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MONETARY POLICY AND EXCHANGE RATE DYNAMICS IN A BEHAVIORAL OPEN ECONOMY MODEL*

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Abstract. We develop and estimate an extension of the open economy New Keynesian model in which agents are boundedly rational á la Gabaix (2020). Our setup successfully mitigates many puzzling aspects of the relationship between exchange rates and interest rates, and remains consistent with recent empirical evidence showing that UIP puzzles vanish when actual – as opposed to rational – exchange rate expectations are used. We find that accounting for myopia dampens the effects of current monetary shocks and lowers the efficacy of forward guidance (FG), but its relative importance in mitigating the "FG puzzle" is decreasing in openness. We also show that bounded rationality makes positive monetary spillovers more likely, increases the persistence of the real exchange rate and net foreign assets, and exacerbates the small open economy unit root problem. Finally, the model provides arguments against using the exchange rate as a nominal anchor.

Keywords: Monetary Policy, Exchange Rates, Bounded Rationality
JEL Codes: F41, E70, E52, E58, G40

1. Introduction

The role of expectations in determining the effectiveness of central bank actions has recently, and yet again, taken center stage. Faced with forces persistently lowering the natural interest rate, and having to deal with large crises such as the Great Recession or COVID-19, monetary policy makers have had to increasingly rely on forward guidance to mitigate the adverse effects associated with reaching the effective lower bound (ELB) on interest rates. While the workhorse New Keynesian (NK) policy framework provided clear mechanisms that gave such policies traction, they appeared *counterfactually* powerful, a feature which soon became known as the "forward guidance puzzle" (FGP, see also Carlstrom et al., 2015; Giannoni et al., 2015; McKay et al., 2016).

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Researchers have since taken several distinct routes in trying to address the FGP. The one of most consequence for our paper was to replace the assumption of full rationality, which has been shown to play a key role, with behavioral alternatives.[1] Woodford (2019), for example, developed an NK framework in which cognitive constraints translated into a finite planning horizon, beyond which agents were "backward looking". Gabaix (2020) proposed a "cognitive discounting" alternative, which introduced partial myopia towards atypical future events.[2] Notably, and as recently demonstrated by Gust et al. (2021), benefits of such models can extend beyond mitigating the FGP as they also fit the data better than their "fully rational" New Keynesian predecessors. Despite these advances, relatively little is known about the implications of such behavioral assumptions in richer theoretical environments. As such, the goal of this paper is to advance the associated research agenda by developing an open economy extension of Gabaix's (2020) behavioral model and characterizing the implications of cognitive discounting in such an environment.

Our point of departure is the well-established, new open economy macroeconomics (NOEM) paradigm.[3] We cast the analysis in a, now standard, incomplete asset market version of that environment and we show that behavioral extensions significantly modify several key equilibrium conditions. For example, one immediate implication is that cognitive discounting exacerbates the well-known unit root problem prevalent in small open economy models, requiring stronger remedial mechanisms.[4] More fundamentally, for degrees of myopia in our estimated range, the behavioral extension we study goes a long way towards resolving several important anomalies typically characterizing the relationship of exchange rates and interest rates. These include the forward premium puzzle (Fama, 1984), the predictability reversal puzzle (Bacchetta and van Wincoop, 2010), the Engel puzzle (Engel, 2016), as well as the forward guidance exchange rate puzzle (Galí, 2020).

At the same time, and in contrast to some recently advocated "rational" solutions to those uncovered interest rate parity (UIP) puzzles,[5] our model is also consistent with the empirical evidence presented in Kalemli-Ozcan and Varela (2021). The paper demonstrates, in particular, that the

[1] Other approaches relied on moving to a perpetual youth structure (Giannoni et al., 2015), introducing heterogeneous agents operating in incomplete asset markets (McKay et al., 2016), introducing imperfect monetary policy credibility (Campbell et al., 2019; Haberis et al., 2019) as well as various departures from "common knowledge" (Carlstrom et al., 2015; Kiley, 2016; Angeletos and Lian, 2018).

[2] Both of these introduced similar forms of discounting into the (linearized) IS and Phillips curves, in line with Angeletos and Lian (2018), where aggregate myopia originates in uncertainty about other agents' beliefs.

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

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

[5] To mitigate the UIP-related puzzles, Bacchetta and van Wincoop (2021) propose a model of delayed portfolio adjustment, while Valchev (2020) and Itskhoki and Mukhin (2021) rely instead on financial frictions.

first three puzzles vanish when actual exchange rate expectations are used instead of realizations *coupled with* the rational expectations assumption (see also Candian and De Leo, 2021). The reason behind our behavioral model's success is that the uncovered interest rate parity (UIP) condition holds exactly when formulated in terms of agents' subjective expectations, but not when reformulated in terms of what it would be rational to expect. Expressed alternatively, testing various implications of UIP on our model simulated data under the assumption of rational expectations would lead to rejections of that *joint hypothesis*. Crucially, however, *not* because UIP fails to hold, but rather because agents in our model are not rational, and so ex post exchange rate realizations provide a biased read of their ex ante expectations.

Turning to implications for monetary policy, we find that the underlying behavioral assumptions weaken the efficacy of future interest path announcements and of 'low for longer' type policies. Therefore, and broadly in line with closed economy results, cognitive discounting also resolves the FGP in an open economy context. Similarly – and to the extent that current monetary shocks are persistent or have persistent effects on policy rates on account of interest rate smoothing – their influence on the economy is also dampened.

There are, however, notable differences between closed and open economy behavioral models. The key one is that, as we show analytically, 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 advocated by the dominant currency paradigm literature (Gopinath et al., 2020). We also show that – when markets are complete and monetary policy is conducted optimally – behavioral discounting generates a unit root in the nominal exchange rate. This means that, unlike under perfect rationality, positive (negative) temporary domestic cost-push shocks result in a permanent appreciation (depreciation) of the exchange rate, making its use as a nominal anchor less desirable.

Finally, we show that behavioral discounting has interesting implications for business cycle properties of open economy variables and for the size of international monetary policy spillovers. According to our model, the more heavily the future is discounted by agents, the more persistent net foreign assets and the real exchange rate become in response to monetary shocks, an outcome that follows from agents underestimating the persistence of interest rate changes. We additionally demonstrate that 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 expenditure switching.

Our paper is related 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. In an open economy setup, Llosa and Tuesta (2008) and Zanna (2009) analyze the equilibrium determinacy properties of monetary and exchange rate rules under adaptive expectations. More recently, Du et al. (2021) look at bounded rationality in a microfounded open economy, their key finding being that learning goes a considerable way towards better accounting for exchange rate dynamics.

The remainder of this paper is structured as follows. Section 2 presents 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 present how behavioral discounting changes the key equilibrium relationships, also discussing the range of parameter values used in numerical experiments. Section 4 discusses how agents' myopia impinges on model stationarity and equilibrium determinacy. Section 5 shows how allowing for behavioral discounting helps resolve some open economy puzzles. In Section 6, we analytically characterize the implications of myopia for the transmission of "surprise" as well as anticipated changes in the real interest rates. Section 7 evaluates the dynamic effects of monetary policy, including both conventional and "low for longer" policies. In section 8, we present the impact of discounting on international monetary policy spillovers. Implications for optimal monetary policy are discussed in Section 9. Section 10 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

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

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

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

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

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

where P_t and P_t^* are the prices of the 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 units of domestic currency per unit of foreign currency, and $\Phi_t = \Phi(B_t^*)$ is a risk premium that depends on the Home country's per capita net foreign asset (NFA) position.

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

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

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

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

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

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 $P_{H,t}^f = \varepsilon_t P_{H,t}^{*,f}$ at every time t. They are subject to a Calvo-style friction. More specifically, each period only a fraction $0 < \theta < 1$ of firms is allowed to reoptimize their prices. The problem of intermediate goods producers is then to maximize

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

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 at 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 assume that, when agents anticipate the future, they shrink their expectations toward some benchmark, which is assumed to be 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

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

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 standard case of rational expectations can be readily obtained for $m = 1$, while lower values of this parameter make 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 do correctly perceive the constraints defining their problems, and hence their decisions are optimal, conditional on their 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

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

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 $C^h_t = C_t$, $N^h_t = N_t$, $B^{*,h}_t = B^*_t$, $B^h_t = B_t = 0$, 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

$$N_t = \int_0^1 N^f_t \,\mathrm{d}f, \tag{9}$$

while goods market clearing requires

$$Y_{H,t} = C_{H,t}, \qquad \text{and} \qquad Y^*_{H,t} = \frac{1-\zeta}{\zeta} C^*_{H,t}. \tag{10}$$

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

$$\hat{\mathbb{E}}_t \left\{ X_{t+k} - X \right\} = m^k \mathbb{E}_t \left\{ X_{t+k} - X \right\}, \tag{11}$$

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.

One issue worth highlighting is that we cannot proceed without precisely defining the set of variables that agents form their expectations about. For example, it matters whether households think about the real exchange rate Q_t or its rate of depreciation Q_t/Q_{t-1} when making projections about the future. To see that, define $\hat{Q}_t \equiv Q_t - Q$, where Q is the steady state of Q_t. We could then have one of two alternatives

$$\begin{aligned} \hat{\mathbb{E}}_t \left\{ \hat{Q}_{t+1} \right\} &= m\mathbb{E}_t \left\{ \hat{Q}_{t+1} \right\} \\ & \qquad\quad \neq \\ \hat{\mathbb{E}}_t \left\{ \Delta \hat{Q}_{t+1} + \hat{Q}_t \right\} &= m\mathbb{E}_t \left\{ \hat{Q}_{t+1} \right\} + (1-m)\hat{Q}_t. \end{aligned} \tag{12}$$

While the choice is admittedly somewhat arbitrary, we find it natural to assume that agents make projections about levels of variables that are constant in the steady state (top equality), as opposed to their rates of change (bottom equality).

3.2. **Linearized Equilibrium Conditions.** When linearizing the model, we focus on the small open economy case, which obtains as the limit when $\zeta \to 0$. 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. Since deriving some of them is not straightforward, we outline the key associated steps in Appendix A.

Solving the household problem results in the following modified IS curve

$$\hat{C}_t = m\mathbb{E}_t\hat{C}_{t+1} - \frac{1}{\sigma}\left(\hat{i}_t - m\mathbb{E}_t\hat{\pi}_{t+1}\right) + (1-m)\frac{1-\beta}{1+\frac{\sigma}{\mu\varphi}}\hat{B}^*_t. \tag{13}$$

The standard New Keynesian relationship can be immediately 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 (13) is derived using subjectively optimal consumption plans. More specifically, agents do not apply discounting to their individual choices, i.e. $\hat{\mathbb{E}}_t\hat{B}^{*,h}_{t+k} \neq m^k\mathbb{E}_t\hat{B}^{*,h}_{t+k}$ 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 stronger than it would have been without the final term in Equation (13).[7] Relatedly, optimal bond holdings of myopic households can be shown to imply an uncovered interest rate parity (UIP) condition

$$\hat{i}_t - m\mathbb{E}_t\left\{\hat{\pi}_{t+1}\right\} = \hat{i}^*_t - m\mathbb{E}_t\left\{\hat{\pi}^*_{t+1} - \hat{Q}_{t+1}\right\} - \hat{Q}_t - \phi\hat{B}^*_t, \tag{14}$$

where $\phi = \Phi'(0)$. 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

$$\hat{\pi}_{H,t} = m\beta\mathbb{E}_t\{\hat{\pi}_{H,t+1}\} + \kappa\hat{MC}_t, \tag{15}$$

where $\kappa \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta}$, and which collapses to the canonical New Keynesian Phillips curve for $m = 1$. Note that, in line with Benchimol and Bounader (2019) and the principle stated in Section

[6] In his baseline formulation, Gabaix (2020) assumes that agents correctly perceive the ex ante real interest rate, which means that expected inflation in Equation 13 is not discounted. This can be seen as yet another manifestation of a certain degree of arbitrariness when defining the set of variables that agents take as given while solving their optimization problem (discussed in the preceding section). Crucially, however, none of our main findings hinge on whether we follow Gabaix in assuming no misperception of the current real interest rate, or if we instead allow for some money illusion, as implicit in Equation 13.

