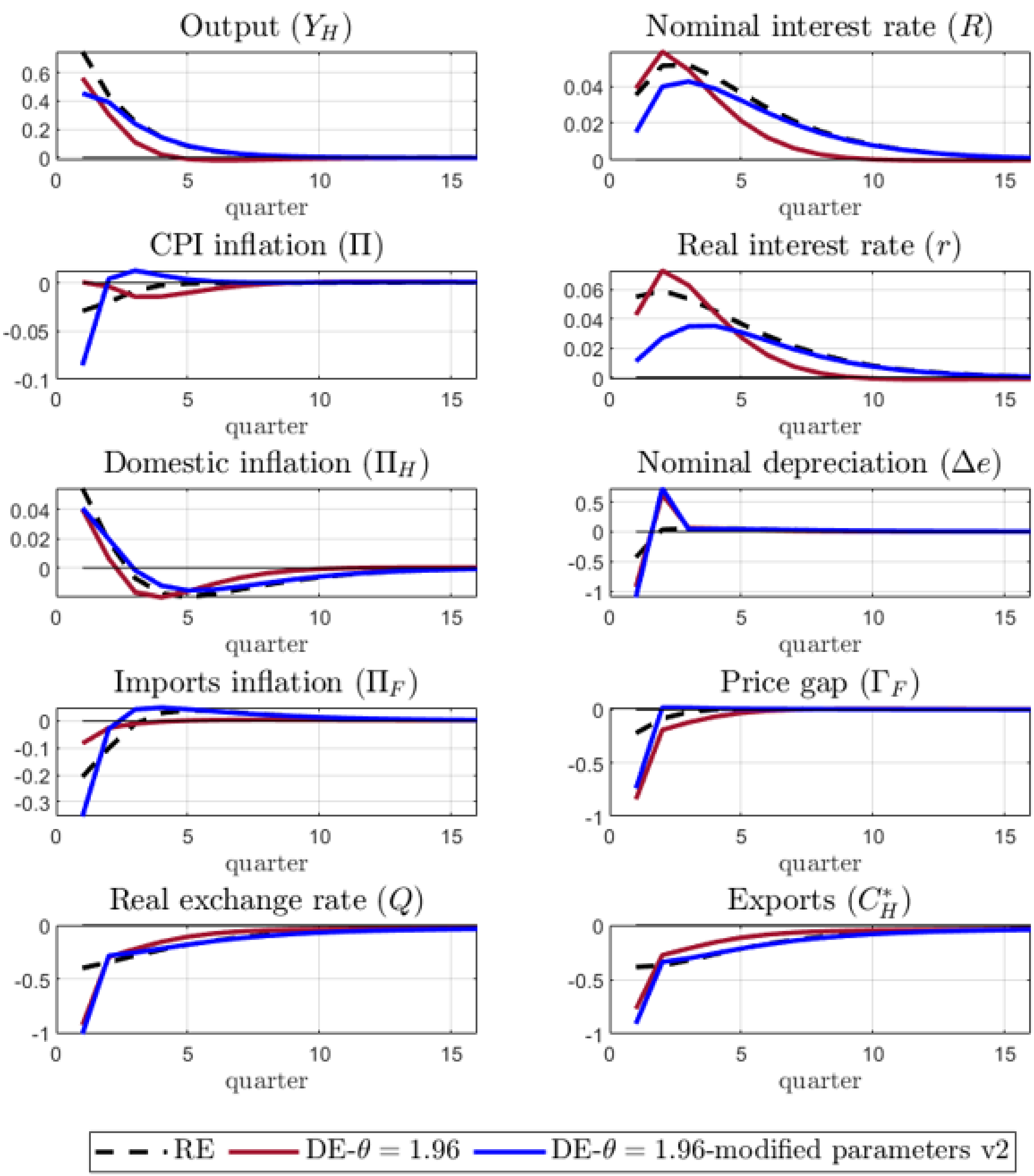
Figure AII.1. Impulse Responses: Monetary Policy Shock (μ_m)



Source: Authors calculations.

Notes: Percent deviations from steady state. The shock is a unit increase. The “modified parameters v2” simulations correspond to the case in which all parameters are set to their Rational Expectations estimates, except for the diagnosticity parameter (θ = 1.96).

