

Journal Pre-proof

Monetary policy and exchange rate dynamics in a behavioral open economy model

Marcin Kolasa, Sahil Ravgotra, Pawel Zabczyk



PII: S0022-1996(25)00043-1

DOI: <https://doi.org/10.1016/j.jinteco.2025.104087>

Reference: INEC 104087

To appear in: *Journal of International Economics*

Received date: 21 November 2023

Revised date: 25 March 2025

Accepted date: 27 March 2025

Please cite this article as: M. Kolasa, S. Ravgotra and P. Zabczyk, Monetary policy and exchange rate dynamics in a behavioral open economy model. *Journal of International Economics* (2025), doi: <https://doi.org/10.1016/j.jinteco.2025.104087>.

This is a PDF file of an article that has undergone enhancements after acceptance, such as the addition of a cover page and metadata, and formatting for readability, but it is not yet the definitive version of record. This version will undergo additional copyediting, typesetting and review before it is published in its final form, but we are providing this version to give early visibility of the article. Please note that, during the production process, errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

© 2025 Published by Elsevier B.V.

Monetary Policy and Exchange Rate Dynamics in a Behavioral Open Economy Model

Marcin Kolasa^{a,b}, Sahil Ravgotra^c, Pawel Zabczyk^a

^a*International Monetary Fund, 700 19th Street, Washington, 20431, DC, USA*

^b*SGH Warsaw School of Economics, al. Niepodleglosci 162, Warszawa, 02-554, Poland*

^c*University of Texas at Austin, 2515 Speedway, Austin, 78712, TX, USA*

Abstract

We analyze the implications of adding boundedly rational agents á la Gabaix (2020) to the canonical New Keynesian open economy model. We show that accounting for myopia mitigates several “puzzling” aspects of the relationship between exchange rates and interest rates and helps explain why some of them only arise in the nested case of rational expectations. Bayesian estimation of the model demonstrates that a high degree of “cognitive discounting” significantly improves empirical fit. We also show that this form of bounded rationality makes positive international monetary spillovers more likely and exacerbates the unit root problem in small open economy models with incomplete markets.

JEL Codes: F41, E70, E52, E58, G40

Keywords: Monetary Policy, Exchange Rates, UIP Condition, Bounded Rationality

1. Introduction

International economics has long had to contend with a number of puzzles, and a lot of research has been devoted to resolving them by including realistic frictions in otherwise standard general equilibrium international macroeconomic models. The puzzles concern both long-term developments¹ as well as ones observed over the business cycle. The latter group often involves exchange rates, which tend to be very volatile when allowed to freely float, exhibit disconnect with macroeconomic fundamentals, and allow arbitrage in foreign exchange (FX) markets.

In a recent paper, Itskhoki and Mukhin (2021) propose a model that can simultaneously account for a number of the exchange rate-related anomalies. A key ingredient of the underlying theoretical setup – which draws on earlier work by De Long et al. (1990), Jeanne and Rose (2002), and Gabaix and Maggiori (2015) – are segmented FX markets, in which noise traders and financial frictions limit arbitrage. This framework gives rise to deviations

¹This group of puzzles includes home bias in trade and asset holdings or limited current account imbalances. Obstfeld and Rogoff (2001) argue that these anomalies can be explained by frictions in international trade in goods.

from uncovered interest rate parity (UIP), which are largely driven by exogenous shifts in noise traders' portfolio decisions. If the corresponding shocks are sufficiently volatile, model fit significantly improves as the exchange rate becomes disconnected from macroeconomic fundamentals, including interest rate differentials. This result aligns well with the literature that estimates open economy DSGE models, which typically finds that shocks to the UIP premium are the major drivers of exchange rates (see, e.g. Adolfson et al., 2007 or Justiniano and Preston, 2010).

However, some puzzles cannot be simply explained by the inclusion of such shocks. One of them is the forward guidance exchange rate puzzle identified by Galí (2020), who showed that expectations of interest rate differentials in the distant future have much smaller effects on the real exchange rate than what is implied by a standard open economy model. Moreover, some recent papers additionally suggest that UIP-related anomalies do not necessarily reflect the failure of the UIP condition *per se*, but more the standard companion assumption of rational expectations (see, e.g., Kalemli-Ozcan and Varela, 2021; Candian and De Leo, 2023; Müller et al., 2024).² In other words, the deviations from the famous international arbitrage condition become much smaller if we calculate them using agents' actual (and not necessarily rational) expectations about the future exchange rate.

Against this backdrop, the goal of this paper is to investigate the open economy consequences of allowing agents to be myopic as in Gabaix (2020), with a particular focus on the exchange rate dynamics and transmission of monetary policy. The reason for picking this type of bounded rationality, often referred to as behavioral (or cognitive) discounting, is its success in the closed economy setting. In particular, cognitive discounting has been shown to resolve the so-called forward guidance puzzle (Carlstrom et al., 2015; Del Negro et al., 2023; McKay et al., 2016), which is relevant here as it has a similar flavor to the aforementioned exchange rate puzzle (Galí, 2020). Moreover, as shown by Gust et al. (2021), allowing for discounting improves the fit of a closed economy New Keynesian model relative to its standard, fully-rational counterpart.

Our point of departure is the well-established, new open economy macroeconomics (NOEM) paradigm,³ and we cast the analysis in a, now standard, incomplete asset market version of that environment. We estimate the model using Bayesian methods and standard macroeconomic time series that also include the exchange rate. We find that overall model fit, as measured by the marginal likelihood, significantly improves for a high degree of myopia, despite the fact that the stochastic structure of the model includes UIP premium shocks, as advocated by Itskhoki and Mukhin (2021).

We then analyze the implications of our model for the relationship between the exchange rate and interest rates conditional on other shocks. We find that, for degrees of myopia consistent with our econometric estimates, the behavioral extension goes a considerable way

²Earlier papers making this claim in the context of the forward premium puzzle include Froot and Frankel (1989), Bacchetta et al. (2009) and Bussiere et al. (2022).

³See, among others, Corsetti and Pesenti (2001), Schmitt-Grohé and Uribe (2001), Kollmann (2002), Benigno and Benigno (2003), Galí and Monacelli (2005).

towards mitigating the forward premium puzzle (Fama, 1984), the predictability reversal puzzle (Bacchetta and van Wincoop, 2010), and the Engel puzzle (Engel, 2016). We also show that incomplete financial markets are key for the model to successfully address the second and third puzzles. Since Itskhoki and Mukhin (2021) show that these three UIP puzzles can be rationalized in a multi-shock model using exogenous variations in the UIP risk premium, therefore one way to interpret our results is that one can rely less on this type of shock if cognitive myopia is also accounted for. Perhaps more importantly, behavioral discounting additionally helps resolve the forward guidance exchange rate puzzle (Galí, 2020).

We next discuss how the implications of the behavioral New Keynesian model of Gabaix (2020) are modified if it is extended to an open economy setting. One result that transpires directly from inspecting the modified IS curve is that cognitive discounting exacerbates the well-known unit root problem prevalent in small open economy models, requiring stronger remedial mechanisms.⁴ Turning to implications for monetary policy, and broadly in line with closed economy results, cognitive discounting also resolves the “forward guidance puzzle” (FGP, see also Carlstrom et al., 2015; Del Negro et al., 2023; McKay et al., 2016) in an open economy context. There are, however, notable differences between closed and open economy behavioral models. The key one is that, while the sensitivity of domestic prices in the fully rational case increases approximately linearly as a function of the forward guidance horizon, this is not the case for the exchange rate. This implies that the FGP is considerably less dramatic in an open economy to begin with, and hence myopia translates into *relatively* less dampening of future interest rate changes, at least in an environment of high exchange rate pass-through to import prices as advocated by the dominant currency paradigm literature (Gopinath et al., 2020). Finally, we show that behavioral discounting has interesting implications for the size of international monetary policy spillovers. In particular, monetary easing in one economy is more likely to be expansionary for its trading partners if these are populated by behavioral agents, which occurs because cognitive discounting attenuates exchange rate-induced expenditure switching.

Our paper is related to the extensive literature that looks at the puzzling relationship between exchange rates and interest rates. Most of the proposed solutions maintain the assumption that agents are rational. Some recent contributions in this line of papers include Bacchetta and van Wincoop (2021), who propose a model of delayed portfolio adjustment, with Valchev (2020) relying on financial frictions. Our work is closer to approaches that allow for irrationality or information frictions. Gourinchas and Tornell (2004) and Burnside et al. (2011) show theoretically how the forward premium puzzle may arise from distorted beliefs of investors, while Ilut (2012) proposes an explanation that combines imperfect information with ambiguity aversion. More recently, Candian and De Leo (2023) and Müller et al. (2024) develop general equilibrium models where information frictions and shock misperception help account for the observed behavior of excess returns. Du et al. (2021) look at learning in an open economy framework, their key finding being that it goes a considerable way towards

⁴The issue arises on account of asset market incompleteness and is discussed in Schmitt-Grohe and Uribe (2003).

better accounting for exchange rate dynamics. Na and Xie (2023) show how limited foresight can account for dynamic overshooting of forecast errors in the real exchange rate.

More broadly, our results relate to the literature developing structural models with bounded rationality. One of the early contributions was due to Brock and Hommes (1997), who integrated heterogeneous expectations and a partial equilibrium cob-web model into the NK framework. Evans and Honkapohja (2001) and Bullard and Mitra (2002) introduced learning where agents forecast only immediate future variables. An alternative form of learning based on infinite horizons was promoted by Preston (2005). Branch and McGough (2009) and De Grauwe (2011) proposed models where some agents are rational while others either learn adaptively or follow simple rules-of-thumb. More recently, and as an alternative to the cognitive discounting setup that we are closest to, Bordalo et al. (2018) formalized the concept of diagnostic expectations and demonstrated how they can lead to financial cycles, while Bianchi et al. (2021) showed how this concept can be introduced into fully-fledged DSGE models.

The remainder of this paper is structured as follows. Section 2 introduces the theoretical setup with two countries and boundedly rational agents. In Section 3, we use a linearized small open economy version of the model to discuss how behavioral discounting changes the key equilibrium relationships, also presenting the range of parameter values used in numerical experiments. Section 4 shows how allowing for behavioral discounting helps mitigate some exchange rate puzzles. In Section 5, we characterize the implications of myopia for the output and inflation aspect of the forward guidance puzzle. Section 6 discusses the impact of discounting on international monetary policy spillovers. Section 7 analyzes how agents' myopia impinges on model stationarity and equilibrium determinacy. Section 8 concludes.