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

3.1, we deviate from Gabaix (2020) while deriving Equation (15) (see also Appendix A.4 for details). However, this deviation does not have a material impact on any of our key results.

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

$$\hat{MC}_t = \sigma \hat{C}_t + \varphi \hat{Y}_t + \frac{\alpha}{1-\alpha}\hat{Q}_t - (1+\varphi)\hat{z}_t, \tag{16}$$

the consumer price inflation (CPI) is given by

$$\hat{\pi}_t = \hat{\pi}_{H,t} + \frac{\alpha}{1-\alpha}\left(\hat{Q}_t - \hat{Q}_{t-1}\right), \tag{17}$$

while the aggregate goods market clearing condition can be written as

$$\hat{Y}_t = (1-\alpha)\hat{C}_t + \alpha \hat{Y}_t^* + \eta \frac{\alpha(2-\alpha)}{1-\alpha}\hat{Q}_t. \tag{18}$$

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

$$\hat{B}_t^* = \beta^{-1}\left(\hat{B}_{t-1}^* + \hat{Y}_t - \hat{C}_t\right). \tag{19}$$

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

$$\hat{i}_t = \rho \hat{i}_{t-1} + (1-\rho)(\phi_\pi \hat{\pi}_t + \phi_y \hat{Y}_t) + \nu_t. \tag{20}$$

Equations (13)–(20) jointly define the equilibrium evolution of $\hat{Y}_t$, $\hat{C}_t$, $\hat{\pi}_t$, $\hat{\pi}_{H,t}$, $\hat{MC}_t$, $\hat{Q}_t$, $\hat{i}_t$, $\hat{B}_t^*$, driven by productivity shocks z_t, monetary policy shocks ν_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

$$\hat{Y}_t^* = m\mathbb{E}_t \hat{Y}_{t+1}^* - \frac{1}{\sigma}\left(\hat{i}_t^* - m\mathbb{E}_t \hat{\pi}_{t+1}^*\right), \tag{21}$$

$$\hat{\pi}_t^* = m\beta \mathbb{E}_t\{\hat{\pi}_{t+1}^*\} + \kappa(\sigma+\varphi)\left(\hat{Y}_t^* - \hat{z}_t^*\right), \tag{22}$$

$$\hat{i}_t^* = \rho \hat{i}_{t-1}^* + (1-\rho)(\phi_\pi \hat{\pi}_t^* + \phi_y \hat{Y}_t^*) + \nu_t^*. \tag{23}$$

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. **Parameter Values.** 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 follow two alternative paths. The first is to show outcomes for values of key structural parameters borrowed from extant literature. This shall allow us to, in particular, tease out the impact of changes in the degree of myopia m. As an alternative, we also perform a full Bayesian estimation of the model and rely on estimated values of structural coefficients instead.

Table 1. **Calibration**

Parameter	Value	Name
α	0.4	Openness
β	0.99	Discount Factor
η	1	Elasticity of Substitution Between Home and Foreign Goods
φ	3	Inverse Frisch Elasticity of Labor Supply
σ	1	Inverse Intertemporal Elasticity of Substitution
μ	1.2	Gross Product Markup
θ	0.85	Calvo Probability of No Price Adjustment
ρ	0.9	Interest Rate Smoothing Parameters
ϕ_π	1.5	Inflation Feedback Taylor Rule
ϕ_y	0.125	Output Feedback Taylor Rule
ϕ	0.01	Intermediation Costs Debt Sensitivity

3.3.1. *Calibration.* Table 1 summarizes our calibration choices, which are largely based on Gali and Monacelli (2005). The model frequency is quarterly. We make the economy fairly open by setting the import share parameter α equal to 0.4. The discount factor β is calibrated at 0.99, which, for zero average inflation, implies a steady state nominal interest rate of 4 per cent per annum. The elasticity of substitution between domestically produced goods and imports η, as well as that describing household intertemporal preferences σ, are both calibrated at 1. The inverse of the Frisch elasticity of labor supply φ is set to 3 and the steady state markup in the goods market μ is calibrated at 1.2. Compared to Gali and Monacelli (2005), we choose a higher value of the Calvo probability ($\theta = 0.85$) to make our model consistent with more recent empirical evidence on the slope of the Phillips curve. As is standard in the DSGE literature, we also allow for interest rate smoothing in the monetary policy rule by setting ρ to 0.9, and we assume standard feedback coefficients to inflation ($\phi_\pi = 1.5$) and the output gap ($\phi_y = 0.125$). As discussed in the next section, we set the slope of the risk premium in the UIP condition ϕ to a relatively small value of 0.01, which is sufficient to induce stationarity for empirically relevant degrees of myopia.

Since the goal of our paper is to investigate the impact of myopia, we start by taking an agnostic stance and show outcomes for values of m ranging from 0.5 to 1. For reference, we note that Gabaix (2020) uses a value of 0.85, which implies that an innovation materializing in a year's time would affect decision rules by just over half as much as a contemporaneous one. However, some papers suggest that even lower values of m cannot be ruled out. For example, empirical estimates of the Euler equation by Fuhrer and Rudebusch (2004) are consistent with an m of 0.65. Relatedly, Gust et al. (2021) 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. Finally, 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.

3.3.2. *Bayesian Estimation.* We also perform a full Bayesian estimation of the model, more details on which are provided in Appendix E. Broadly, the Home and Foreign economies are represented by Canada and the US, respectively. 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 that ends in 2019 (so that it includes the Great Recession and its aftermath up to the COVID-19 pandemic). The prior distributions of estimated parameters are centered at the calibrated values discussed in the preceding section, and their tightness is motivated by the DSGE literature that estimates open economy models (see, e.g., Adolfson et al., 2007; Justiniano and Preston, 2010).

Marked differences in values of posterior odds support high empirical relevance of behavioral discounting, also in an open economy setting. More specifically, the value of m significantly deviates from the prior that we centered at 0.85, with the posterior mean coming in as low as 0.53 for our baseline data sample. Other parameter estimates are close to typical values reported in the literature. In summary, our estimates strongly favor a high degree of behavioral discounting.

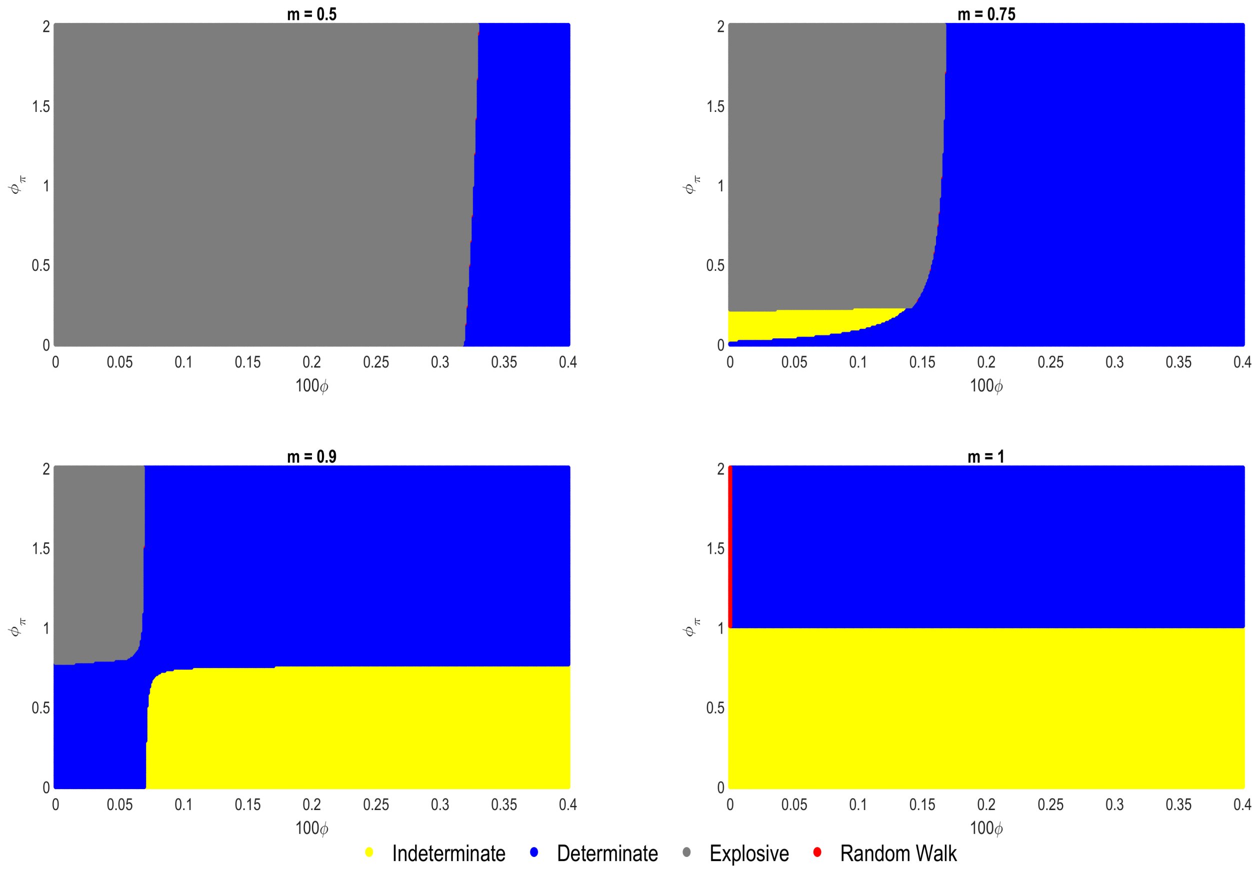
4. Stationarity and Determinacy

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).[8] 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 (Senhadji, 2003), and in our setup it can be 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 1, which demonstrates, in particular, that *any* positive risk premium ensures stationarity, while satisfying the Taylor principle guarantees uniqueness.

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 (13), which clarifies that, except for the final term, 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 stationarizing 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 1 by noting that the explosive area tends to expand when m becomes smaller. Clearly, the size of this area also depends on other model parameters, such as the import penetration ratio α. If the latter is large, exchange rate movements have a stronger effect on consumption, which has a stationarizing property. Because

[8] The 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 14. The IS curve 13 then implies that consumption has a unit root.