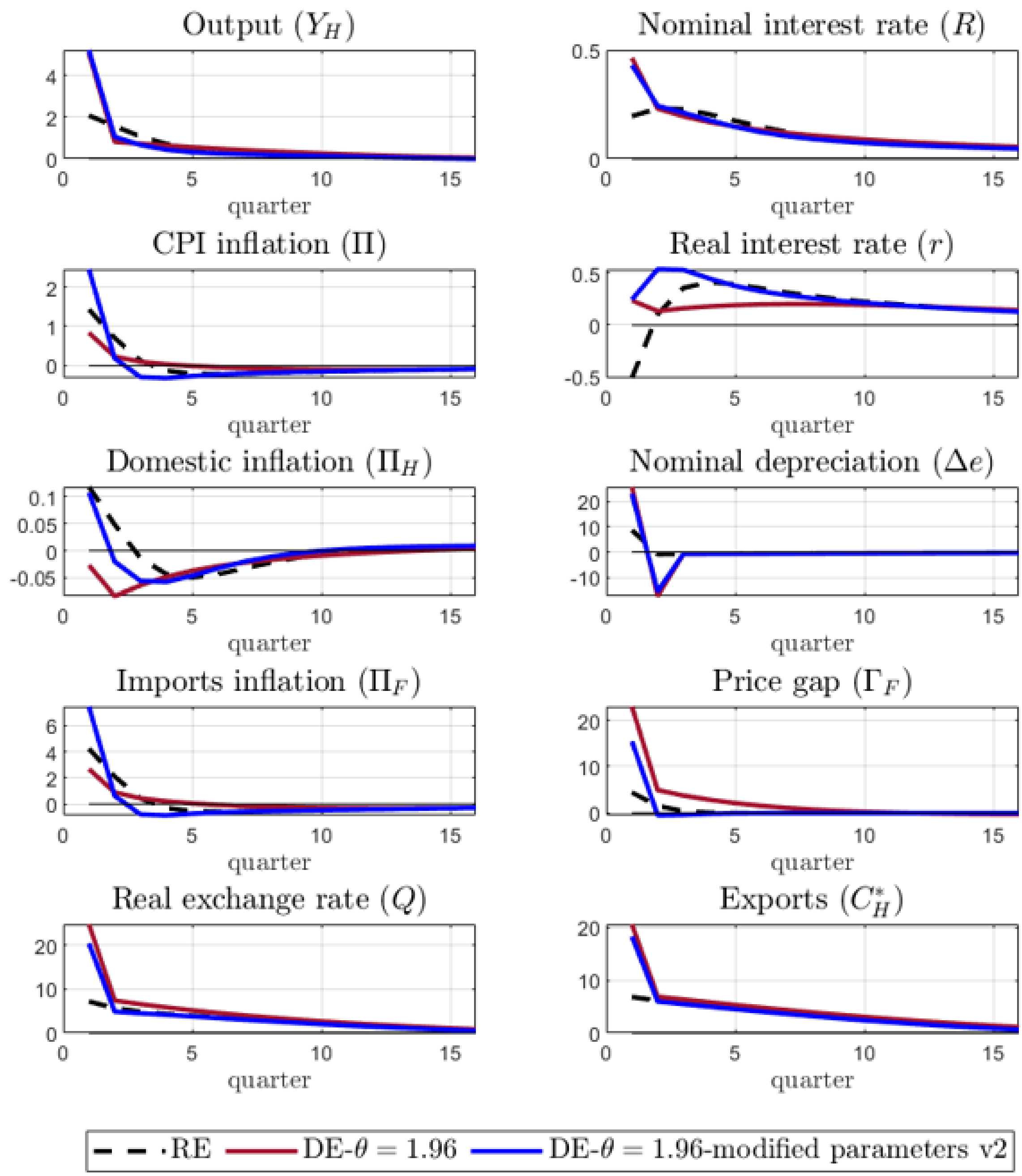
Figure AIII.2. Impulse Responses: Government Spending Shock (μ_g)



Source: Authors calculations.

Notes: Percent deviations from steady state. The shock is a unit increase. The “modified parameters v2” simulations correspond to the case in which all parameters are set to their Rational Expectations estimates, except for the diagnosticity parameter (θ = 1.96).