2. Theoretical Setup

We develop a two-country NOEM model with myopic agents. We refer to one of the economies as Home and the other as Foreign. Both are populated by a continuum of households and monopolistically competitive firms. We normalize the world population to unity and use $\zeta \in (0, 1)$ to indicate the share of Home agents, with the mass of Foreign agents equal to $1 - \zeta$. The two economies are linked by trade in goods and cross-border borrowing, and they have separate monetary authorities. Since both countries are isomorphic, in the rest of this section we focus only on problems faced by Home agents.

2.1. Households

The household sector is populated by a large number of infinitely-lived dynasties. At any time t , household h maximizes a discounted stream of period utility flows that depends on consumption C_t^h and labor supply N_t^h

$$U_t^h = \hat{\mathbb{E}}_t \sum_{T=t}^{\infty} \beta^{T-t} \left[\frac{(C_T^h)^{1-\sigma}}{1-\sigma} - \frac{(N_T^h)^{1+\varphi}}{1+\varphi} \right], \quad (1)$$

where $0 < \beta < 1$ is the subjective discount factor, $\sigma > 0$ is the inverse of the elasticity of intertemporal substitution, $\varphi > 0$ is the inverse of the Frisch elasticity of labor supply, and $\hat{\mathbb{E}}_t$ indicates the expected value operator under the subjective expectations of households that we shall specify subsequently. The consumption basket is made of goods produced domestically $C_{H,t}^h$ and imports $C_{F,t}^h$, aggregated according to

$$C_t^h = \left[(1 - \alpha)^{\frac{1}{\eta}} (C_{H,t}^h)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} (C_{F,t}^h)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad (2)$$

where $0 < \alpha < 1$ controls the degree of openness and $\eta > 0$ is the trade elasticity.

Households have access to one-period bonds denominated in Home currency B_t^h and in Foreign currency $B_t^{*,h}$, of which only the latter is internationally traded, and which pay nominal interest rate i_t and i_t^* , respectively. Labor is remunerated at the real rate W_t , and each dynasty also receives an aliquot share in real firm profits D_t . The real budget constraint can hence be written as

$$C_t^h + \frac{B_t^h}{1 + i_t} + \frac{Q_t}{\Phi_t} \frac{B_t^{*,h}}{1 + i_t^*} = \frac{B_{t-1}^h}{\Pi_t} + Q_t \frac{B_{t-1}^{*,h}}{\Pi_t^*} + W_t N_t^h + D_t, \quad (3)$$

where P_t and P_t^* are the prices of Home and Foreign consumption baskets, $\Pi_t \equiv P_t/P_{t-1}$ and $\Pi_t^* \equiv P_t^*/P_{t-1}^*$ are the associated gross inflation rates, $Q_t \equiv \varepsilon_t P_t^*/P_t$ is the real exchange rate, with ε_t denoting the number of units of domestic currency per unit of foreign currency, and $\Phi_t = \Phi(B_t^*, \varrho_t)$ representing a risk premium that depends on the Home country's per capita net foreign asset (NFA) position and an exogenous shock ϱ_t .⁵

2.2. Firms

Final goods sold domestically $Y_{H,t}$ and for exports $Y_{H,t}^*$ are made of intermediate inputs indexed by f and aggregated according to the following Dixit-Stiglitz technology

$$Y_{H,t} = \left[\int_0^1 \left(Y_{H,t}^f \right)^{\frac{1}{\mu}} df \right]^{\mu}, \quad \text{and} \quad Y_{H,t}^* = \left[\int_0^1 \left(Y_{H,t}^{*,f} \right)^{\frac{1}{\mu}} df \right]^{\mu}, \quad (4)$$

where $\mu > 1$ controls the degree of substitution between individual inputs.

Intermediate inputs are produced by monopolistically competitive firms that operate a production function linear in labor

$$Y_{H,t}^f + Y_{H,t}^{*,f} = z_t N_t^f. \quad (5)$$

where z_t is a common productivity shock. Firms set the same prices for domestic and export sales, quoting them in domestic currency (producer currency pricing) so that $P_{H,t}^f = \varepsilon_t P_{H,t}^{*,f}$ in every period t . They are subject to a Calvo-style friction. More specifically, each period

⁵This can be microfounded by assuming that international capital flows are intermediated by specialized agents facing limited risk-bearing capacity, with exogenous fluctuations in the premium reflecting the presence of noise traders. See Gabaix and Maggiori (2015) or Itskhoki and Mukhin (2021).

only a fraction $0 < \theta < 1$ of firms is allowed to reoptimize their prices. The problem of intermediate goods producers is then to maximize

$$V_t^f = \hat{\mathbb{E}}_t \sum_{T=t}^{\infty} \theta^{T-t} \Lambda_{t,T} \left[P_{H,t}^f (Y_{H,T}^f + Y_{H,T}^{*,f}) - W_T N_T^f \right], \quad (6)$$

subject to production technology (5) and demand constraints implied by aggregation (4). Since firms are owned by households, they discount future profits using $\Lambda_{t,T} \equiv \beta^{T-t} u_1(C_T, N_T)$, i.e., their stochastic discount factor is consistent with household preferences, and their expectations are in line with those in Equation (1).

2.3. Myopia

When solving their problems in every period t , households and firms form subjective expectations denoted by the operator $\hat{\mathbb{E}}_t$. We deviate from rational expectations by assuming that agents are myopic and cannot correctly anticipate the evolution of variables that are beyond their control. More specifically, we follow Gabaix (2020) and the microfoundation discussed therein, and assume that when agents anticipate the future, they shrink their expectations toward a benchmark represented by the economy's steady state.

Formally, for any variable X_t that agents take as given during optimization, the perceived equilibrium law of motion is

$$X_{t+1} - X = m \mathbf{G}^X(\mathbf{X}_t - \mathbf{X}, \epsilon_{t+1}), \quad (7)$$

where \mathbf{X}_t is a vector of aggregate state variables, ϵ_t is a vector of mean-zero innovations to stochastic processes driving economic fluctuations, \mathbf{G}^X is the equilibrium aggregate policy function for variable X_t , and where variables without time subscripts indicate steady state values, with $0 \leq m \leq 1$ denoting a cognitive discounting parameter. The specification nests the standard case of rational expectations, which readily obtains for $m = 1$, with lower values of m making agents myopic in that they expect future macroeconomic conditions to revert back to the steady state faster.

It is important to stress that agents misperceive laws of motion of variables beyond their individual control. More specifically, and as in Woodford (2013), households and firms correctly perceive the constraints defining their individual problems, and hence their decisions are optimal, conditional on subjective beliefs about the future evolution of variables that they take as given.

2.4. Monetary Authority

Unless indicated otherwise, the monetary authority follows a standard Taylor-like feedback rule

$$i_t = \rho i_{t-1} + (1 - \rho) [i + \phi_\pi (\Pi_t - \Pi) + \phi_y \log(Y_t/Y)] + \nu_t, \quad (8)$$

where $0 \leq \rho < 1$ controls the degree of interest rate smoothing, ϕ_π and ϕ_y determine the reaction to deviations of inflation $\Pi_t \equiv P_t/P_{t-1}$ and output $Y_t \equiv Y_{H,t} + Y_{H,t}^*$ from their steady state levels, and ν_t denotes a monetary policy shock.

2.5. General Equilibrium

In equilibrium, all households make identical choices so that individual allocations are equal to aggregate per capita quantities, implying $C_t^h = C_t$, $N_t^h = N_t$, $B_t^{*,h} = B_t^*$, $B_t^h = B_t = 0$, where the last equality follows from the fact that bonds denominated in Home currency can only be traded by Home households.

Labor supplied by households must be equal to labor demand, leading to the following condition

$$N_t = \int_0^1 N_t^f df, \quad (9)$$

while goods market clearing requires

$$Y_{H,t} = C_{H,t}, \quad \text{and} \quad Y_{H,t}^* = \frac{1-\zeta}{\zeta} C_{H,t}^*. \quad (10)$$

3. Linearized Model for a Small Open Economy

3.1. Linear Approximation to Behavioral Discounting

For tractability, we consider a linearized version of the model defined in the previous section. As shown by Gabaix (2020), this simplifying assumption allows us to approximate behavioral k -period ahead expectations of any variable X_t that agents take as given during optimization as

$$\hat{\mathbb{E}}_t \{X_{t+k} - X\} = m^k \mathbb{E}_t \{X_{t+k} - X\}, \quad (11)$$

where \mathbb{E}_t is the rational expectations operator. As this formula reiterates, agents are myopic with respect to deviations from the – correctly perceived – steady state, particularly if those deviations occur in the distant future.

3.2. Linearized Equilibrium Conditions

When linearizing the model, we focus on the small open economy case, which obtains as the limit when $\zeta \rightarrow 0$. We also assume zero steady state inflation ($\Pi = 1$) and zero steady state net foreign assets ($B^* = 0$), which also implies $C = Y$. We define the following transformations: $\hat{i}_t \equiv \log(1 + i_t) - \log(\beta^{-1})$, $\hat{\pi}_t \equiv \log(\Pi_t)$, $\hat{B}_t^* \equiv (B_t^* Q_t - B^*)/Y$, with corresponding expressions for their Foreign analogs. All other ‘hat’ variables are defined as percent deviations from steady state, i.e. $\hat{X}_t \equiv (X_t - X)/X$.

Below we present and discuss the linearized equilibrium conditions. Let us reiterate here that agents are assumed to be myopic only about aggregate states (and hence prices), but not about their individual choices given these states. This means that deriving some of the equilibrium conditions is not straightforward. For example, it requires formulating the household-level consumption function that depends only on those (current and future) variables that are beyond control of individual agents. Only by doing this can we apply formula (11). We outline the key steps associated with the model derivation in Appendix A.

Solving the household problem results in the following modified IS curve

$$\hat{C}_t = m\mathbb{E}_t\hat{C}_{t+1} - \frac{1}{\sigma} \left(\hat{i}_t - m\mathbb{E}_t\hat{\pi}_{t+1} \right) + (1-m)\frac{1-\beta}{1+\frac{\sigma}{\mu\varphi}}\hat{B}_t^*. \quad (12)$$

The standard New Keynesian relationship can immediately be recovered by setting $m = 1$. If $m < 1$, expectations about future consumption and inflation are discounted, similarly to the closed economy New Keynesian model considered by Gabaix (2020).⁶ Notably, however, the move to an open economy setup is associated with an extra term in the behavioral IS curve, which now additionally depends on the country's net foreign asset position. This term crops up because Equation (12) is derived using subjectively optimal consumption plans. More specifically, agents do not apply discounting to their individual choices, i.e. $\mathbb{E}_t\hat{B}_{t+k}^{*,h} \neq m^k\mathbb{E}_t\hat{B}_{t+k}^{*,h}$ for $k \geq 1$, but do it only when forming expectations about variables beyond their control. In particular, they correctly predict their future consumption and accumulated assets *conditional on* expectations about future prices, and only have distorted views about the latter. As a result, following an asymmetric positive income shock that Home households want to smooth over by increasing foreign bond holdings (net foreign assets in aggregate), the equilibrium response of consumption will be bigger than it would have been without the final term in Equation (12).⁷

Relatedly, optimal bond holdings of myopic households can be shown to imply an uncovered interest rate parity (UIP) condition

$$\hat{i}_t - m\mathbb{E}_t\{\hat{\pi}_{t+1}\} = \hat{i}_t^* - m\mathbb{E}_t\{\hat{\pi}_{t+1}^* - \hat{Q}_{t+1}\} - \hat{Q}_t - \phi\hat{B}_t^* + \varrho_t, \quad (13)$$

where $\phi = \Phi'(0,0)$. Again, a standard risk premium-augmented UIP condition obtains for $m = 1$.