FIGURE 1. **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 as in our baseline calibration described in Table 1, except that we set $\phi_y = 0$.

consumption underreacts due to myopia, the associated accumulation of net foreign assets lowers the risk premium, which appreciates the exchange rate and hence increases consumption. Therefore, the greater the openness to foreign trade, the lower the ϕ needed to induce stationarity.

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 1, where the area corresponding to indeterminacy decreases in line with the cognitive discounting parameter m. Interestingly, we find that openness to international trade affects how indeterminacy regions change with myopia but this effect is small. For example, our baseline calibration implies that, for $m = 0.85$, determinacy is established if $\phi_\pi > 0.555$ while this threshold drops to 0.545 when we cut the import penetration ratio by half. The explanation for this result can be found in Section 6, where we show that myopia generates relatively less dampening of future interest rate changes on inflation when the economy is more open to trade. Consequently, the ability of discounting to reduce the complementarity between agents' actions (reactiveness to other agents' future decisions) is also smaller, making sunspot equilibria more likely.

Moreover, Figure 1 reveals how the two considerations discussed above interact in a non-trivial way: for moderate degrees of discounting – such as those in its counterdiagonal panels – 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 moderate degrees of discounting, however, with the upper left panel of Figure 1 highlighting a case in which stability can *only* be achieved by setting the risk premium parameter ϕ sufficiently high. For this reason, and also for ease of comparison with extant New Keynesian contributions, in the remainder we ensure stationarity by setting $\phi = 0.01$. This proves sufficient for all the values of m that we consider, while being sufficiently small to avoid unduly affecting the short-term dynamics of our model.

5. Exchange Rate Dynamics

As discussed in Section 3, our model implies a standard uncovered interest rate parity condition, except for the fact that the expectation operators appearing in it are behavioral rather than rational. Once these behavioral terms are reexpressed using their rational equivalents, we arrive at the "behavioral" UIP condition (Equation 14), which is repeated here for convenience

$$\hat{i}_t - m\mathbb{E}_t\left\{\hat{\pi}_{t+1}\right\} = \hat{\iota}_t^* - m\mathbb{E}_t\left\{\hat{\pi}_{t+1}^* - \hat{Q}_{t+1}\right\} - \hat{Q}_t, \tag{24}$$

and where we define $\hat{\iota}_t^* \equiv \hat{i}_t^* - \phi\hat{B}_t^*$ as the "premium adjusted" foreign nominal interest rate.[9] These observations have several strong and testable implications. First, we would expect the standard UIP condition to hold when actual expectations are used instead of their rational equivalents, particularly if actual expectations were, in fact, formed in a behavioral fashion.[10] The former

[9] We 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, $\hat{\iota}_t^*$ 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.

[10] Starting with the the influential work of Fama (1984) a large literature used realized exchange rates to document violations of the UIP condition, showing, in particular, that high interest rate currencies do not sufficiently depreciate, implying – on average – excess investment returns from carry trade strategies.

appears in line with a growing body of evidence. For example, Kalemli-Ozcan and Varela (2021) show that there are no overshooting and predictability reversal puzzles – for any currency – when using *actual* exchange rate expectations to calculate the UIP premium. Our model therefore appears broadly consistent with these new empirical findings.

While the results above are reassuring, it is also true that there are many possible ways of deviating from rational expectations and it does not necessarily follow that the behavioral discounting route proposed by Gabaix (2020) performs well in an open economy context. In what follows we therefore analyze the forward premium puzzle of Fama (1984) as well as the predictability reversal puzzle of Bacchetta and van Wincoop (2010) and Engel (2016) through the lens of our model. Crucially, we demonstrate that our behavioral framework can match the patterns underlying those two sets of puzzles, and we also explain the economic mechanism contributing to its empirical success.

5.1. **Forward Premium.** 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 even when an exchange rate depreciation is fully factored in. We now investigate whether our behavioral model can help account for this feature of the data.

We first observe that behavioral agents correctly perceive the current level of the real exchange rate and only discount its future level. Accordingly, the UIP condition (14) can be rewritten as

$$\hat{\imath}_t - \hat{\imath}_t^* = m\mathbb{E}_t\left\{\Delta\hat{\varepsilon}_{t+1}\right\} - (1-m)\hat{Q}_t. \tag{25}$$

Broadly, this equation 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 behavioral UIP condition as

$$\mathbb{E}_t\left\{\Delta\hat{\varepsilon}_{t+1}\right\} = \frac{1}{m}\left(\hat{\imath}_t - \hat{\imath}_t^*\right) + \left(\frac{1}{m} - 1\right)\hat{Q}_t. \tag{26}$$

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

$$\Delta\hat{\varepsilon}_{t+1} = a_0 + a_1 \left(\hat{i}_t - \hat{\imath}_t^*\right) + \epsilon_t, \tag{27}$$

where empirical estimates suggest values of the slope coefficient close to zero, or even negative, while standard UIP counterfactually implies $a_1 = 1$. Population regression techniques combined with the omitted variable bias formula allow us to express the value of the a_1 coefficient as

$$\begin{aligned}
\mathbb{E}a_1 &= \frac{1}{m} + \left(\frac{1}{m} - 1\right) \frac{\mathbb{E}\left\{\hat{Q}_t \left(\hat{i}_t - \hat{\imath}_t^*\right)\right\}}{\mathbb{E}\left\{\left(\hat{i}_t - \hat{\imath}_t^*\right)^2\right\}} \\
&= \frac{1}{m} + \left(\frac{1}{m} - 1\right) Corr\left\{\hat{Q}_t, \hat{i}_t - \hat{\imath}_t^*\right\} \frac{Std\left\{\hat{Q}_t\right\}}{Std\left\{\hat{i}_t - \hat{\imath}_t^*\right\}}
\end{aligned} \tag{28}$$

where, to fix attention, and as is standard in the literature, we subsequently focus on the case in which monetary policy shocks are key drivers of real exchange rate and interest rate dynamics.

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. Offsetting that, the second term is negative for $m < 1$ as when home monetary shocks are dominant, the real exchange rate is almost perfectly negatively correlated with the interest rate differential (or the home interest rate in a small open economy setup).

Whether discounting helps address the Fama puzzle thus crucially depends on the variability of the real exchange rate relative to that of the interest rate. Since the former clearly exceeds the latter in floating exchange rate regimes, and also in our model, there are reasons to expect improvements in fit. In Table 2 we confirm that conjecture by plugging in exact values of the standard deviations into Equation (28) and computing the slope coefficient for different combinations of the interest rate smoothing parameter (ρ) and discounting (m).

We find that a large degree of discounting, coupled with high interest rate smoothing, is capable of generating negative values of the Fama coefficient, in line with empirical results based on realized returns. 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,

Table 2. **Fama Regression Coefficients**

Parameter	$m = 0.50$	$m = 0.75$	$m = 0.90$	$m = 1.00$
$\rho = 0.95$	-0.07	-0.04	0.37	1.00
$\rho = 0.90$	0.17	0.36	0.67	1.00
$\rho = 0.75$	0.51	0.69	0.86	1.00
$\rho = 0.50$	0.75	0.86	0.94	1.00
Estimated model	0.44 (for $m = 0.53$, $\rho = 0.84$)			

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). Importantly, and as shown by the final row in Table 2, the Fama coefficient implied by our estimates deviates significantly from unity, which goes a long way towards resolving the forward premium puzzle.

5.2. **Predictability Sign Reversal.** We now 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

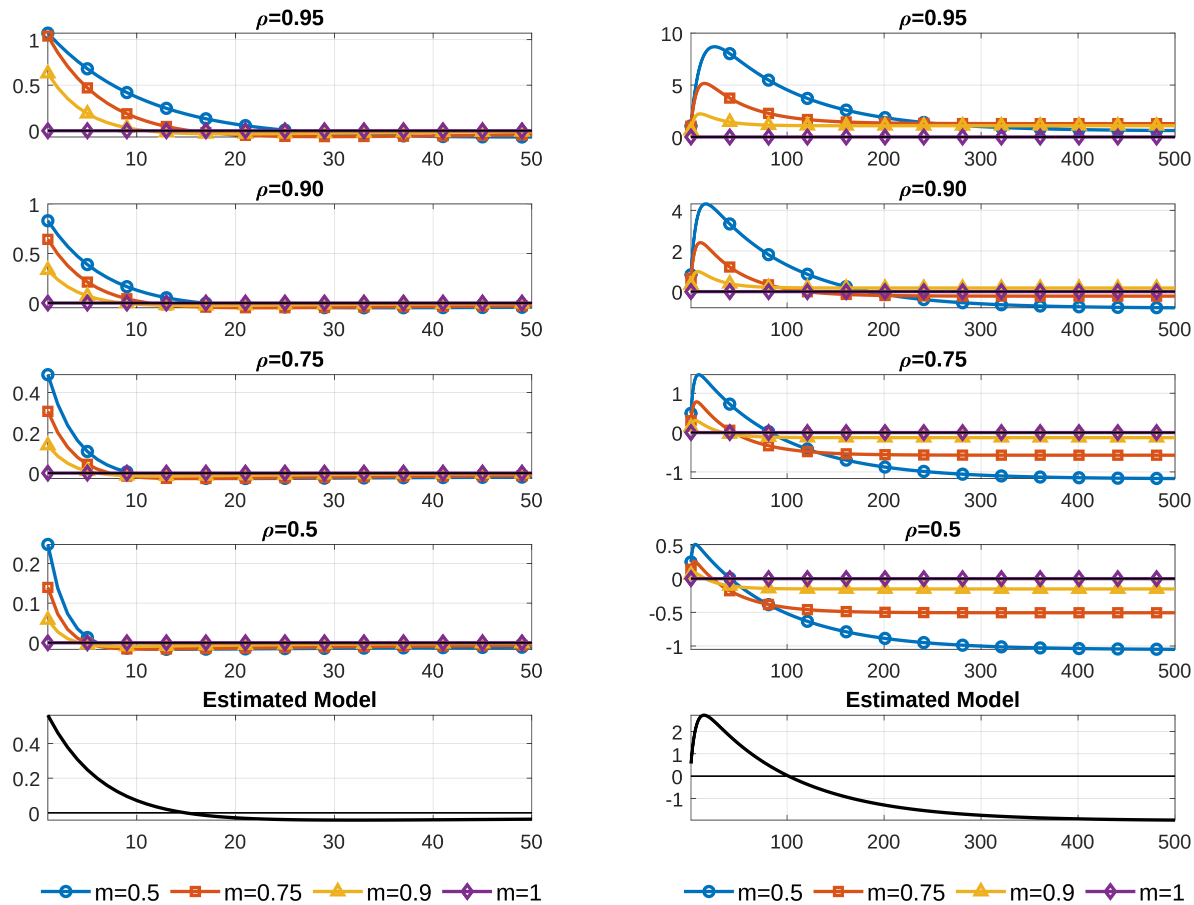
$$r^x_{t+1} \equiv \hat{i}_t - \hat{i}^*_t - \Delta\hat{\varepsilon}_{t+1} = b_{s,0} + b_{s,1}\left(\hat{i}_{t-s} - \hat{i}^*_{t-s}\right) + \epsilon_t, \tag{29}$$

where $s = 0, 1, ...$[11] 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 $Cov\left\{\mathbb{E}_t \sum_{s=0}^{\infty} r^x_{t+s+1}, \hat{i}_t - \hat{i}^*_t\right\} < 0$, 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 2 provides an overview of its key implications. Specifically, the left panels show our model-implied $b_{s,1}$ coefficients as a function of s (x-axis) for values of interest rate smoothing ranging from $\rho = 0.95$ in the top panel to $\rho = 0.5$ in the bottom one. To highlight the role of discounting, each chart covers four different m values, varying from $m = 1$ (no discounting / rational expectations) to $m = 0.5$ (discounting

[11] Note that for $s = 0$ the above is equivalent to a Fama-type regression (Equation 27), in which $b_{0,1} = 1 - a_1$.