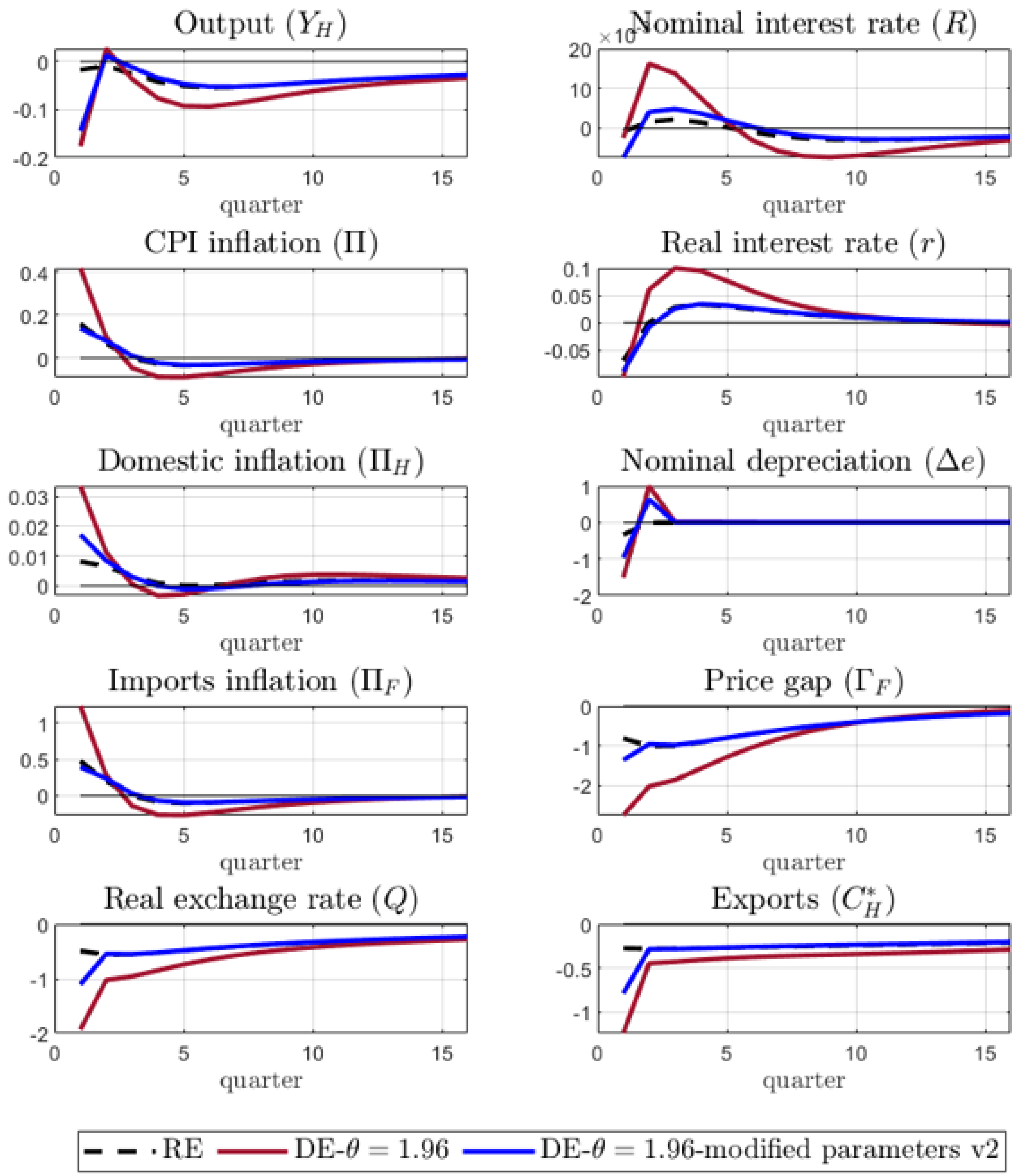
Figure AIII.3. Impulse Responses: Risk Premium Shock (μ_{rp})



Source: Authors calculations.

Notes: Percent deviations from steady state. The shock is a unit increase. The “modified parameters v2” simulations correspond to the case in which all parameters are set to their Rational Expectations estimates, except for the diagnosticity parameter (θ = 1.96).