Optimal price setting by myopic firms leads to the following Phillips curve for domestic prices

$$\hat{\pi}_{H,t} = m\beta\mathbb{E}_t\{\hat{\pi}_{H,t+1}\} + \kappa\hat{M}C_t, \quad (14)$$

where $\kappa \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta}$, and which collapses to the canonical New Keynesian Phillips curve for $m = 1$ (see also A.4 for details).

The remaining equilibrium conditions are not affected by discounting. In particular, the real marginal cost, deflated by the producer price index is

$$\hat{M}C_t = \sigma\hat{C}_t + \varphi\hat{Y}_t + \frac{\alpha}{1-\alpha}\hat{Q}_t - (1+\varphi)\hat{z}_t, \quad (15)$$

⁶In his baseline formulation, and for reasons alluded to in footnote 17, Gabaix (2020) assumes that agents correctly perceive the ex ante real interest rate, which means that expected inflation in Equation 12 is not discounted. Crucially, none of our main findings hinge on whether we follow Gabaix in assuming that the current real interest rate is “special” and perceived without bias, or if we instead treat it in line with all other variables beyond an agent's control, as implicit in Equation 12.

⁷See also A.3 for more details and Appendix C for a discussion of how this result is modified when markets are complete so that accumulation of net foreign assets becomes irrelevant.

the consumer price inflation (CPI) is given by

$$\hat{\pi}_t = \hat{\pi}_{H,t} + \frac{\alpha}{1-\alpha} (\hat{Q}_t - \hat{Q}_{t-1}), \quad (16)$$

while the aggregate goods market clearing condition can be written as

$$\hat{Y}_t = (1-\alpha)\hat{C}_t + \alpha\hat{Y}_t^* + \eta \frac{\alpha(2-\alpha)}{1-\alpha} \hat{Q}_t. \quad (17)$$

Aggregating the budget constraints of all Home agents leads to the following law of motion for net foreign assets

$$\hat{B}_t^* = \beta^{-1} (\hat{B}_{t-1}^* + \hat{Y}_t - \hat{C}_t). \quad (18)$$

Finally, the linearized version of the monetary policy rule (8) is

$$\hat{i}_t = \rho \hat{i}_{t-1} + (1-\rho)(\phi_\pi \hat{\pi}_t + \phi_y \hat{Y}_t) + \nu_t. \quad (19)$$

Equations (12)–(19) jointly define the equilibrium evolution of \hat{Y}_t , \hat{C}_t , $\hat{\pi}_t$, $\hat{\pi}_{H,t}$, $\hat{M}C_t$, \hat{Q}_t , \hat{i}_t , \hat{B}_t^* , driven by productivity shocks z_t , monetary policy shocks ν_t , risk premium shocks ϱ_t , and foreign variables \hat{Y}_t^* , $\hat{\pi}_t^*$, \hat{i}_t^* , which are exogenous from the Home country perspective (on account of the SOE assumption).

For given foreign productivity shocks z_t^* and monetary shocks ν_t^* , equilibrium conditions characterizing the evolution of foreign output, inflation and interest rates are then given by

$$\hat{Y}_t^* = m\mathbb{E}_t \hat{Y}_{t+1}^* - \frac{1}{\sigma} (\hat{i}_t^* - m\mathbb{E}_t \hat{\pi}_{t+1}^*), \quad (20)$$

$$\hat{\pi}_t^* = m\beta\mathbb{E}_t \{\hat{\pi}_{t+1}^*\} + \kappa(\sigma + \varphi) (\hat{Y}_t^* - \hat{z}_t^*), \quad (21)$$

$$\hat{i}_t^* = \rho \hat{i}_{t-1}^* + (1-\rho)(\phi_\pi \hat{\pi}_t^* + \phi_y \hat{Y}_t^*) + \nu_t^*. \quad (22)$$

These equations follow from the same principles as in the Home economy, but additionally account for the fact that the Foreign economy can be treated as closed.

3.3. Estimation

To investigate the implications of behavioral discounting in an open economy, we shall combine closed-form derivations – which help account for results of stylized experiments – with numerical simulations designed to shed light on more analytically-involved questions. For the latter, we will need to assign numerical values to model parameters. To that end, we perform a full Bayesian estimation of the model, more details on which are provided in Appendix D. Broadly, the Home and Foreign economies are represented by Canada and the US, respectively. We use standard macroeconomic time series (output, inflation, short-term interest rate) for each of the two countries as well as their bilateral exchange rate. Our baseline sample of quarterly data covers the period 1972-2007, but we also verify the

robustness of our results by using a subsample starting in 1982 (so that it excludes the Great Inflation), and an extended sample that ends in 2019 (so that it includes the Great Recession and its aftermath up to the COVID-19 pandemic).

As is standard in the DSGE literature, we fix the subset of parameters that can be pinned down by long-term averages observed in the data, or which are weakly identified when using standard macroeconomic time series. We make the economy fairly open by setting the import share parameter α equal to 0.4. The discount factor β is calibrated to 0.99, which, for zero average inflation, implies a steady state nominal interest rate of 4 per cent per annum. The steady state markup in the goods market μ is set equal to 1.2. We set the slope of the risk premium in the UIP condition ϕ to a relatively small value of 0.01.⁸ As discussed subsequently, this value is sufficient to induce stationarity for empirically relevant degrees of myopia.

We center the prior distributions of the remaining parameters on values used by Gali and Monacelli (2005), except that we choose a higher value of the Calvo probability to make our model consistent with more recent empirical evidence on the slope of the Phillips curve. The tightness of the prior distributions is motivated by the DSGE literature that estimates open economy models (see, e.g., Adolfson et al., 2007; Justiniano and Preston, 2010). Most importantly, the cognitive discounting parameter m is assumed to follow a beta distribution with mean 0.8 and standard deviation of 0.07. The mode of the prior hence implies that an innovation materializing in a year's time would affect decision rules by about half as much as a contemporaneous one (as chosen by Gabaix, 2020). This choice can be considered a fairly conservative take on the degree of myopia.⁹

Table 1 summarizes the key results of Bayesian estimation. Comparing the first two columns reveals that the marginal likelihood is significantly improved for the behavioral open economy model relative to its rational benchmark (obtained by fixing m at 1). Moreover, the posterior distribution of the myopia parameter m is significantly shifted from the prior, with the posterior mean coming in as low as 0.68 for our baseline model. As the marginal posterior distribution of this parameter is left skewed, which reflects the shape of the prior distribution that we tilt towards the rational benchmark, the posterior median is somewhat higher but still indicates a large deviation from rationality. The high empirical relevance of behavioral discounting is further supported by an alternative specification, in which we increase the standard deviation of the prior distributions of all estimated parameters by a half, keeping the means unchanged, so that the posterior estimates are more influenced by

⁸In models with debt-elastic UIP premia like ours, ϕ can also be interpreted as a measure of FX market depth, see Gabaix and Maggiori (2015). The assumed value of 0.01 is consistent with fairly deep markets that typically characterize advanced economies, in line with evidence presented in Chen et al. (2023). As that paper shows, ϕ can be significantly higher for emerging market economies.

⁹Empirical estimates of the Euler equation by Fuhrer and Rudebusch (2004) are consistent with an m of 0.65. Relatedly, Gust et al. (2022) estimate a closed economy New Keynesian model with a finite planning horizon as in Woodford (2019), and arrive at discounting in the IS curve close to 0.5. Brzoza-Brzezina et al. (2025) estimate a two-country behavioral model for Poland and the euro area, obtaining $m = 0.68$. Ilabaca et al. (2020) allow for a different degree of behavioral discounting by households and firms, estimating corresponding values of m equal to 0.71 and 0.41, respectively.

Table 1: **Estimation Results**

		RATIONAL ($m = 1$)	BEHAVIORAL	INFLATED PRIORS
Prior m	Mean	-	0.80	0.80
	Std.	-	0.07	0.10
Posterior m	Mean	-	0.68	0.62
	Median	-	0.69	0.64
	[5%, 95%]	-	[0.54, 0.83]	[0.37, 0.81]
Log Marginal Likelihood		-1075.4	-1050.6	-1020.5

the data. In this case, fit is further improved and the mean and median estimates of m shift away from unity even more.¹⁰

4. Exchange Rate Puzzles

The estimates presented in the previous section are based on models that allow for an exogenous shock to the UIP risk premium. Itskhoki and Mukhin (2021) argue that this type of shocks is key to resolve a number of puzzles associated with the exchange rate, including its relationship with the interest rate differential. However, even though we use all these variables as observable when estimating our models, and despite the presence of UIP shocks, our results speak strongly in favor of sizable myopia. This suggests that the framework we propose may offer a complementary explanation of UIP-related puzzles relative to that advocated by Itskhoki and Mukhin (2021).¹¹ To check if this is indeed the case, we investigate the extent to which we can mitigate the puzzles without relying on UIP-premium shocks. We focus on three now classical results: forward premium puzzle of Fama (1984), the predictability reversal puzzle (Bacchetta and van Wincoop, 2010), and the Engel puzzle (Engel, 2016). Additionally, we consider Galí's (2020) exchange rate forward puzzle, which cannot be explained by exogenous UIP shocks. As is typically done in the literature, and mainly for expositional purposes, we present the intuition conditional on monetary shocks, though we note that very similar results obtain for productivity and cost-push shocks as well.

As discussed in Section 3, our approach implies a standard risk-adjusted uncovered interest rate parity condition, except for the fact that the expectation operators appearing

¹⁰Increasing the standard deviation of the prior distribution of m in a way that preserves its mean can lead to bimodality in the posterior distribution. This bimodality vanishes if we assume a symmetric prior distribution, i.e., center it on 0.5 rather than closer to the rational benchmark. The resulting posterior estimate of this parameter then becomes even lower than reported in Table 2.