FIGURE 2. **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 (29), as a function of s, using the calibrated version of the model for different values of m and ρ (first four rows) and its estimated version (last row). The right panels plot the corresponding cumulative sums $\sum_{s=0}^{T} b_{s,1}$ for T ranging from 0 to 500.

in line with Gust et al. (2021)). Given the equivalence between $Cov\left\{\mathbb{E}_t \sum_{s=0}^{\infty} r^x_{t+s+1}, \hat{i}_t - \hat{i}^*_t\right\} < 0$ 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 (at which point there are no discernible differences between the truncated and infinite sums).

The first four rows of Figure 2 confirm 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 all values of the discounting parameter m *except* for the rational expectations (RE) case of $m = 1$. 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, our model can account for Engel's excess volatility puzzle, provided that there is sufficient cognitive discounting and that interest rate smoothing is not excessive.

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

$$\mathbb{E}_t r^x_{t+1} \equiv \hat{i}_t - \hat{\imath}^*_t - \mathbb{E}_t \left\{ \Delta \hat{\varepsilon}_{t+1} \right\} = (m-1)\mathbb{E}_t \left\{ \hat{Q}_{t+1} + \hat{\pi}_{t+1} - \hat{\pi}^*_{t+1} \right\}. \tag{30}$$

We first note that the real exchange rate depreciates persistently in response to domestic policy easing. This initially leads to an accumulation of net foreign assets on account of greater price competitiveness. As we show in the next section, however, after some time the real exchange rate ends up appreciating relative to its steady state, which facilitates decumulation of net foreign assets, allowing them to converge to their steady state level. An implication of Equation (30) is that, in the presence of discounting, excess returns depend negatively on the real exchange rate. Accordingly, the evolution of this premium will be the mirror image of what we described above, i.e., an increase in the interest rate differential will lead to a persistent exchange rate appreciation and an increase in excess return, followed by a depreciation and a fall in excess return below zero. Which is precisely the sign reversal documented in Figure 2.

The intuition behind the second stylized fact is closely related to the argument of Bacchetta and van Wincoop (2021), who show that – in their gradual portfolio adjustment model – the Engel condition is violated whenever interest rate inertia is high. In both cases, 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 are not offset by future reversals.

Finally, and as documented in the last row of panels in Figure 2, both the sign reversal and the Engel condition are satisfied in the estimated version of our model. This is fully in line with the discussion above, as our Bayesian estimates imply a high degree of discounting and moderately high levels of interest rate smoothing.

5.3. **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

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

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 (13) vanishes when markets are complete, leading to

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

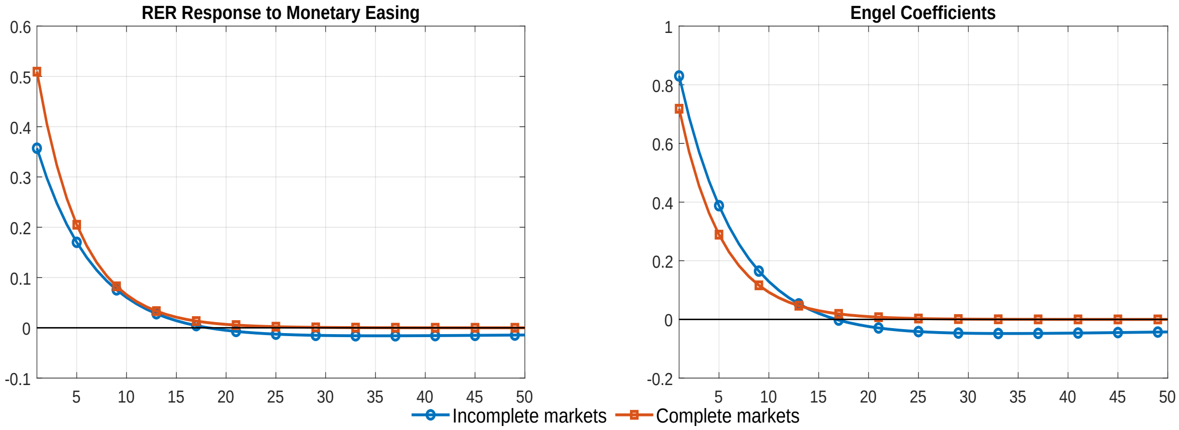
Combining the modified IS curve and its Foreign analog with the risk sharing condition (31) yields the following UIP relationship

$$\hat{i}_t - m\mathbb{E}_t\left\{\hat{\pi}_{t+1}\right\} = \hat{i}_t^* - m\mathbb{E}_t\left\{\hat{\pi}_{t+1}^* - \hat{Q}_{t+1}\right\} - \hat{Q}_t, \tag{33}$$

which is like formula (14) 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, as we show in Appendix C, this version of our model implies very similar Fama regression coefficients to those reported in Table 2 for the incomplete markets setup. It also generates very similar attenuation of current and expected monetary policy shocks to what we discuss in the subsequent sections.

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 5.2, 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 (30), this 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.

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 calibrated parameter values, with $m = 0.85$. The right panel shows the corresponding Engel regression coefficients, i.e., $b_{s,1}$ from Equation (29), as a function of s.

6. Monetary Policy Transmission - Inspecting the Mechanism

We now investigate the impact of discounting on monetary transmission, highlighting, in particular, the role played by openness. Our goal is to provide tractable, analytical foundations by working with Home and Foreign real interest rates defined, respectively, as $\hat{r}_t \equiv \hat{i}_t - m\mathbb{E}_t\hat{\pi}_{t+1}$ and $\hat{r}_t^* \equiv \hat{i}_t^* - m\mathbb{E}_t\hat{\pi}_{t+1}^*$. Except for slight differences in these definitions,[12] our approach closely follows that of Gabaix (2020), 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.

6.1. **Real Exchange Rate.** Our point of departure is the discussion of how monetary policy affects the real exchange rate (RER). Because our focus is on the effects of domestic monetary policy actions in a small open economy, we treat all foreign variables as fixed. Accordingly, the RER reaction is key to understand the differences between the closed and open economy setups.

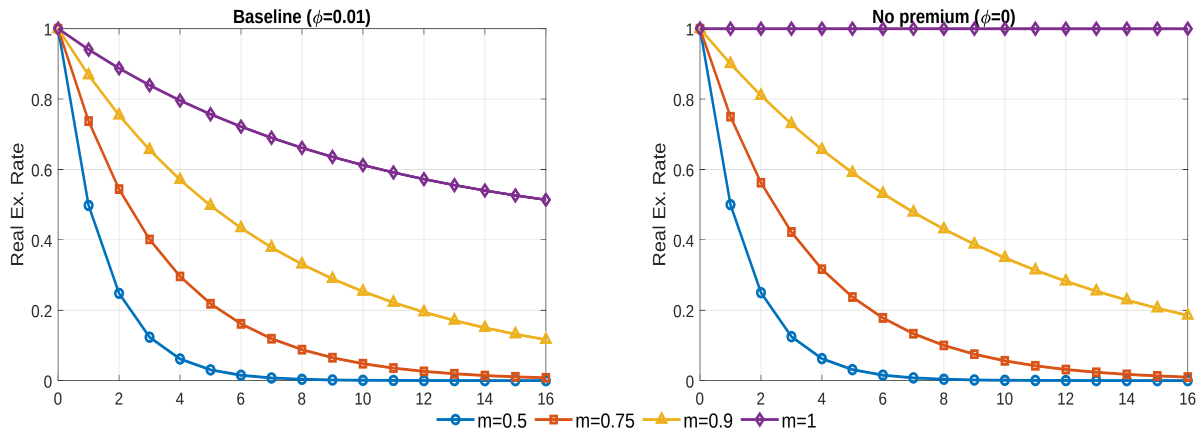
First, by iterating forward on the UIP condition (14), we arrive at

$$\hat{Q}_t = -\mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t} \left(\hat{r}_T - \hat{r}_T^* + \phi \hat{B}_T^* \right), \tag{34}$$

[12] To reiterate: in contrast to Gabaix (2020), we do not assume away the impact of biases in inflationary perceptions on the real interest rate.

where responses of the real exchange rate to real interest rate changes at different horizons are also depicted in the left panel of Figure 4.[13] Both 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 the exchange rate forward guidance puzzle of Galí (2020).

FIGURE 4. **Effects of Forward Guidance: Real Exchange Rate**



Note: This figure shows the normalized initial response of the real exchange rate as a function of forward guidance horizon. The left panel depicts the case where the UIP premium $\phi = 0.01$ and the right panel corresponds to the case of no UIP premium ($\phi = 0$).

It is worth noting, and may seem puzzling, that the RER response depicted in Figure 4 is declining in FG horizon at a rate *faster* than m, and even absent discounting (e.g., the purple line corresponding to $m = 1$ shows decay even though one could, in principle, expect a flat line).[14] This apparent discrepancy – between the rate of decay as a function of forward guidance horizon and m – arises because of the endogenous response of net foreign assets. The strength of that response varies depending on FG horizon and it feeds back to the UIP premium. The right panel of Figure 4 corroborates this conjecture by applying Equation (34) while keeping ϕ equal to 0, and it shows, in particular, that in that case the purple line remains flat.

To clarify why NFA responds differently at different FG horizons, even for $m = 1$, it proves useful to iterate forward on the consumption Euler condition (Equation 13) to obtain the following

[13] We normalize by dividing through the response to an unanticipated shock at horizon zero.

[14] Importantly, however, in that case the forward guidance puzzle is still present and FG remains very potent even at distant horizons. This is because the purple line corresponding to $m = 1$ does not asymptote to zero but eventually stabilizes at around 0.4.

relationship

$$\hat{C}_t = -\frac{1}{\sigma}\mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t}\hat{r}_T + (1-m)\frac{1-\beta}{1+\frac{\sigma}{\mu\varphi}}\mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t}\hat{B}^*_T. \tag{35}$$

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 now discuss, a similar relationship can be derived for output (see Equation 37), 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, which eventually translate into larger NFA accumulation.