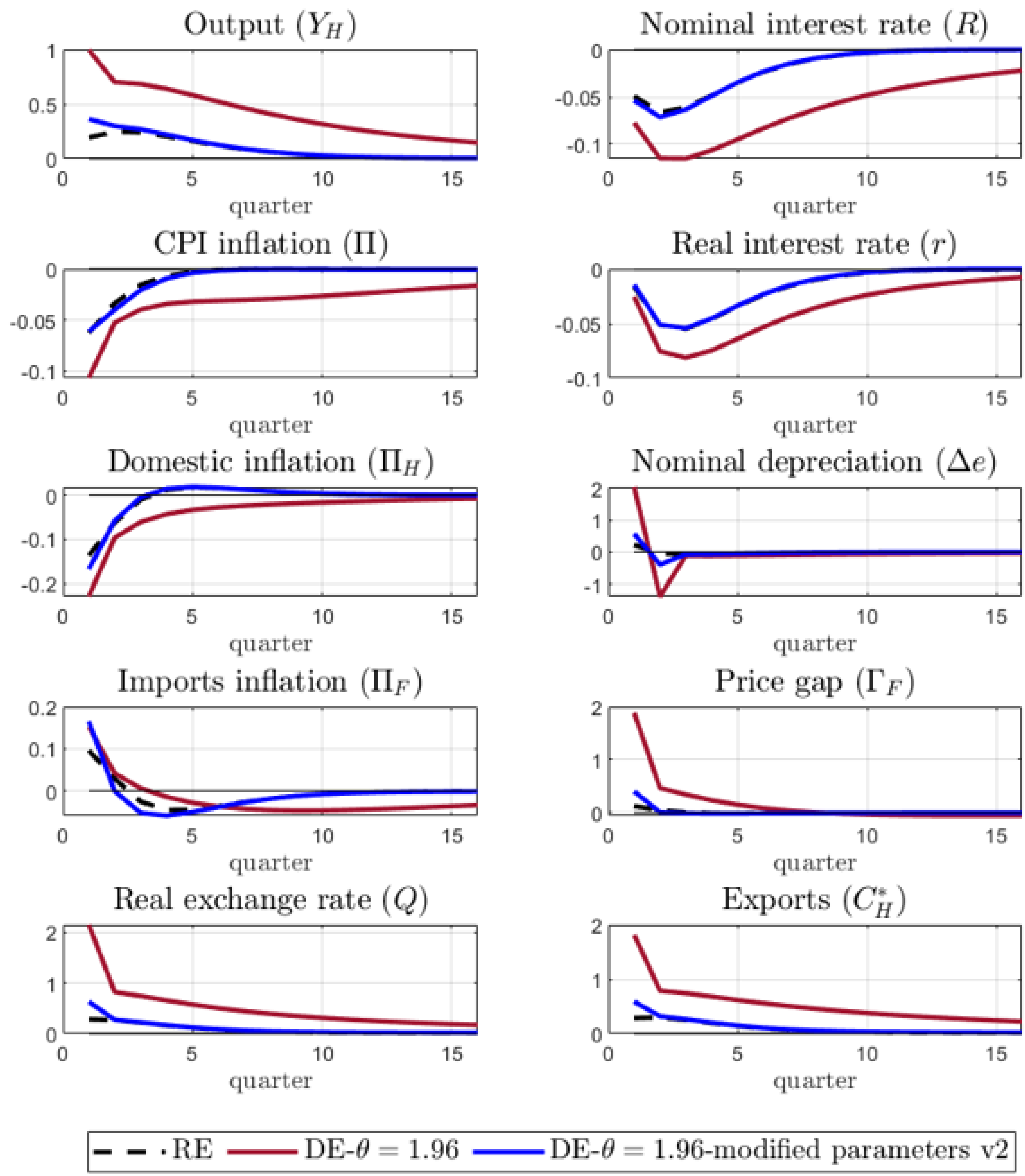
Figure AIII.4. Impulse Responses: Imports Cost-Push Shock (μ_{cp})



Source: Authors calculations.

Notes: Percent deviations from steady state. The shock is a unit increase. The "modified parameters v2" simulations correspond to the case in which all parameters are set to their Rational Expectations estimates, except for the diagnosticity parameter (θ = 1.96).

Figure AIII.5. Impulse Responses: Productivity Shock (μ_a)



Source: Authors calculations.

Notes: Percent deviations from steady state. The shock is a unit increase. The "modified parameters v2" simulations correspond to the case in which all parameters are set to their Rational Expectations estimates, except for the diagnosticity parameter (θ = 1.96).

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