¹¹This conclusion is reinforced by the outcomes of global sensitivity analysis (Ratto, 2008) of our model, which indicates that smaller values of m are particularly crucial for the fit of the exchange rate series (and also for domestic inflation, in line with the literature estimating closed economy models with behavioral discounting).

in it are behavioral rather than rational. Once these behavioral terms are reexpressed as a function of their rational equivalents and the exogenous UIP premium is dropped, we arrive at the following “behavioral” UIP condition, which simply rewrites Equation (13) for $\varrho_t = 0$

$$\hat{i}_t - \hat{i}_t^* = m\mathbb{E}_t\{\Delta\hat{\varepsilon}_{t+1}\} - (1 - m)\hat{Q}_t, \quad (23)$$

and where we define $\hat{i}_t^* \equiv \hat{i}_t^* - \phi\hat{B}_t^*$ as the foreign nominal interest rate adjusted by the endogenous component of the risk premium.¹² We will make extensive use of this formula when explaining why our model can significantly mitigate the extent of the aforementioned puzzles.

4.1. Forward Premium Puzzle

Under uncovered interest rate parity, the domestic currency is expected to depreciate if the home interest rate exceeds the foreign. As alluded to above, however, Fama (1984) famously showed that this simple prediction is at odds with the data, where high interest currencies tend to offer higher returns. We now investigate whether our behavioral model can help account for this feature of the data.

The UIP condition ((23)) in our behavioral model points to two opposing forces affecting the forward premium. On the one hand, the fact that the expected future depreciation is discounted tends to generate lower returns on high-interest currencies, thus deepening the Fama puzzle. On the other hand, the premium will be affected by the comovement between interest rates and the real exchange rate, which is typically negative and hence acts in the opposite direction.

To move beyond such qualitative statements and to compare the relative contributions of both terms, we first rewrite the UIP condition as

$$\mathbb{E}_t\{\Delta\hat{\varepsilon}_{t+1}\} = \frac{1}{m}(\hat{i}_t - \hat{i}_t^*) + \left(\frac{1}{m} - 1\right)\hat{Q}_t. \quad (24)$$

This formulation is designed to resemble “Fama (1984) regressions” typically used to document the forward premium puzzle, i.e.,

$$\Delta\hat{\varepsilon}_{t+1} = a_0 + a_1(\hat{i}_t - \hat{i}_t^*) + \epsilon_t, \quad (25)$$

where ϵ_t is the regression residual. It is well known that empirical estimates of this equation suggest values of the slope coefficient a_1 that is close to zero, or even negative, while standard UIP counterfactually implies $a_1 = 1$.

If we estimated Equation (25) using data simulated from our behavioral model, the

¹²We define the “premium adjusted” nominal interest rate for analytical convenience as it allows us to write the UIP condition in its canonical form. Note that, since we calibrate ϕ to be small, \hat{i}_t^* is very close to \hat{i}_t^* . We have verified that all results presented further in this section, and which use the “premium adjusted” foreign rate, are very similar to those obtained without such an adjustment.

expected value of the a_1 coefficient would be

$$\begin{aligned}\mathbb{E}a_1 &= \frac{1}{m} + \left(\frac{1}{m} - 1\right) \frac{\mathbb{E}\left\{\hat{Q}_t(\hat{i}_t - \hat{i}_t^*)\right\}}{\mathbb{E}\left\{(\hat{i}_t - \hat{i}_t^*)^2\right\}} \\ &= \frac{1}{m} + \left(\frac{1}{m} - 1\right) \text{Corr}\left\{\hat{Q}_t, \hat{i}_t - \hat{i}_t^*\right\} \frac{\text{Std}\left\{\hat{Q}_t\right\}}{\text{Std}\left\{\hat{i}_t - \hat{i}_t^*\right\}},\end{aligned}\quad (26)$$

where we have combined the population regression and omitted variable bias formulas. We first observe that, for $m = 1$, the second term vanishes and so $\mathbb{E}a_1 = 1$, replicating the original forward premium puzzle. We also see that as m becomes lower than unity, the first term pushes the model-implied regression coefficient above one, exacerbating the puzzle. However, this effect can be more than offset by the second term if it is sufficiently negative. This is typically the case, especially conditional on monetary shocks as they imply that the real exchange rate is almost perfectly negatively correlated with the interest rate differential.

Indeed, as we show in Table 2, the posterior mean parameter values obtained by estimating our baseline behavioral model bring the Fama coefficient down to 0.61, which can be considered a significant improvement over the rational expectations benchmark. Bearing in mind that the empirical estimates typically find this coefficient to be close to zero, we can go as far as half-way towards resolving the forward premium puzzle if we consider our model estimation with inflated priors, since it implies an even higher degree of behavioral discounting (i.e., lower m).

Table 2: **Fama Regression Coefficients**

MODEL	m	ρ	FAMA COEFF.
Rational	1.00	0.87	1.00
Baseline	0.68	0.86	0.61
Inflated priors	0.62	0.86	0.53
Baseline, low ρ	0.68	0.75	0.75
Baseline, high ρ	0.68	0.95	0.35

More generally, and as is clear from Equation (26), the extent to which behavioral discounting helps address the Fama puzzle crucially depends not only on the value of m , but also on the variability of the real exchange rate relative to that of the interest rate. The last two rows in Table 2 document this model property by recomputing the expected value of the slope coefficient a_1 for alternative values of the interest rate smoothing parameter ρ , keeping all other parameters at their baseline posterior means. A large degree of behavioral discounting is capable of generating particularly low values of the Fama coefficient if it is coupled with high interest rate smoothing. Intuitively, the reason why such parameter

combinations perform well is because higher values of smoothing decrease the volatility of interest rates relative to the real exchange rate. This, in turn, occurs because real exchange rates depend on the whole future path of interest rates, and the fact that these become positively autocorrelated under greater smoothing tends to amplify the variance of the sum (i.e., makes it exceed the sum of individual variances by more).

4.2. Predictability Sign Reversal Puzzle

We next turn to Engel-style regressions and discuss our model's ability to match the empirical patterns documented in Bacchetta and van Wincoop (2010) and confirmed in real form by Engel (2016). To that effect, we focus on regressions specified as

$$r_{t+1}^x \equiv \hat{i}_t - \hat{i}_t^* - \Delta \hat{\varepsilon}_{t+1} = b_{s,0} + b_{s,1} (\hat{i}_{t-s} - \hat{i}_{t-s}^*) + \epsilon_t, \quad (27)$$

where $s = 0, 1, \dots$ ¹³ As first shown by Bacchetta and van Wincoop (2010), the coefficient $b_{s,1}$ turns from positive to negative in the data for some s . Engel (2016) additionally argues that the data satisfy an even stronger requirement, namely that $Cov \left\{ \mathbb{E}_t \sum_{s=0}^{\infty} r_{t+s+1}^x, \hat{i}_t - \hat{i}_t^* \right\} < 0$, which can be shown to be equivalent to $\sum_{s=0}^{\infty} b_{s,1} < 0$. An immediate implication of this condition (Engel condition henceforth) is that the *level* of the high-yielding country's exchange rate is stronger than implied by UIP, or, expressed alternatively, that exchange rate volatility exceeds what could be predicted based on the simple uncovered interest rate parity condition.

To relate our open economy behavioral model to these stylized facts, Figure 1 provides an overview of its key implications. Specifically, for the different model variants defined when discussing the forward premium puzzle, the left panels show the model-implied $b_{s,1}$ coefficients as a function of s (x-axis). Given the equivalence between $Cov \left\{ \mathbb{E}_t \sum_{s=0}^{\infty} r_{t+s+1}^x, \hat{i}_t - \hat{i}_t^* \right\} < 0$ and infinite sums of $b_{s,1}$ appearing in the Engel condition, the right-hand panels additionally plot the cumulative sums $\sum_{s=0}^T b_{s,1}$ for values of T ranging from 0 to 500.

The first row of Figure 1 confirms two important findings. First, and as shown in the left panels, cognitive discounting is capable of generating sign reversals in Engel regression coefficients. We see, in particular, that $b_{s,1}$ eventually becomes negative for both estimated versions of the behavioral model, but not for the rational expectations (RE) case. It thus appears that the RE model's inability to match the sign reversal findings of Bacchetta and van Wincoop (2010) is a knife-edge result specific to "full rationality". Second, and as made clear by the right panels, the behavioral model can account for Engel's excess volatility puzzle.

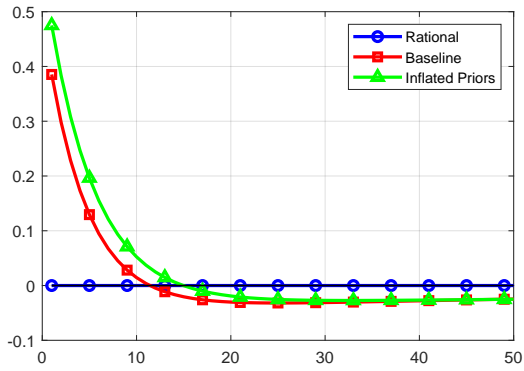
To build intuition for these findings, we start by expressing excess returns as

$$\mathbb{E}_t r_{t+1}^x \equiv \hat{i}_t - \hat{i}_t^* - \mathbb{E}_t \{ \Delta \hat{\varepsilon}_{t+1} \} = (m-1) \mathbb{E}_t \left\{ \hat{Q}_{t+1} + \hat{\pi}_{t+1} - \hat{\pi}_{t+1}^* \right\}. \quad (28)$$

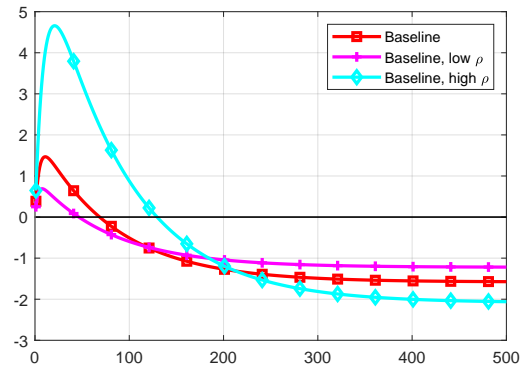
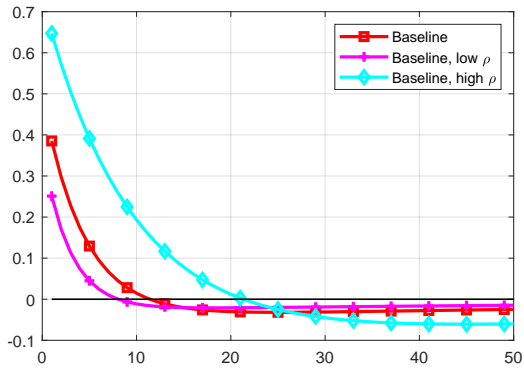
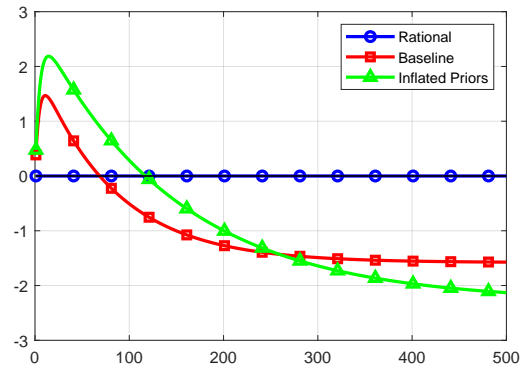
¹³Note that for $s = 0$ the above is equivalent to a Fama-type regression (Equation 25), in which $b_{0,1} = 1 - a_1$.