6.2. **Output.** Combining the consumption Euler Equation (13) with the resource constraint (18) and the UIP condition (14), and using the small open economy assumption to eliminate foreign variables, allows us to derive an IS curve for output[15]

$$\hat{Y}_t = m\mathbb{E}_t\hat{Y}_{t+1} - \left(\frac{1-\alpha}{\sigma} + \eta\frac{\alpha(2-\alpha)}{1-\alpha}\right)\hat{r}_t - \left[\eta\frac{\alpha(2-\alpha)}{1-\alpha}\phi\hat{B}^*_t - (1-m)(1-\alpha)\frac{1-\beta}{1+\frac{\sigma}{\mu\varphi}}\right]\hat{B}^*_t. \tag{36}$$

Iterating forward on this equation yields

$$\begin{aligned}\hat{Y}_t = &-\left(\frac{1-\alpha}{\sigma} + \eta\frac{\alpha(2-\alpha)}{1-\alpha}\right)\mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t}\hat{r}_T \\ &- \left[\eta\frac{\alpha(2-\alpha)}{1-\alpha}\phi - (1-m)(1-\alpha)\frac{1-\beta}{1+\frac{\sigma}{\mu\varphi}}\right]\mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t}\hat{B}^*_T,\end{aligned} \tag{37}$$

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

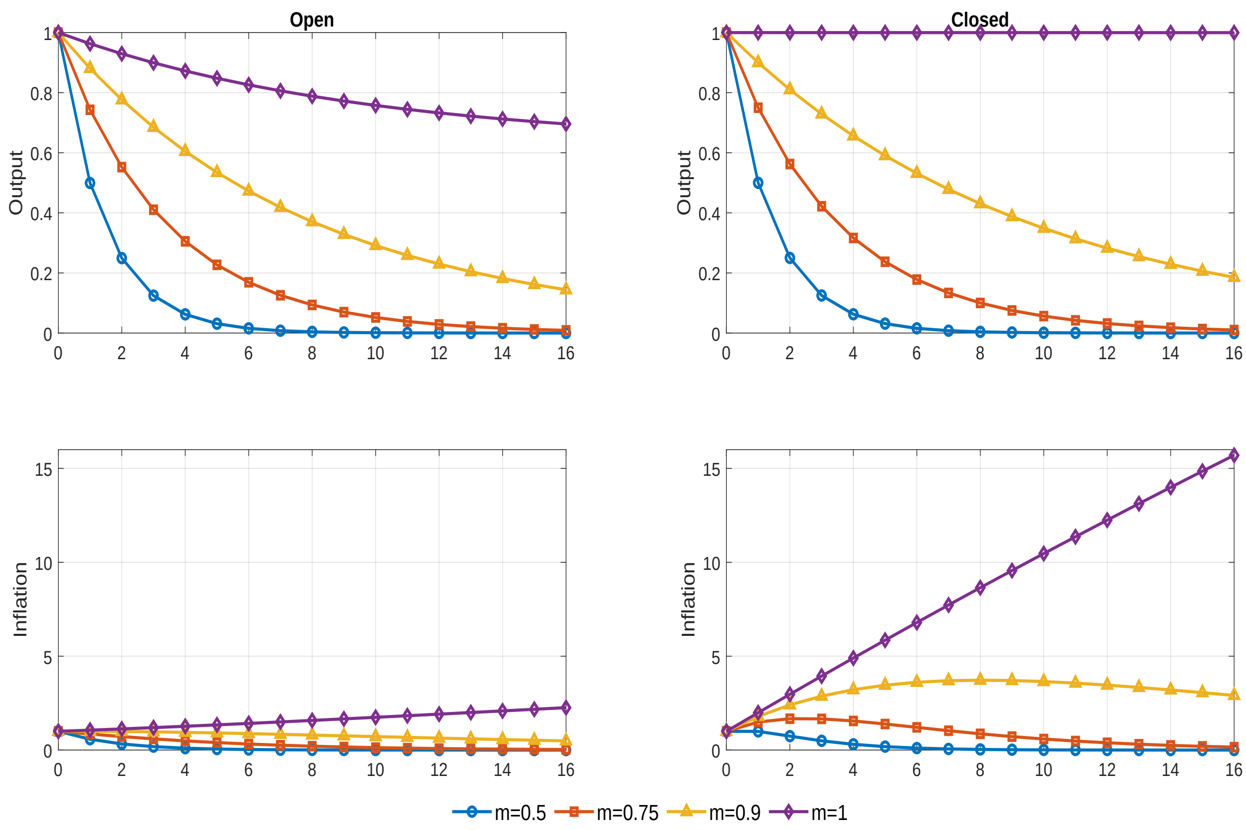
[15] See also Appendix B for details of the derivation.

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 can be stated as

$$\eta < \frac{1-\alpha}{2-\alpha}\sigma^{-1} \leq \frac{1}{2}\sigma^{-1},$$

which is satisfied for 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.

FIGURE 5. **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.

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

The effect of behavioral discounting on the initial response of output to current and future real interest rate changes of a given size is depicted in the first row of Figure 5. As done for the real exchange rate, we normalize by the contemporaneous output response, with the chart clearly showing that lower m translates into a faster decay of FG efficiency (as a function of its horizon), both in the open and closed economy cases.

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 (37) (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 positive, at least for values of ϕ necessary to induce stationarity. Overall, and in line with Figure 5, the rate of decay is faster in an open economy, which actually also holds absent discounting. Crucially, however, when $m = 1$ FG remains very efficient over very long horizons as the purple line does not go down to zero, but rather asymptotes at around 0.6, consistent with studies confirming the presence of the FGP also in rational expectations open economy models.

6.3. **Inflation.** We first focus on the domestic component of inflation, which is characterized in Equation (15), repeated here for ease of reference

$$\hat{\pi}_{H,t} = \beta m \mathbb{E}_t\{\hat{\pi}_{H,t+1}\} + \kappa \left(\sigma \hat{C}_t + \varphi \hat{Y}_t + \frac{\alpha}{1-\alpha} \hat{Q}_t - (1+\varphi)\hat{z}_t \right).$$

Building on the preceding analysis, we know that – relative to the closed economy case – a change in the real interest rates (current or future) translates into unchanged (if $m = 1$) or greater responses of consumption, greater responses of output (for typical values of trade and intertemporal elasticities), with real exchange rate depreciations additionally boosting marginal cost. It then follows that higher responsiveness of domestic inflation to real interest rate changes also translates into greater responsiveness of CPI inflation.

However, as the second row of Figure 5 highlights, the FGP for inflation 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 marginal costs, and all three marginal cost components depend on the future path of real interest rates. After some algebra, where we drop productivity shocks to focus on the effects of domestic 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 follows[17]

$$\hat{\pi}_t \approx -\frac{\kappa a}{\beta(1-m)}\mathbb{E}_t \sum_{T=t}^{\infty}\left[m^{T-t+1} - (\beta m)^{T-t+1}\right]\hat{r}_T - \frac{\alpha}{1-\alpha}\mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t}\hat{r}_T - \frac{\alpha}{1-\alpha}\hat{Q}_{t-1}, \qquad (38)$$

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 $\beta \to 1$, we arrive at

$$\hat{\pi}_t \approx \underbrace{-\kappa a \mathbb{E}_t \sum_{T=t}^{\infty}(T-t+1)\, m^{T-t}\hat{r}_T}_{\text{Domestic Marginal Cost}} \underbrace{-\frac{\alpha}{1-\alpha}\mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t}\hat{r}_T}_{\text{Import Prices}} - \frac{\alpha}{1-\alpha}\hat{Q}_{t-1}, \qquad (39)$$

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. Notably, the key implications of Equation (39) are perfectly consistent with the patterns documented in Figure 5. In particular, and because of the first component (the only one present in the closed economy case), which is a product of exponential decay and linear growth, the relationship between the effect on inflation and FG horizon is linear for no discounting $m = 1$, non-monotonic for small discounting (increasing and then decreasing), and decreasing for strong discounting.[18] In an open economy the picture is modified by the presence of the second component, which does not depend on the FG horizon for $m = 1$, and the relative weight on which increases in openness α. As a consequence, the forward guidance puzzle is less pronounced in an open economy, implying that the mitigating effect of discounting on the FGP is also *relatively* smaller compared to the closed economy case.

7. Dynamic Effects of Monetary Policy

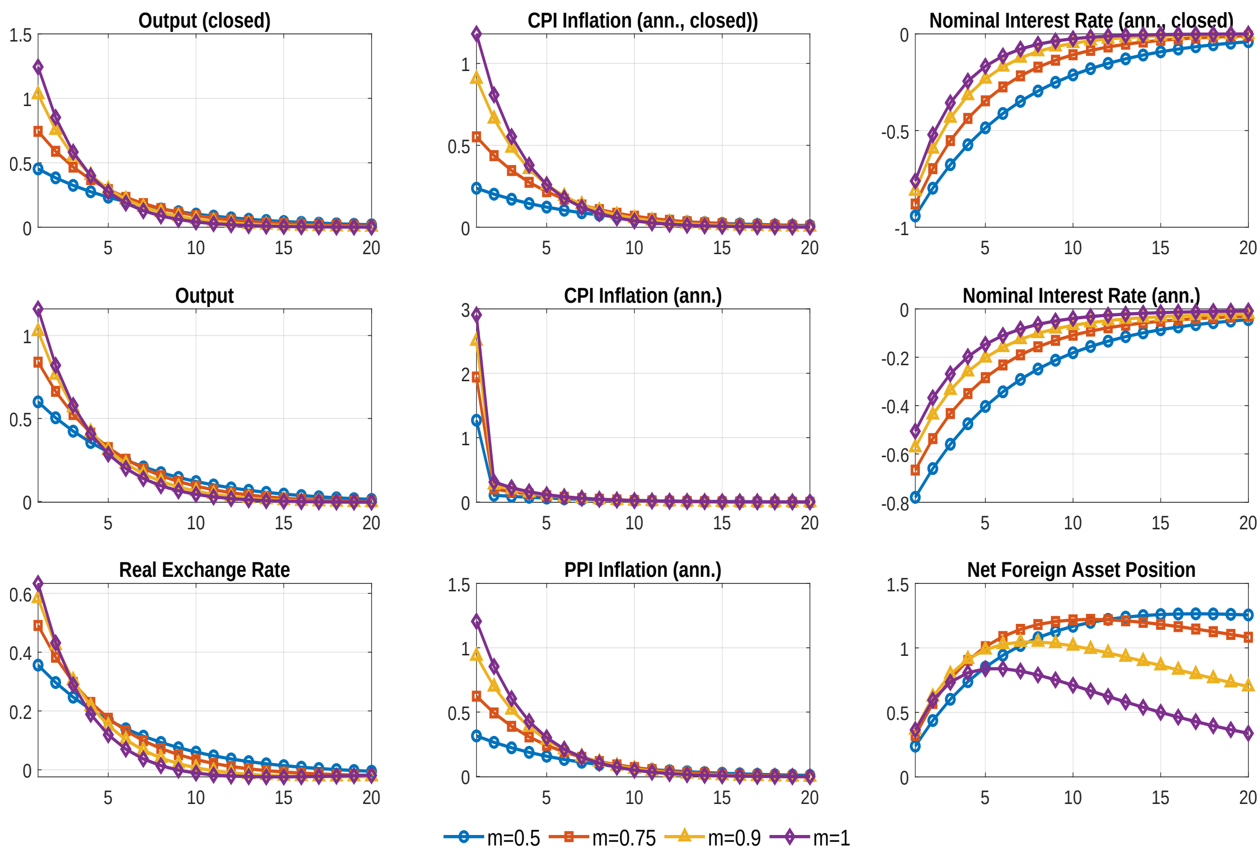
7.1. **Conventional Monetary Shocks.** Having developed intuition on how cognitive discounting affects transmission of real interest rates, we now move on to more standard policy experiments. We first study the dynamic responses to monetary policy (MP) shocks, defined conventionally as

[17] See Appendix B for full details of the derivation.