Figure 1: Engel Regression Results

(a) Engel Coefficients



(b) Cumulative Sums of Engel Coeffs.



Note: The left panels show Engel regression coefficients, i.e., $b_{s,1}$ from Equation (27), as a function of s , using various versions of the estimated regression model (first row) or the baseline behavioral model with alternative assumptions on the interest rate smoothing coefficient ρ . The right panels plot the corresponding cumulative sums $\sum_{s=0}^T b_{s,1}$ for T ranging from 0 to 500.

We first note that the real exchange rate depreciates persistently in response to a domestic policy tightening. This initially leads to a decumulation of net foreign assets on account of lower price competitiveness. However, the real exchange rate must eventually depreciate relative to its steady state to facilitate the accumulation of net foreign assets, allowing them to converge to the steady state. We note that, as per Equation (28), excess returns depend negatively on the real exchange rate if agents are myopic ($m < 1$). Accordingly, the evolution of this premium will reflect the adjustment process that we described above, i.e., an increase in the interest rate differential will initially lead to a persistent exchange rate appreciation and an increase in excess returns, followed by a depreciation and a fall in excess returns below zero. Which is precisely the sign reversal documented in Figure 1.

The second row of panels in Figure 1 presents the sensitivity of these results to different values of the interest rate smoothing coefficient in the monetary policy rule. The higher is ρ , the more delayed the sign reversal. The intuition behind this result is closely related to the argument of Bachetta and van Wincoop (2021), who show that – in their gradual portfolio adjustment model – the Engel condition may be violated whenever interest rate inertia is very high. This is because higher interest rate autocorrelation amplifies the initial response of excess returns, which also inherit some of the underlying persistence, the confluence of which implies that they may not be offset by future reversals. Notably, however, in our behavioral model even a high value of ρ eventually generates the sign reversal in excess returns, at least for the estimated value of behavioral discounting.

4.3. Exchange Rate Forward Guidance Puzzle

We now discuss the exchange rate forward guidance puzzle identified by Galí (2020), who showed that the interest rate differentials in the near (distant) future have much larger (smaller) effects on the real exchange rate (RER) than what would be implied by the standard UIP condition. It is important to note that this puzzle is robust to the presence of a time-varying exogenous risk premium, and hence cannot be resolved by the approach advocated in Itskhoki and Mukhin (2021).

To investigate how behavioral discounting affects this puzzle, we can iterate forward on the UIP condition (13), so that we arrive at

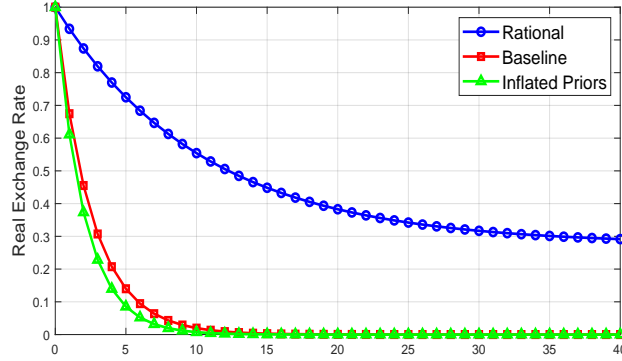
$$\hat{Q}_t = -\mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t} \left(\hat{r}_T - \hat{r}_T^* + \phi \hat{B}_T^* \right), \quad (29)$$

where we have defined Home and Foreign real interest rates as $\hat{r}_t \equiv \hat{i}_t - m\mathbb{E}_t \hat{\pi}_{t+1}$ and $\hat{r}_t^* \equiv \hat{i}_t^* - m\mathbb{E}_t \hat{\pi}_{t+1}^*$. The responses of the real exchange rate to exogenous changes in the Home real interest rate at different horizons are also depicted in Figure 2. Our presentation closely follows that of Gabaix (2020) for inflation, i.e., we shall obtain valuable insights into how monetary policy and forward guidance propagate by studying the impact of real interest rate changes in selected periods, while holding their values fixed at all other horizons.¹⁴ Both

¹⁴We normalize by dividing through the response to an unanticipated shock at horizon zero.

the formula and the figure make it immediately apparent that cognitive discounting dampens the effects of future real interest rate changes on the current exchange rate, making them less relevant the longer the horizon. In so doing, the move from rational expectations to behavioral discounting thus appears to immediately address one of the two key elements of the exchange rate forward guidance puzzle.

Figure 2: **Effects of Forward Guidance on the Real Exchange Rate**



Note: This figure shows the normalized initial response of the real exchange rate as a function of forward guidance horizon.

It is worth noting that the RER response depicted in Figure 2 is declining in forward guidance horizon at a rate *faster* than m , and even absent discounting (e.g., the blue line corresponding to $m = 1$ decays instead of being flat). This arises because of the endogenous response of net foreign assets, which compresses the premium-adjusted interest rate differential. Crucially, net foreign assets respond differently at different forward guidance horizons, even for $m = 1$.

To see why, it proves useful to iterate forward on the consumption Euler condition (Equation 12) to obtain the following relationship

$$\hat{C}_t = -\frac{1}{\sigma} \mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t} \hat{r}_T + (1-m) \frac{1-\beta}{1+\frac{\sigma}{\mu\varphi}} \mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t} \hat{B}_T^*. \quad (30)$$

Absent discounting, and because we fix $\hat{r}_t = 0$ at all horizons except for the forward guidance horizon H , the expression simplifies to

$$\hat{C}_t = \begin{cases} \forall t \leq H : & -\frac{1}{\sigma} \hat{r}_H, \\ \forall t > H : & 0. \end{cases}$$

We thus see that the initial response of consumption does not depend on H , and that consumption remains elevated at that higher level for the entire duration of forward guidance. For example, an anticipated 1pp decrease in the real interest rate ten periods ahead (holding real rates in all other periods unchanged) implies that consumption will be $\frac{1}{\sigma}$ percent

above the steady state level for exactly eleven periods. As we shall discuss below, a similar relationship can be derived for output (see Equation 35), with the crucial difference that, for realistic calibrations, the interest rate elasticity exceeds $\frac{1}{\sigma}$. This means that the longer the horizon of an anticipated decrease in the real interest rate, the longer the period over which the economy generates trade surpluses. This translates into larger NFA accumulation and lower premium-adjusted future interest rate differentials, thus helping mitigate the exchange rate forward guidance puzzle, even under rational expectations. Importantly, however, in that case the forward guidance puzzle is still present and future policy announcements remain very potent even at distant horizons. This is because the blue line corresponding to $m = 1$ does not asymptote to zero but eventually stabilizes somewhat below 0.3.

4.4. The Role of Market Incompleteness

As has become standard in the NOEM literature, our model assumes that international financial markets are incomplete. We now discuss how the results presented so far change if we adopt a less realistic, but analytically more tractable, complete markets setup.

The key implication of complete markets is that the perfect international risk sharing condition holds. Using our notation, it can be written in log-linear form as

$$\sigma (\hat{C}_t - \hat{C}_t^*) = \hat{Q}_t. \quad (31)$$

Note that this relationship is not affected by myopia as long as subjective probabilities of future states are the same for all agents, which we have assumed throughout. Further, as we show in Appendix C, the last term in the IS curve (12) vanishes when markets are complete, leading to

$$\hat{C}_t = m\mathbb{E}_t\hat{C}_{t+1} - \frac{1}{\sigma} \left(\hat{i}_t - m\mathbb{E}_t\hat{\pi}_{t+1} \right). \quad (32)$$

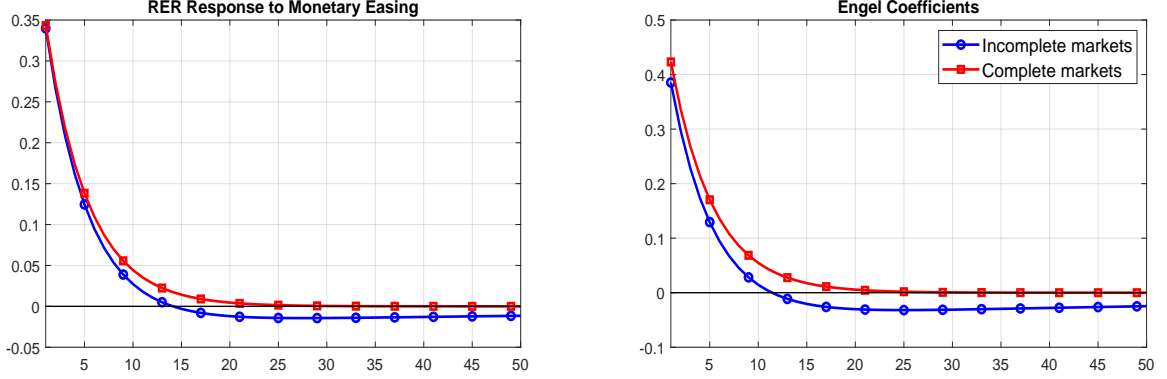
Combining the modified IS curve and its Foreign analog with the risk sharing condition (31) yields the following UIP relationship

$$\hat{i}_t - m\mathbb{E}_t\{\hat{\pi}_{t+1}\} = \hat{i}_t^* - m\mathbb{E}_t\{\hat{\pi}_{t+1}^* - \hat{Q}_{t+1}\} - \hat{Q}_t, \quad (33)$$

which is like formula (13) in our baseline model except for the stationarizing risk premium component $\phi\hat{B}_t^*$ no longer being present. As ϕ is assumed small, we can expect behavioral discounting to help address UIP-related anomalies also when markets are complete. Indeed, this version of our model implies Fama regression coefficients very similar to those reported in Table 2 for the incomplete markets setup and it still helps mitigate the exchange rate forward guidance puzzle.

However, market incompleteness turns out to be key in the context of the predictability sign reversal puzzle. The explanation is linked to the role played by the exchange rate in restoring the long-run equilibrium, which we described in Section 4.2, and which we additionally illustrate in Figure 3. As the figure demonstrates, when markets are incomplete, net foreign asset accumulation driven by the initially-weak exchange rate must eventually be reversed, allowing the trade balance to deteriorate. As indicated by formula (28), this

Figure 3: Engel Regression Results – Role of Market Incompleteness



Note: The left panel shows the impulse response of the real exchange rate to a 25bp (100 bp annualized) negative monetary policy shock, expressed in percent deviation from the steady state. The numbers are generated using the posterior mean parameter values from the baseline estimation of the model. The right panel shows the corresponding Engel regression coefficients, i.e., $b_{s,1}$ from Equation (27), as a function of s .

is exactly what flips the excess return sign. While the former relationship still holds in the complete markets case, net foreign assets no longer play a role in equilibrium exchange rate dynamics, which eliminates the flip in the exchange rate and excess returns.

5. Output and Inflation Forward Guidance Puzzle

We now investigate the impact of discounting on the transmission of future monetary policy announcements to two other macroeconomic variables, namely output and inflation, highlighting the role played by openness.

5.1. Output

Combining the consumption Euler Equation (12) with the resource constraint (17) and the UIP condition (13), ignoring the exogenous component of the risk premium, and using the small open economy assumption to eliminate foreign variables, allows us to derive an IS curve for output¹⁵

$$\hat{Y}_t = m\mathbb{E}_t\hat{Y}_{t+1} - \left(\frac{1-\alpha}{\sigma} + \eta \frac{\alpha(2-\alpha)}{1-\alpha} \right) \hat{r}_t - \left[\eta \frac{\alpha(2-\alpha)}{1-\alpha} \phi \hat{B}_t^* - (1-m)(1-\alpha) \frac{1-\beta}{1+\frac{\sigma}{\mu\varphi}} \right] \hat{B}_t^*. \quad (34)$$

¹⁵See also Appendix B for details of the derivation.

Iterating forward on this equation yields

$$\hat{Y}_t = - \left(\frac{1-\alpha}{\sigma} + \eta \frac{\alpha(2-\alpha)}{1-\alpha} \right) \mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t} \hat{r}_T - \left[\eta \frac{\alpha(2-\alpha)}{1-\alpha} \phi - (1-m)(1-\alpha) \frac{1-\beta}{1 + \frac{\sigma}{\mu\varphi}} \right] \mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t} \hat{B}_T^*, \quad (35)$$

where the closed economy case readily obtains by setting $\alpha = 0$ and imposing $\hat{B}_t^* = 0$ for all t .

Initially focusing on the first line allows us to derive some key predictions. First we observe that, relative to a closed economy, the same change in the real interest path will have a stronger direct effect on output, unless trade elasticity η is very low. More specifically, the formal criterion for the real interest rate to be more powerful can be stated as

$$\eta > \frac{1-\alpha}{2-\alpha} \sigma^{-1} \geq \frac{1}{2} \sigma^{-1},$$

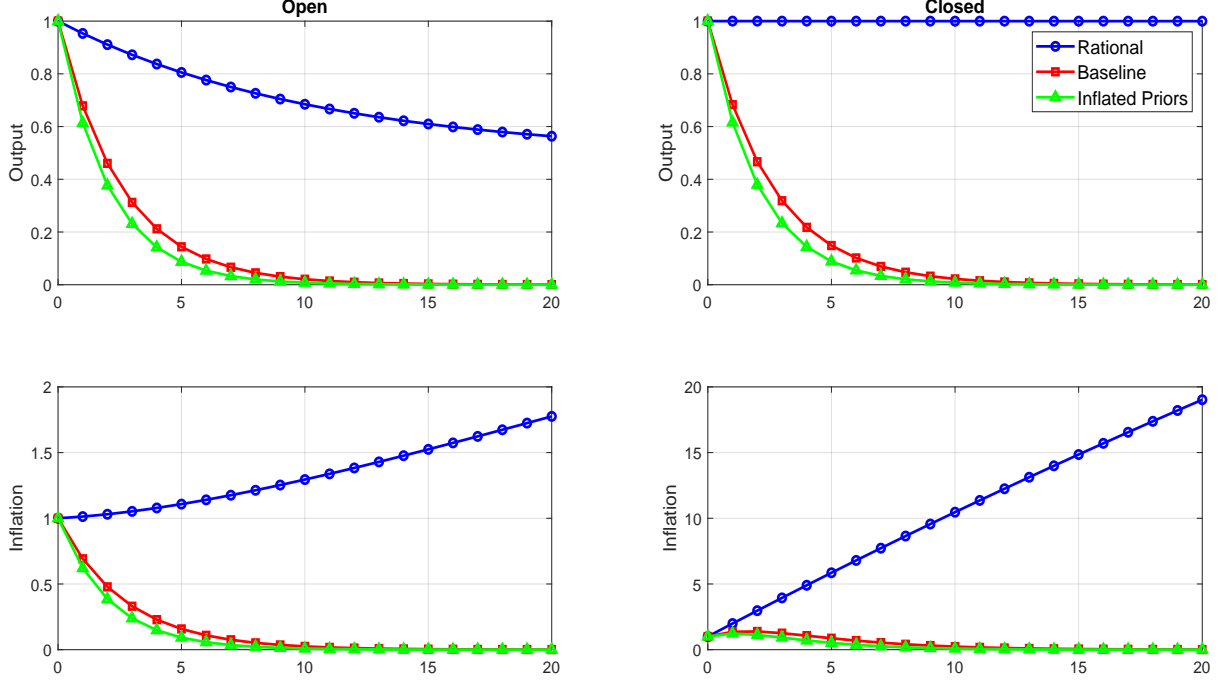
which is satisfied by the posterior mean in all model versions that we estimate, and which also holds more broadly when one takes into account typical parameterizations used in the open economy macroeconomic literature, including papers allowing for low trade elasticity.¹⁶ In addition, and in line with the closed economy case, discounting dampens the effects of real interest rate changes occurring further into the future, helping mitigate the output part of the FGP.

The effect of behavioral discounting on the initial response of output to current and future real interest rate changes is depicted in the first row of Figure 4, where we follow the presentation strategy from Section 4.3. The chart clearly shows that behavioral discounting allows for a decay of FG efficiency (as a function of its horizon), both in open and closed economies.

The differences between the open and closed economy cases can be traced back to the endogenous net foreign asset response, i.e., the second line of Equation (35) (which is absent in the closed economy case, in which $B_t^* \equiv 0$). Following a pattern similar to the one described before, a longer FG horizon leads to greater accumulation of net foreign assets, which tends to depress output. The latter follows from the fact that the term in the square brackets is typically positive. Overall, and in line with Figure 4, the rate of decay is faster in an open economy, which actually also holds absent discounting. Crucially, however, in the fully rational case, FG remains very efficient over very long horizons as the blue line does not go down to zero, but rather asymptotes at around 0.5, consistent with studies confirming the presence of the FGP also in rational expectations open economy models.

¹⁶See Bodenstein (2010) for a discussion of the consequences of low trade elasticity.

Figure 4: Effects of Forward Guidance: Open vs Closed Economy



Note: This figure shows the normalized initial response of output and inflation as a function of forward guidance horizon. The left panel represents the open economy with UIP premium of 0.01 and the right panel represents the closed economy.

5.2. Inflation

We now turn to the reaction of inflation, which is depicted in the second row of Figure 4. It is clear that, for this variable, the FGP is much less pronounced in an open economy, even without discounting. The reasons why may not appear immediately obvious, particularly as domestic inflation is the discounted sum of future marginal cost, and all its three endogenous components depend on the future path of real interest rates. In an open economy, however, inflation also depends on import prices, which are heavily influenced by the exchange rate.

After some algebra, where we drop terms independent of monetary policy and invoke the small open economy assumption that allows us to treat foreign rates as exogenous, we can characterize the relationship between inflation and domestic real rates as follows¹⁷

$$\hat{\pi}_t \approx -\frac{\kappa a}{\beta(1-m)} \mathbb{E}_t \sum_{T=t}^{\infty} \left[m^{T-t+1} - (\beta m)^{T-t+1} \right] \hat{r}_T - \frac{\alpha}{1-\alpha} \mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t} \hat{r}_T - \frac{\alpha}{1-\alpha} \hat{Q}_{t-1}, \quad (36)$$

¹⁷See Appendix B for full details of the derivation.

where we have defined

$$a \equiv \varphi \left(\frac{1 - \alpha}{\sigma} + \eta \frac{\alpha(2 - \alpha)}{1 - \alpha} \right) + \frac{1}{1 - \alpha},$$

and where the approximation comes from omitting several terms loading on NFA, which are quantitatively very small, and which would otherwise obscure the non-monotonic relationship between forward guidance horizon $T - t$ and inflation. In the limiting case $\beta \rightarrow 1$, we arrive at

$$\hat{\pi}_t \approx \underbrace{-\kappa a \mathbb{E}_t \sum_{T=t}^{\infty} (T - t + 1) m^{T-t} \hat{r}_T}_{\text{Domestic Marginal Cost}} - \underbrace{\frac{\alpha}{1 - \alpha} \mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t} \hat{r}_T - \frac{\alpha}{1 - \alpha} \hat{Q}_{t-1}}_{\text{Import Prices}}, \quad (37)$$

where the first term captures effects due to marginal cost, while the other one is related to the direct effects of exchange rates on prices of imported goods.

The key implications of Equation (37) are perfectly consistent with the patterns documented in Figure 4. In a closed economy, because the marginal cost component (the only one present in this case) is a product of exponential decay and linear growth, the relationship between the effect on inflation and FG horizon is linear for the rational model ($m = 1$), and possibly non-monotonic for the behavioral model (increasing and then decreasing).¹⁸ In an open economy, the picture is modified by the presence of the import price component, which does not grow with the FG horizon even for the rational case of $m = 1$, and decays very fast for $m < 1$, largely reflecting the strongly mitigating effect of myopia on the exchange rate FGP discussed in Section 4.3. As a consequence, the inflation component of the FGP is much less pronounced in an open economy, implying that the mitigating effect of discounting on this puzzle is also *relatively* smaller compared to the closed economy case.

6. International Monetary Policy Spillovers

As we shall show in this Section, our behavioral open economy model also features interesting implications for international monetary spillovers. To analyze these, we first combine the consumption Euler equation (12) with the resource constraint (17) and iterate on the outcome to arrive at

$$\hat{Y}_t = \underbrace{\alpha \hat{Y}_t^*}_{\text{Demand Channel}} + \underbrace{\eta \frac{\alpha(2 - \alpha)}{1 - \alpha} \hat{Q}_t}_{\text{Expenditure Switching Channel}} - \underbrace{\frac{1 - \alpha}{\sigma} \mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t} \hat{r}_T}_{\text{Endogenous Home Policy Response}} + \underbrace{(1 - m)(1 - \alpha) \frac{1 - \beta}{1 + \frac{\sigma}{\mu\varphi}} \mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t} \hat{B}_T^*}_{\text{Myopia "Damper"}}. \quad (38)$$

¹⁸This explains the hump shape also documented, though not accounted for, in Gabaix (2020).