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

innovations in the policy rule describing the evolution of the nominal rate (20). Broadly, since our empirically motivated Taylor rule features interest rate smoothing, the outcomes shall end up being a combination of standard monetary policy and forward guidance shocks studied in the preceding sections. Given these tight links, in what follows we augment numerical simulations using the analytical results just described.

FIGURE 6. **Dynamic Responses to a Monetary Easing**



Note: This figure shows the impulse response functions to a 25bp (100 bp annualized) negative monetary policy shock. The first row depicts responses of output, CPI inflation and the nominal interest rate for the closed economy. The second and the third rows show IRFs for variables in the open economy. Responses of inflation and the interest rate are in annualized percentage points.

Figure 6 presents impulse responses to 100bp (annualized) worth of conventional monetary easing, contrasting the closed economy version of our model (row 1) with its fully-fledged, open economy counterpart (rows 2 and 3). We immediately see that discounting fairly efficiently dampens the effects of current monetary policy shocks. Intuitively, this occurs because under interest rate smoothing the policy rate will be lower for some time into the future, which behavioral agents "cognitively discount", i.e., they expect a less low path than the one that ends up materializing. Consistently with analytical results from the previous section, discounting matters more for domestic inflation than for the exchange rate, and hence also for CPI. As output depends on the CPI-deflated real interest rate, its response is also less sensitive to discounting in the open economy case.

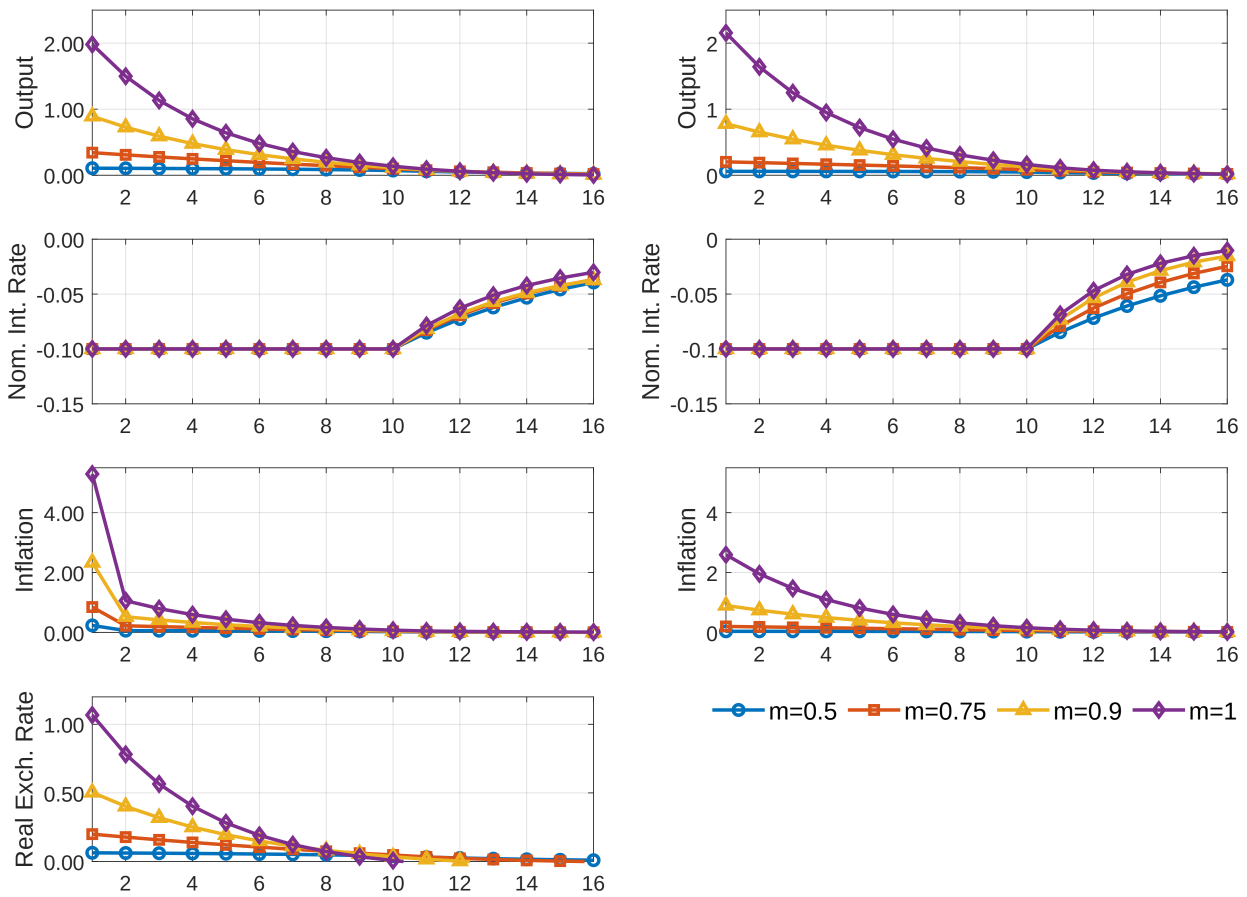
Another notable open economy finding is that discounting tends to make the accumulation of net foreign assets more persistent. Consistently with the line of reasoning provided above, agents underestimate the persistence of future interest rates and so end up being surprised by their actual level, which plays out as additional unanticipated shocks, which in turn delay NFA accumulation. This is entirely in line with the preceding discussion of stationarity issues, and specifically with the observation that net foreign assets are closer to being non-stationary under cognitive discounting. More inertial NFA also translates into more persistence in the real exchange rate, delaying its eventual appreciation relative to the steady state value, thus also postponing the sign reversal in excess returns that we discussed in Section 5.2.

7.2. **Low for Longer Policies.** We now focus on a variant of monetary policy often dubbed as "low for longer" (LFL). The idea, due to Reifschneider and Willams (2000), is that if the policy rate cannot be lowered by the desired amount, it may be cut by less, but kept at that level for a prolonged period of time. Model-based analyses (see e.g., Kiley and Roberts, 2017) have suggested that these policies are effective, which is perhaps unsurprising as the commitment to keeping rates low means that LFL policies inherit some of the (counterfactual) potency of forward guidance.

The experiments we consider in this section implicitly assume that the central bank desires to provide stimulus to the economy by unexpectedly deviating from the Taylor rule by 100bp (annualized), as in Figure 6. Since the proximity of the effective lower bound makes that impossible, it therefore lowers the policy rate by 10bp, but keeps it at that level for 10 quarters, with Figure 7 presenting the outcomes. Comparing these to Figure 6, for the the case of no discounting, confirms that LFL is very effective in both closed and open economy cases, which implicitly reflects the underlying FGP.

In line with our discussion in Section 6, which highlighted that the forward guidance puzzle was more pronounced in a closed economy setting, we find that "low for longer" policies are particularly efficient in that case as well. However, even for moderate levels of discounting, e.g., $m = 0.9$,

Figure 7. **Low for Longer Policy**



(a) Open Economy (b) Closed Economy

Note: In this figure, we show the impulse response functions to two and a half years of a "Low for Longer" policy for different values of m.

these results can flip sign, with LFL becoming less efficient than the corresponding "conventional" stimulus. Finally, but also in line with our discussion in Section 6, Figure 7 highlights that the potency of "low for longer" policies is relatively more affected by "cognitive discounting" in the closed economy case.

8. 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 (13) with the resource constraint (18) and iterate on the outcome to arrive at

$$\hat{Y}_t = \underbrace{\alpha \hat{Y}_t^*}_{\text{Demand Channel}} + \underbrace{\eta \frac{\alpha(2-\alpha)}{1-\alpha} \hat{Q}_t}_{\text{Expenditure Switching Channel}}$$
$$\underbrace{-\frac{1-\alpha}{\sigma} \mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t} \hat{r}_T}_{\text{Endogenous Home Policy Response}} \underbrace{+ (1-m)(1-\alpha) \frac{1-\beta}{1+\frac{\sigma}{\mu\varphi}} \mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t} \hat{B}_T^*}_{\text{Myopia “Damper”}}. \tag{40}$$

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 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.[20] 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.

To provide more insight 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 (40) 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 (21) forward, substituting in the outcome for foreign output, and then using the UIP condition (34) to substitute for the real exchange rate, yields

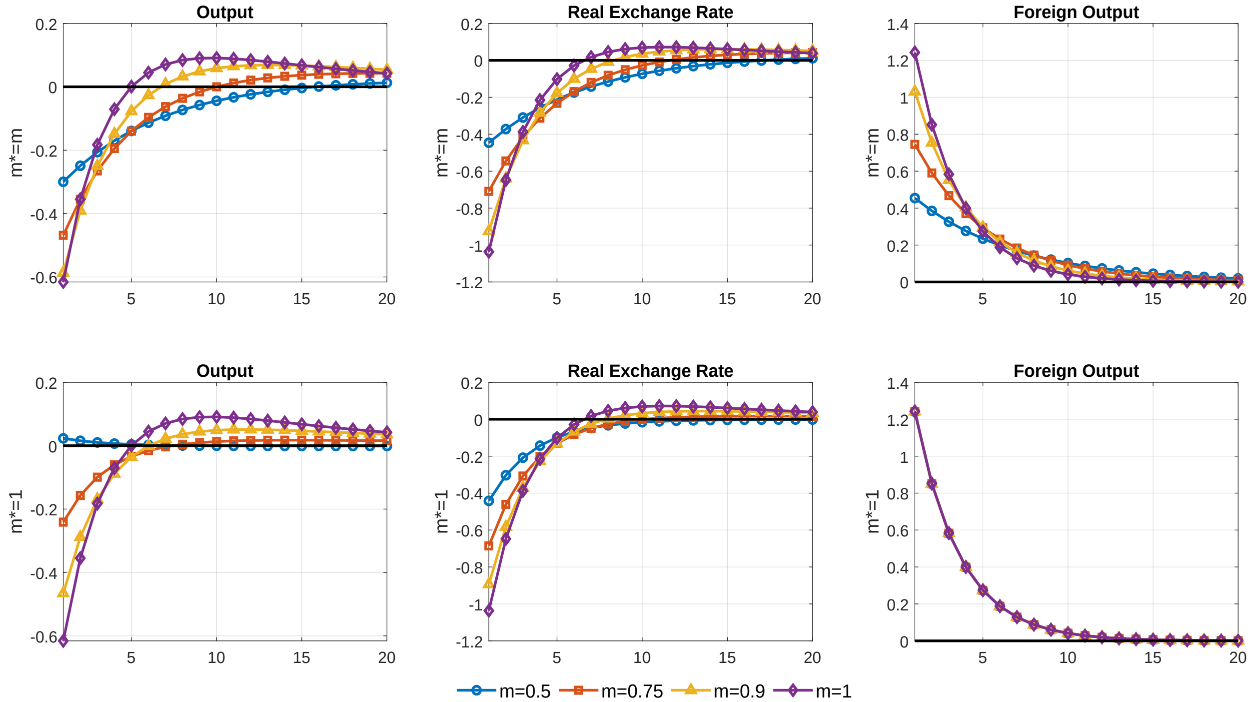
$$\hat{Y}_t \approx \left(-\frac{\alpha}{\sigma} + \eta \frac{\alpha(2-\alpha)}{1-\alpha}\right) \mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t} \hat{r}_T^*, \tag{41}$$

where the approximation comes from omitting terms depending on the net foreign asset position, which are quantitatively small and hence immaterial for the results.