The first two terms on the right hand side represent two traditional channels of international spillovers. The first one captures the positive effect of an increase in foreign output, and hence demand for the Home economy's exports. The second is associated with expenditure switching effects caused by the endogenous reaction of the real exchange rate. As the exchange rate appreciates when foreign interest rates go down, this channel acts in the opposite direction to the foreign demand channel, potentially more than offsetting the positive effects of an increase in foreign output.¹⁹ The third term describes the effects of an endogenous response of the Home real interest rate, highlighting the fact that any meaningful evaluation of international spillovers must condition on the monetary policy reaction of the recipient country. Finally, the last term shows up only under myopia, and will typically make the response of Home output to Foreign monetary easing smaller, as the net foreign asset position deteriorates due to an exchange rate appreciation that follows foreign monetary easing.

To provide more intuition on how behavioral discounting affects the size of spillovers, and in line with the preceding observation on their conditionality, we further assume that the Home monetary authority always keeps the real interest rate constant, so that the third term in Equation (38) disappears and the expenditure switching channel -- represented by the reaction of the real exchange rate -- becomes exogenous to the Home economy. Iterating the foreign IS curve (20) forward, substituting in the outcome for foreign output, using the UIP condition (29) to substitute for the real exchange rate, and finally dropping the exogenous component of the risk premium (as it is independent of foreign policy) yields

$$\hat{Y}_t \approx \underbrace{-\frac{\alpha}{\sigma} \mathbb{E}_t \sum_{T=t}^{\infty} m^{*T-t} \hat{r}_T^*}_{\text{Demand Channel}} + \underbrace{\eta \frac{\alpha(2-\alpha)}{1-\alpha} \mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t} \hat{r}_T^*}_{\text{Expenditure Switching Channel}}, \quad (39)$$

where the approximation comes from omitting terms depending on the net foreign asset position, which are quantitatively small and hence immaterial for this part of our results. Clearly, for given degree of myopia abroad m^* , behavioral discounting in the Home economy weakens the negative impact of the expenditure switching channel, and hence contributes to positive cross-country comovement in output conditional on foreign monetary shocks.

7. Stationarity and Determinacy

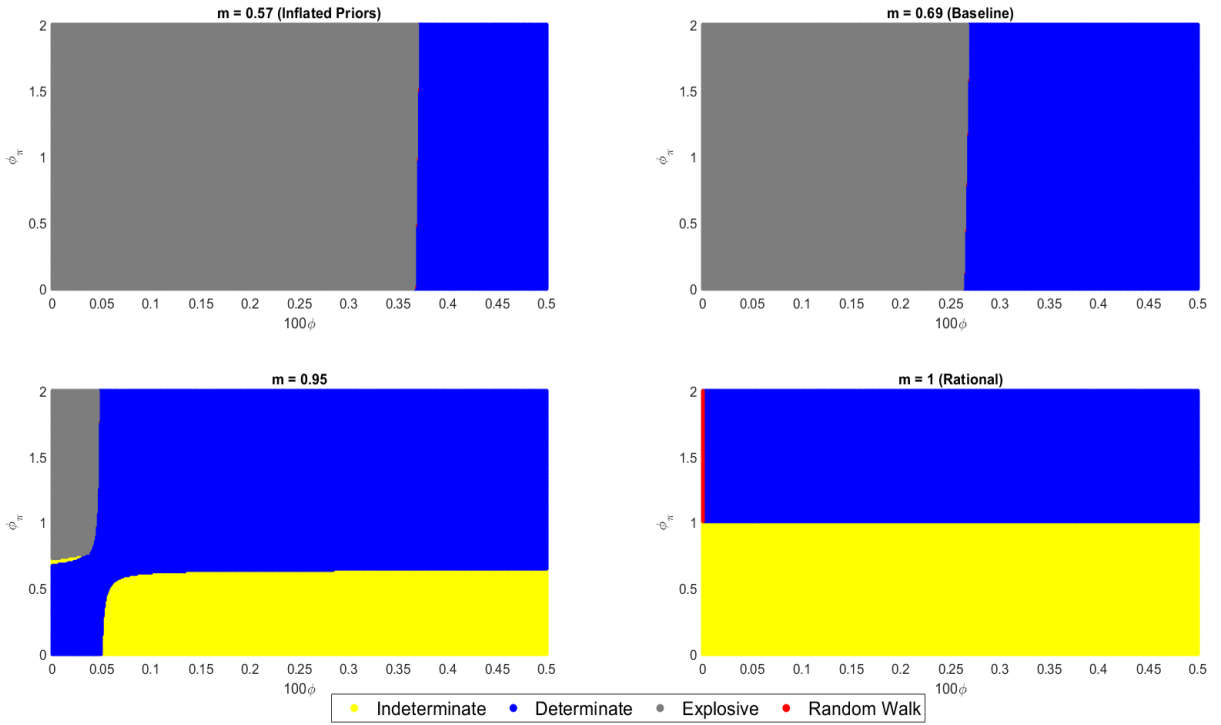
It is well understood that, in small open economy models with rational agents, the assumption of incomplete asset markets engenders stationarity issues (see also Schmitt-Grohe and Uribe, 2003).²⁰ Among several methods to induce stationarity considered in the NOEM literature, a debt-elastic risk premium on foreign bond holdings is by far the most popular

¹⁹Notably, for given reactions of foreign output and the real exchange rate, the relative importance of these two spillover channels does not depend on discounting.

²⁰The intuition is that when $m = 1$, and in the absence of a risk premium ($\phi = 0$), the Home real interest rate becomes tied to the (exogenous from the small economy's perspective) foreign real interest rate via the UIP condition 13. The IS curve 12 then implies that consumption has a unit root.

(Senhadji, 2003), and in our setup it is introduced by setting $\phi > 0$. It is also well known that standard New Keynesian models can generate sunspot equilibria when the interest rate does not respond sufficiently strongly to endogenous variables. For example, if the policy rate only reacts to inflation ($\phi_y = 0$), determinacy requires it to respond more than one-for-one to deviations of inflation from target ($\phi_\pi > 1$, Taylor principle). This canonical rational expectations case is illustrated in the bottom right panel of Figure 5, which demonstrates, in particular, that *any* positive risk premium ensures stationarity, while satisfying the Taylor principle guarantees uniqueness.

Figure 5: **Stationarity and Determinacy Regions**



Note: This figure shows the type of equilibrium in the linearized version of the model for different values of behavioral discounting m , UIP risk premium parameter ϕ , and monetary policy feedback to inflation ϕ_π . All other parameters are set to the posterior mean in our baseline estimation, except that we set $\phi_y = 0$.

As the remaining panels reveal, things change dramatically when agents are myopic. Two effects are at play. First of all, behavioral discounting exacerbates the stationarity problem. To see why, it is instructive to inspect Equation (12), which clarifies that, except for the final term and if the real interest rate is effectively exogenous from the home economy's perspective, the consumption path becomes *explosive* whenever $m < 1$. While the endogenous evolution of net foreign assets associated with the final term mitigates this effect somewhat, the associated feedback turns out to be too weak to induce stationarity. As a result, and for standard parameter values adopted in our calibration, the case for an additional stationar-

izing mechanism (such as the debt elastic premium, $\phi > 0$) becomes stronger when agents form behavioral rather than rational expectations. In addition, and unlike in the rational case, we cannot use an arbitrarily small positive ϕ to achieve stationarity. Intuitively, this is because myopic agents are less sensitive to future values of the risk premium, and so the responses of their consumption to temporary income shocks are too small to prevent boundless accumulation or decumulation of assets, *unless* ϕ is sufficiently large. This effect is stronger for higher degrees of myopia and can be observed in Figure 5 by noting that the explosive area tends to expand when m becomes smaller.

The second consideration – documented by Gabaix (2020) in a closed economy setup – is that behavioral discounting shrinks the indeterminacy region, so that a weaker response of the policy rate to inflation may suffice to eliminate sunspot equilibria. This effect can be clearly seen in Figure 5, where the area corresponding to indeterminacy decreases in line with the cognitive discounting parameter m . Moreover, Figure 5 reveals how the two considerations discussed above interact in a non-trivial way: for small degrees of discounting – such as those in lower-left panel – stability may not require a debt-elastic risk premium, but can alternatively be achieved by sufficiently deviating from the Taylor principle. As is well known from the New Keynesian literature, in that case one eigenvalue moves inside the unit circle. It thus ensures model stability by offsetting the impact of the unstable root associated with the Euler equation. This only “works” for small degrees of discounting, however, with the upper left panel of Figure 5 highlighting a case in which stability can *only* be achieved by setting the risk premium parameter ϕ sufficiently high. Nevertheless, the minimal value of ϕ that ensures stability is still fairly small, and the parameterization we adopt ($\phi = 0.01$) is more than sufficient even for a very high degree of myopia.

8. Conclusions

In this paper, we have studied the implications of extending the standard open economy New Keynesian framework by adding behavioral agents á la Gabaix (2020). We have shown that the resulting model fits the data better, and also markedly improves upon its fully rational variant along several additional dimensions. First, it helps mitigate puzzles related to the uncovered interest rate parity condition in a way that is consistent with recent empirical evidence reassessing those puzzles using survey-based measures of expectations. Second, accounting for myopia decreases the efficacy of policies that rely on announcements of future actions, like “low for longer”, thus rectifying a key element of the forward guidance puzzle, both for the exchange rate and inflation. Third, by decreasing the relative strength of the exchange rate channel, the behavioral open economy model can better account for international output comovement. In an earlier draft (Kolasa et al., 2022), we have also shown that cognitive discounting has important implications for the optimal conduct of monetary policy in an open economy, including calling into question the desirability of using the exchange rate as a nominal anchor.

While incorporating behavioral aspects in a consistent way is not costless, and doing so can quickly become quite involved in more complex environments, we believe that the price is worth paying as the benefits in the form of better empirical fit and more reasonable

implications are significant. As our analysis suggests, this is true both when working with closed and open economy models, but, arguably, particularly so for the latter on account of the numerous anomalies which cognitive discounting helps mitigate.

Acknowledgements

We have benefited from very useful suggestions by co-editor Tommaso Monacelli and two anonymous referees. We also gratefully acknowledge comments by our discussant Lahcen Bounader and those by Tobias Adrian, Francesco Bianchi, Stephane Dupraz, Chris Erceg, Stefano Eusepi, Xavier Gabaix, Cosmin Ilut, Herve Le Bihan, Jesper Linde, Julien Matheron, Ruperto Mujica, and Felipe Zanna. We are also grateful to participants in seminars at the IMF and University of Surrey, as well as those in the ASSA Annual Meeting in San Antonio, North American Summer Meetings of the Econometric Society in Los Angeles, EEA-ESEM Congress in Milan, CEF Conference in Dallas, Behavioral Macro Workshop in Bamberg, Dynare Conference in Lancaster, MMF Annual Conference in Canterbury, MMF PhD Conference in Edinburgh. Sahil Ravgotra thanks the Monetary Policy Modeling Unit of the IMF for hospitality during his 2021 summer internship. The views expressed here are those of the authors and do not necessarily represent the views of the IMF, its Executive Board, or IMF management.

References

- Adjemian, S., Bastani, H., Juillard, M., Karame, F., Mailh, J., Mihoubi, F., Mutschler, W., Perendia, G., Pfeifer, J., Ratto, M., Villemot, S., 2021. Dynare: Reference Manual Version 4. Dynare Working Papers 1. CEPREMAP.
- Adolfson, M., Laseen, S., Linde, J., Villani, M., 2007. Bayesian estimation of an open economy DSGE model with incomplete pass-through. *Journal of International Economics* 72, 481–511.
- Bacchetta, P., Mertens, E., van Wincoop, E., 2009. Predictability in financial markets: What do survey expectations tell us? *Journal of International Money and Finance* 28, 406–426.
- Bacchetta, P., van Wincoop, E., 2010. Infrequent Portfolio Decisions: A Solution to the Forward Discount Puzzle. *American Economic Review* 100, 870–904.
- Bacchetta, P., van Wincoop, E., 2021. Puzzling exchange rate dynamics and delayed portfolio adjustment. *Journal of International Economics* 131, 103460.
- Benigno, G., Benigno, P., 2003. Price stability in open economies. *The Review of Economic Studies* 70, 743–764.
- Bianchi, F., Ilut, C.L., Saijo, H., 2021. Diagnostic Business Cycles. NBER Working Papers 28604. National Bureau of Economic Research, Inc.
- Bodenstein, M., 2010. Trade elasticity of substitution and equilibrium dynamics. *Journal of Economic Theory* 145, 1033–1059.
- Bordalo, P., Gennaioli, N., Shleifer, A., 2018. Diagnostic expectations and credit cycles. *The Journal of Finance* 73, 199–227.
- Branch, W.A., McGough, B., 2009. A New Keynesian Model with Heterogeneous Expectations. *Journal of Economic Dynamics and Control* 33, 1036–1051.
- Brock, W.A., Hommes, C.H., 1997. A Rational Route to Randomness. *Econometrica* 65, 1059–1095.
- Brzoza-Brzezina, M., Galinski, P., Makarski, K., 2025. Monetary and fiscal policy in a two-country model with behavioral expectations. *Journal of International Money and Finance* (forthcoming).
- Bullard, J., Mitra, K., 2002. Learning about monetary policy rules. *Journal of Monetary Economics* 49, 1105–1129.
- Burnside, C., Han, B., Hirshleifer, D., Wang, T.Y., 2011. Investor Overconfidence and the Forward Premium Puzzle. *Review of Economic Studies* 78, 523–558.

- Bussiere, M., Chinn, M., Ferrara, L., Heipertz, J., 2022. The New Fama Puzzle. *IMF Economic Review* 70, 451–486.
- Candian, G., De Leo, P., 2023. Imperfect exchange rate expectations. *Review of Economics and Statistics* (forthcoming).
- Carlstrom, C.T., Fuerst, T.S., Paustian, M., 2015. Inflation and output in new keynesian models with a transient interest rate peg. *Journal of Monetary Economics* 76, 230–243.
- Chen, K., Kolasa, M., Linde, J., Wang, H., Zabczyk, P., Zhou, J., 2023. An Estimated DSGE Model for Integrated Policy Analysis. *IMF Working Papers* 2023/135. International Monetary Fund.
- Corsetti, G., Pesenti, P., 2001. Welfare and Macroeconomic Interdependence. *The Quarterly Journal of Economics* 116, 421–445.
- De Grauwe, P., 2011. Animal Spirits and Monetary Policy. *Economic Theory* 47, 423–457.
- De Long, J.B., Shleifer, A., Summers, L.H., Waldmann, R.J., 1990. Noise Trader Risk in Financial Markets. *Journal of Political Economy* 98, 703–738.
- Del Negro, M., Giannoni, M.P., Patterson, C., 2023. The Forward Guidance Puzzle. *Journal of Political Economy Macroeconomics* 1, 43–79.
- Du, Q., Eusepi, S., Preston, B., 2021. Non-rational Beliefs in an Open Economy. *Review of Economic Dynamics* 41, 174–204.
- Engel, C., 2016. Exchange Rates, Interest Rates, and the Risk Premium. *American Economic Review* 106, 436–474.
- Evans, G.W., Honkapohja, S., 2001. *Learning and expectations in macroeconomics*. Princeton University Press.
- Fama, E.F., 1984. Forward and spot exchange rates. *Journal of Monetary Economics* 14, 319–338.
- Froot, K.A., Frankel, J.A., 1989. Forward Discount Bias: Is it an Exchange Risk Premium? *The Quarterly Journal of Economics* 104, 139–161.
- Fuhrer, J.C., Rudebusch, G.D., 2004. Estimating the euler equation for output. *Journal of Monetary Economics* 51, 1133–1153.
- Gabaix, X., 2020. A Behavioral New Keynesian Model. *American Economic Review* 110, 2271–2327.
- Gabaix, X., Maggiori, M., 2015. International Liquidity and Exchange Rate Dynamics. *The Quarterly Journal of Economics* 130, 1369–1420.

- Galí, J., 2015. *Monetary Policy, Inflation, and the Business Cycle: an Introduction to the New Keynesian Framework and its Applications*. Princeton University Press.
- Galí, J., 2020. Uncovered Interest Parity, Forward Guidance and the Exchange Rate. *Journal of Money, Credit and Banking* 52, 465–496.
- Galí, J., Monacelli, T., 2005. Monetary Policy and Exchange Rate Volatility in a Small Open Economy. *Review of Economic Studies* 72, 707–734.
- Gopinath, G., Boz, E., Casas, C., Diez, F.J., Gourinchas, P.O., Plagborg-Møller, M., 2020. Dominant currency paradigm. *American Economic Review* 110, 677–719.
- Gourinchas, P.O., Tornell, A., 2004. Exchange rate puzzles and distorted beliefs. *Journal of International Economics* 64, 303–333.
- Gust, C., Herbst, E., Lopez-Salido, J.D., 2021. Short-term Planning, Monetary Policy, and Macroeconomic Persistence. *American Economic Journal: Macroeconomics* .
- Gust, C., Herbst, E., Lopez-Salido, J.D., 2022. Short-term Planning, Monetary Policy, and Macroeconomic Persistence. *American Economic Journal: Macroeconomics* 14, 174–209.
- Ilabaca, F., Meggiorini, G., Milani, F., 2020. Bounded rationality, monetary policy, and macroeconomic stability. *Economics Letters* 186, 108522.
- Ilut, C., 2012. Ambiguity Aversion: Implications for the Uncovered Interest Rate Parity Puzzle. *American Economic Journal: Macroeconomics* 4, 33–65.
- Itskhoki, O., Mukhin, D., 2021. Exchange rate disconnect in general equilibrium. *Journal of Political Economy* 129, 2183–2232.
- Jeanne, O., Rose, A.K., 2002. Noise Trading and Exchange Rate Regimes. *The Quarterly Journal of Economics* 117, 537–569.
- Justiniano, A., Preston, B., 2010. Monetary policy and uncertainty in an empirical small open-economy model. *Journal of Applied Econometrics* 25, 93–128.
- Kalemli-Ozcan, S., Varela, L., 2021. Five Facts about the UIP Premium. NBER Working Papers 28923. National Bureau of Economic Research, Inc.
- Kolasa, M., Ravgotra, S., Zabczyk, P., 2022. Monetary Policy and Exchange Rate Dynamics in a Behavioral Open Economy Model. IMF Working Papers 2022/112. International Monetary Fund.
- Kollmann, R., 2002. Monetary policy rules in the open economy: effects on welfare and business cycles. *Journal of Monetary Economics* 49, 989–1015.
- McKay, A., Nakamura, E., Steinsson, J., 2016. The power of forward guidance revisited. *American Economic Review* 106, 3133–58.

- Müller, G.J., Wolf, M., Hettig, T., 2024. Delayed overshooting: The case for information rigidities. *American Economic Journal: Macroeconomics* 16, 310–342.
- Na, S., Xie, Y., 2023. A Behavioral New Keynesian Model of a Small Open Economy under Limited Foresight. Technical Report.
- Obstfeld, M., Rogoff, K., 2001. The Six Major Puzzles in International Macroeconomics: Is There a Common Cause?, in: *NBER Macroeconomics Annual 2000, Volume 15*. National Bureau of Economic Research, Inc. NBER Chapters, pp. 339–412.
- Preston, B., 2005. Learning about Monetary Policy Rules when Long-Horizon Expectations Matter. *International Journal of Central Banking* 1, 81–126.
- Ratto, M., 2008. Analysing DSGE Models with Global Sensitivity Analysis. *Computational Economics* 31, 115–139.
- Schmitt-Grohé, S., Uribe, M., 2001. Stabilization policy and the costs of dollarization. *Journal of Money, Credit and Banking* 33, 482–509.
- Schmitt-Grohe, S., Uribe, M., 2003. Closing small open economy models. *Journal of International Economics* 61, 163–185.
- Senhadji, A.S., 2003. External Shocks and Debt Accumulation in a Small Open Economy. *Review of Economic Dynamics* 6, 207–239.
- Valchev, R., 2020. Bond Convenience Yields and Exchange Rate Dynamics. *American Economic Journal: Macroeconomics* 12, 124–166.
- Woodford, M., 2003. *Interest and Prices. Foundations of a Theory of Monetary Policy*. Princeton University Press.
- Woodford, M., 2013. Macroeconomic Analysis Without the Rational Expectations Hypothesis. *Annual Review of Economics* 5, 303–346.
- Woodford, M., 2019. Monetary Policy Analysis when Planning Horizons are Finite. *NBER Macroeconomics Annual* 33, 1–50.
- Wu, J.C., Xia, F.D., 2016. Measuring the macroeconomic impact of monetary policy at the zero lower bound. *Journal of Money, Credit and Banking* 48, 253–291.

Declaration of interests

☐ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☒ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Marcin Kolasa reports financial support was provided by International Monetary Fund. Sahil Ravgotra reports financial support was provided by International Monetary Fund. Pawel Zabczyk reports financial support was provided by International Monetary Fund. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