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

[20] Recall that, and as explained in Section 7.1, discounting moderates the Home interest rate channel.

FIGURE 8. **Monetary Spillovers**



Note: This figure shows the impulse response functions to a 25bp (100 bp annualized) negative foreign monetary policy shock. The first row shows the case where $m^* = m$ while the second row corresponds to $m^* = 1$.

Note that, unless the trade elasticity is very low (the formal condition being again $\eta < \frac{1-\alpha}{2-\alpha}\sigma^{-1} \leq \frac{1}{2}\sigma^{-1}$, see Section 6.2), the coefficient on the real interest rate path is positive and hence, assuming constant real interest rates at Home at all times, output spillovers from current or expected future monetary easing abroad are negative.

How is their magnitude affected by discounting? Similarly to the case of domestic effects discussed in Section 6, the impact of future real interest rate changes on other countries' output declines with agent myopia, so that forward guidance becomes less powerful also in the context of international spillovers. Furthermore, to the extent that foreign monetary policy easing generates persistent effects on the foreign real rate, as is typically the case because of interest rate smoothing, the international transmission of current policy easing in the Foreign economy is also weaker. This effect is illustrated in the first row of Figure 8, which also demonstrates that the role of both spillover channels decreases in the degree of myopia, resulting in a lower response in Home economy's output, conditional on it keeping its own real interest rate constant.

Finally, it is also worth noting that spillovers can be even less negative if agents are less myopic in the Foreign economy compared to Home agents. In the more general case of $m^* \neq m$, Equation (41) becomes

$$\hat{Y}_t \approx \underbrace{-\frac{\alpha}{\sigma}\mathbb{E}_t \sum_{T=t}^{\infty} m^{*T-t}\hat{r}_T^*}_{\text{Demand Channel}} + \underbrace{\eta \frac{\alpha(2-\alpha)}{1-\alpha}\mathbb{E}_t \sum_{T=t}^{\infty} m^{T-t}\hat{r}_T^*}_{\text{Expenditure Switching Channel}}, \tag{42}$$

where, again, the first term represents the foreign demand channel while the second one corresponds to the expenditure switching channel. Clearly, $m^* > m$ increases the importance of the former, which acts towards positive cross-country comovement in output conditional on foreign monetary shocks. We illustrate this effect in the second row of Figure 8 by assuming $m^* = 1$, i.e. we consider the extreme case of fully rational foreign agents. As explained, myopia of Home agents makes the effects of foreign monetary policy easing less negative when the Home real interest rate is kept constant, and can even turn them positive for a sufficiently high degree of discounting.

9. Optimal Monetary Policy

We finally discuss the implications of agents' myopia for the optimal conduct of monetary policy. To make our analysis tractable, we follow Gali and Monacelli (2005) and make several simplifying assumptions.[21] More specifically, we focus on the case of complete markets and assume the presence of an employment subsidy that neutralizes the static monopolistic distortion in production of intermediate goods. We also stick to our baseline calibration by fixing the elasticity of intertemporal substitution and price elasticity of international trade at unity. Following most of the behavioral literature, including Gabaix (2020), the welfare criterion is defined as the utility of a representative household under rational expectations. All of the above allows us to approximate the welfare loss in quadratic form as (see Appendix D for derivations)

$$\mathbb{U}_t \approx -\frac{1-\alpha}{2}\mathbb{E}_t \sum_{T=t}^{\infty} \beta^{T-t}\left[\frac{\mu}{\kappa(\mu-1)}\hat{\pi}_{H,T}^2 + (1+\varphi)\hat{x}_T^2\right] + t.i.p., \tag{43}$$

where $\hat{x}_t \equiv \log(Y_t/\bar{Y}_t)$ is the output gap, defined as the log-deviation of output from its efficient level $\bar{Y}_t$, which coincides with flexible price output under rational expectations, and *t.i.p.* stands for terms independent of policy.

[21] By making these assumptions we essentially extend the analysis in Gali and Monacelli (2005) to the behavioral case. See De Paoli (2009) for how market incompleteness complicates formulation of optimal policy under RE.

Having the welfare loss approximation in quadratic form allows us to characterize the optimal policy problem to second-order, using the linearized equilibrium conditions that summarize agents' decisions as constraints. The key one is the domestic Phillips curve (15), which we can rewrite in output gap terms as follows

$$\hat{\pi}_{H,t} = m\beta\mathbb{E}_t\{\hat{\pi}_{H,t+1}\} + \kappa(1+\varphi)\hat{x}_t + \xi_t, \tag{44}$$

where we also add a standard cost-push shock ξ_t to create a monetary policy tradeoff. Solving the problem under commitment (timeless perspective) results in the following optimal targeting rule

$$\hat{\pi}_{H,t} + \frac{\mu-1}{\mu}(\hat{x}_t - m\hat{x}_{t-1}) = 0, \tag{45}$$

and the optimal producer price level follows

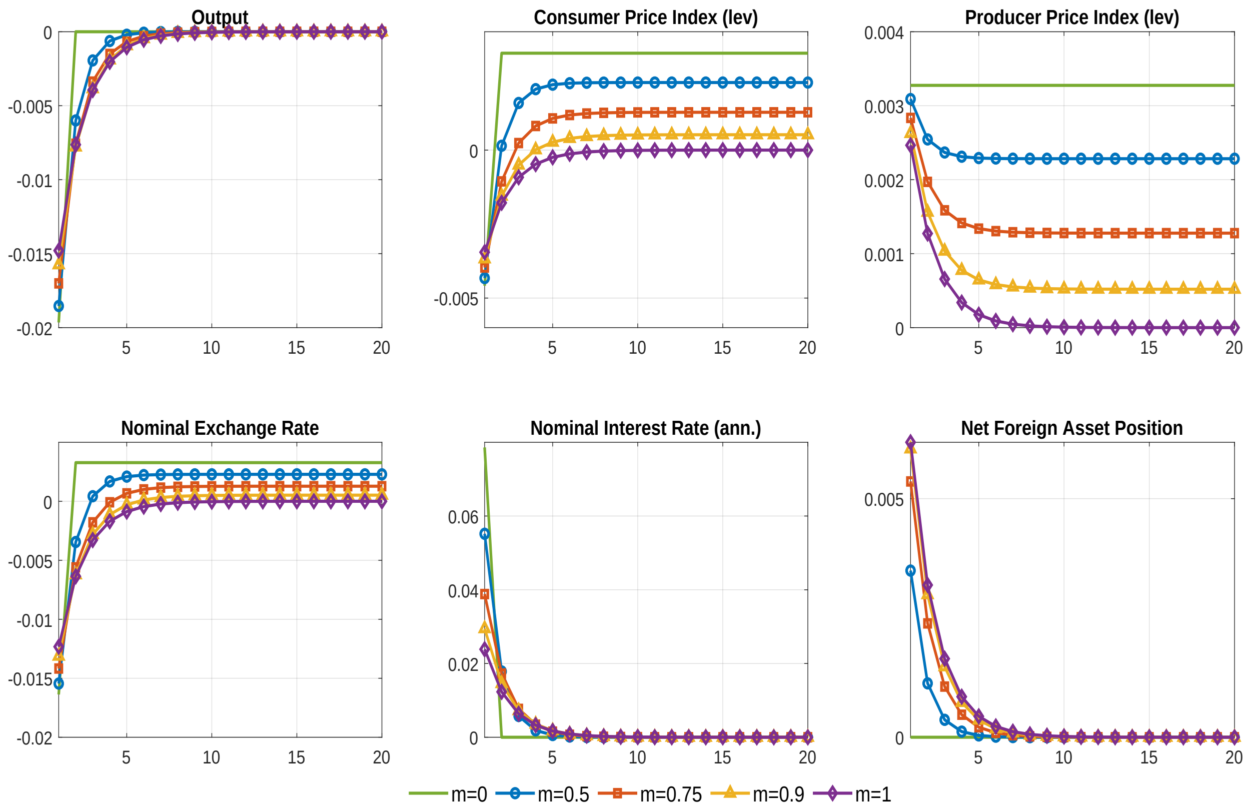
$$\hat{P}_{H,t} = \frac{\mu-1}{\mu}\left[\hat{x}_t - (1-m)\sum_{T=0}^{t-1}\hat{x}_T\right] \tag{46}$$

with $\hat{P}_{H,t} \equiv \log(P_{H,t}/P_{H,-1}) = \log(P_{H,t})$ denoting the log-deviation of the producer price index from its initial level, and where the latter is normalized to unity without loss of generality.

Formulas (45) and (46) above are the same as in Gabaix (2020) and Benchimol and Bounader (2019), who however consider closed economy setups where the distinction between domestic and final consumption goods disappears. Absent cost-push shocks, it is then optimal for the central bank to perfectly stabilize producer prices as that guarantees an efficient allocation. In contrast, when cost-push shocks are present, the monetary authority should deviate from period by period stabilization of producer prices. Importantly, and in line with optimal monetary policy analysis with closed economy behavioral models, equation (46) implies that, unless $m = 1$ as in the RE case, price level targeting is no longer optimal even in the long run: positive cost-push shocks (which open a negative output gap) push the price level permanently up.

To illustrate and further study these results, Figure 9 plots optimal impulse responses to a positive i.i.d. cost-push shock. When agents are forward-looking and the central bank can credibly commit to future actions, it is optimal to generate a longer lasting recession even when the shock has zero persistence. This is because promising future deflation helps bring the current inflation down. This motive becomes weaker when agents (firms in this case) are myopic, and hence the optimizing policy maker exploits it less. As a result, despite tightening more and generating a deeper fall in output on impact, the outcome is a higher and permanent increase in producer prices. In this way, when agents are myopic, optimal monetary policy under commitment comes closer to the discretionary case. Indeed, in the extreme case of $m = 0$, the optimal responses to an i.i.d. cost-push shock correspond to the discretionary policy outcome: output falls below its steady state level only in the period of the shock while the price level goes up on impact and then remains flat.

FIGURE 9. **Optimal Responses to a Cost-Push Shock**



Note: This figure shows the impulse response functions to a 0.25% i.i.d. cost-push shock. The purple and green lines indicate the extreme cases of no discounting ($m = 1$) and full discounting ($m = 0$).

These considerations have important consequences in an open economy context. Since, independently of the degree of discounting, the optimal response is to tighten monetary policy, the exchange rate appreciates on impact and then depreciates. However, while it eventually comes back to its initial level when agents are fully rational, it becomes permanently weaker when they are instead myopic, consistent with a permanent increase in the producer price level. An implication is that, when monetary policy is conducted optimally, the nominal exchange rate follows a random walk, even when all relative prices such as the terms of trade or the real exchange rate are stationary. Our results thus suggest that attempting to use the exchange rate as a nominal anchor – a potentially attractive alternative for emerging economies lacking monetary credibility (see, e.g., Frankel, 2010) – becomes considerably less appealing when agents are myopic.

We finally note that optimal policy in an economy with behavioral agents makes the net foreign asset position less responsive to shocks, as can be gleaned from the last panel of Figure 9. Again, this feature reflects incentives of the policy maker to exploit forward-looking behavior of agents to keep consumption down for longer, which is reflected in a positive value of net portfolio vis-a-vis the rest of the world. As explained before, this incentive is lower when agents are myopic and, in the extreme case of $m = 0$, net foreign assets do not respond at all to temporary cost-push shocks.

10. Conclusions

In this paper, we have extended the standard open economy New Keynesian framework by adding behavioral agents. We have shown that the resulting model significantly improves upon its fully rational variant along many dimensions. First, it helps resolve several 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 mitigating the forward guidance puzzle. Third, by decreasing the relative strength of the exchange rate channel, the behavioral open economy model can better account for international output comovement. We have also shown that cognitive discounting has important implications for the optimal conduct of monetary policy, 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 eliminate.

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Appendices

Appendix A. Key Derivations

In this Appendix we present the key steps necessary to derive the linearized equilibrium conditions of a small open economy version of our model. Unless indicated otherwise, we use the variable transformations defined in Section 3.

A.1. **Household Budget Constraint and Optimality Conditions.** Linearizing the budget constraint (3) yields

$$\hat{B}_t^{*,h} + \hat{B}_t^h = \beta^{-1}\left(\hat{B}_{t-1}^{*,h} + \hat{B}_{t-1}^h + \mu^{-1}(\hat{W}_t + \hat{N}_t^h) + \hat{D}_t - \hat{C}_t^h\right), \tag{A.1}$$

where $\hat{D}_t \equiv (D_t - D)/Y$, and where we used the assumption of zero steady state assets ($B^* = B = 0$), as well as the result that the steady state labor share is the inverse of the (gross) product markup μ.

Given the household's utility function (1) and budget constraint (3), the optimization problem yields the following linearized Euler equations associated with Home and Foreign bond holdings

$$\hat{C}_t^h = \hat{\mathbb{E}}_t \hat{C}_{t+1}^h - \frac{1}{\sigma}\hat{\mathbb{E}}_t\left\{\hat{i}_t - \hat{\pi}_{t+1}\right\}, \tag{A.2}$$

$$\hat{C}_t^h = \hat{\mathbb{E}}_t \hat{C}_{t+1}^h - \frac{1}{\sigma}\hat{\mathbb{E}}_t\left\{\hat{i}_t^* - \hat{\pi}_{t+1}^* + \hat{Q}_{t+1} - \hat{Q}_t - \phi\hat{B}_t^*\right\}, \tag{A.3}$$

where $\phi = \Phi'(0)$, and the intratemporal labor supply condition is

$$\hat{W}_t = \sigma\hat{C}_t^h + \varphi\hat{N}_t^h. \tag{A.4}$$

Combining equations (A.2) and (A.3) results in

$$\hat{\mathbb{E}}_t\left\{\hat{i}_t - \hat{\pi}_{t+1}\right\} = \hat{\mathbb{E}}_t\left\{\hat{i}_t^* - \hat{\pi}_{t+1}^* + \hat{Q}_{t+1} - \hat{Q}_t - \phi\hat{B}_t^*\right\}. \tag{A.5}$$

Since this equation features expectations in aggregate variables that are beyond the control of an individual agent, and which are expressed as deviations from their respective steady state values, we can use the behavioral discounting formula (11) for $k = 0, 1$ to write

$$\hat{i}_t - m\mathbb{E}_t\left\{\hat{\pi}_{t+1}\right\} = \hat{i}_t^* - m\mathbb{E}_t\left\{\hat{\pi}_{t+1}^* - \hat{Q}_{t+1}\right\} - \hat{Q}_t - \phi\hat{B}_t^*, \tag{A.6}$$

which is the UIP condition (14) in the main text.

A.2. **Deriving the Individual Consumption Function.** Let us iterate the linearized budget constraint forward and use the standard transversality condition to write

$$\hat{B}_{t-1}^{*,h} + \hat{B}_{t-1}^h = \hat{\mathbb{E}}_t \sum_{T=t}^{\infty} \beta^{T-t}\left(\hat{C}_T^h - \mu^{-1}(\hat{W}_T + \hat{N}_T^h) + \hat{D}_T\right). \tag{A.7}$$

Note that by multiplying the Euler equation (A.2) by β and iterating forward we obtain

$$\hat{C}_t^h = (1-\beta)\hat{\mathbb{E}}_t \sum_{T=t}^{\infty} \beta^{T-t} \hat{C}_T^h - \frac{\beta}{\sigma}\hat{\mathbb{E}}_t \sum_{T=t}^{\infty} \beta^{T-t} \left(\hat{i}_T - \hat{\pi}_{T+1}\right). \tag{A.8}$$

Combining the two and rearranging yields

$$\hat{C}_t^h = (1-\beta)\left(\hat{B}_{t-1}^{*,h} + \hat{B}_{t-1}^h\right) + \hat{\mathbb{E}}_t \sum_{T=t}^{\infty} \beta^{T-t} \left[(1-\beta)\left(\frac{1}{\mu}(\hat{W}_T + \hat{N}_T^h) + \hat{D}_T\right) - \frac{\beta}{\sigma}\left(\hat{i}_T - \hat{\pi}_{T+1}\right)\right]. \tag{A.9}$$

We can now use the equilibrium condition (A.4) to eliminate individual labor supply

$$\hat{C}_t^h = (1-\beta)\left(\hat{B}_{t-1}^{*,h} + \hat{B}_{t-1}^h\right) + \hat{\mathbb{E}}_t \sum_{T=t}^{\infty} \beta^{T-t} \left[(1-\beta)\left(\frac{\varphi+1}{\mu\varphi}\hat{W}_T - \frac{\sigma}{\mu\varphi}\hat{C}_T^h + \hat{D}_T\right) - \frac{\beta}{\sigma}\left(\hat{i}_T - \hat{\pi}_{T+1}\right)\right], \tag{A.10}$$

and again exploit Equation (A.8) to finally obtain

$$\left(1+\frac{\sigma}{\mu\varphi}\right)\hat{C}_t^h = (1-\beta)\left(\hat{B}_{t-1}^{*,h} + \hat{B}_{t-1}^h\right) + \hat{\mathbb{E}}_t \sum_{T=t}^{\infty} \beta^{T-t} \left[(1-\beta)\left(\frac{\varphi+1}{\mu\varphi}\hat{W}_T + \hat{D}_T\right) - \frac{\beta}{\sigma}\left(1+\frac{\sigma}{\mu\varphi}\right)\left(\hat{i}_T - \hat{\pi}_{T+1}\right)\right]. \tag{A.11}$$

The equation above is the individual consumption function that incorporates labor supply choice.

A.3. **Deriving the IS Curve.** Since Equation (A.11) features expectations only about aggregate variables, we can apply to it the behavioral discounting formula (11) for $k = 0, 1, 2, ...$

$$\left(1+\frac{\sigma}{\mu\varphi}\right)\hat{C}_t^h = (1-\beta)\left(\hat{B}_{t-1}^{*,h} + \hat{B}_{t-1}^h\right) + \mathbb{E}_t \sum_{T=t}^{\infty} (\beta m)^{T-t} \left[(1-\beta)\left(\frac{\varphi+1}{\mu\varphi}\hat{W}_T + \hat{D}_T\right) - \frac{\beta}{\sigma}\left(1+\frac{\sigma}{\mu\varphi}\right)\left(\hat{i}_T - m\hat{\pi}_{T+1}\right)\right], \tag{A.12}$$

so that it now uses the rational expectations operator rather than the subjective one. Since we no longer need to make a distinction between macroeconomic aggregates and individual choices, we can drop indexing consumption and assets by h and use the Home bond market clearing condition $B_t = 0$. After some algebra, we can write Equation (A.12) recursively

$$\left(1+\frac{\sigma}{\mu\varphi}\right)\hat{C}_t = (1-\beta)\left(\hat{B}_{t-1}^{*} + \hat{B}_{t-1} - m\beta\hat{B}_t^* - m\beta\hat{B}_t\right) + (1-\beta)\left(\frac{\varphi+1}{\mu\varphi}\hat{W}_t + \hat{D}_t\right) - \frac{\beta}{\sigma}\left(1+\frac{\sigma}{\mu\varphi}\right)\left(\hat{i}_t - m\mathbb{E}_t\hat{\pi}_{t+1}\right) + m\beta\left(1+\frac{\sigma}{\mu\varphi}\right)\mathbb{E}_{t+1}\hat{C}_{t+1}. \tag{A.13}$$

Now we can use the budget constraint (A.1) and the Home currency bond market clearing condition $B_t = 0$ to obtain

$$\left(\beta + \frac{\sigma}{\mu\varphi}\right)\hat{C}_t = (1-\beta)(1-m)\beta\hat{B}^*_t + \frac{1-\beta}{\mu}\left(\frac{1}{\varphi}\hat{W}_t - \hat{N}_t\right) - \frac{\beta}{\sigma}\left(1+\frac{\sigma}{\mu\varphi}\right)\left(\hat{i}_t - m\mathbb{E}_t\hat{\pi}_{t+1}\right) + m\beta\left(1+\frac{\sigma}{\mu\varphi}\right)\mathbb{E}_{t+1}\hat{C}_{t+1}. \quad \text{(A.14)}$$

Finally, using the optimal labor supply condition (A.4) results in

$$\hat{C}_t = m\mathbb{E}_t\hat{C}_{t+1} - \frac{1}{\sigma}\left(\hat{i}_t - m\mathbb{E}_t\hat{\pi}_{t+1}\right) + (1-m)\frac{1-\beta}{1+\frac{\sigma}{\mu\varphi}}\hat{B}^*_t, \quad \text{(A.15)}$$

which is the aggregate IS curve (13) in the main text.

A.4. **Deriving the Phillips Curve.** Aggregation of intermediate inputs into final goods according to Dixit-Stiglitz formulas (4) yields the following isoelastic demand condition

$$Y^f_{H,t} + Y^{*,f}_{H,t} = \left(\frac{P^f_{H,t}}{P_{H,t}}\right)^{\frac{\mu}{1-\mu}}\left[Y_{H,t} + Y^*_{H,t}\right], \quad \text{(A.16)}$$

where the aggregate price indices are

$$P_{H,t} = \left[\int_0^1 \left(P^f_{H,t}\right)^{\frac{1}{1-\mu}}\mathrm{d}f\right]^{1-\mu}, \qquad \text{and} \qquad P^*_{H,t} = \left[\int_0^1 \left(P^{*,f}_{H,t}\right)^{\frac{1}{1-\mu}}\mathrm{d}f\right]^{1-\mu}, \quad \text{(A.17)}$$

and where we used the law of one price $P^f_{H,t} = \varepsilon_t P^{*,f}_{H,t}$, which also implies $P_{H,t} = \varepsilon_t P^*_{H,t}$.

Using the demand conditions (A.16) and production technology (5) allows us to rewrite the firm problem consistent with maximization of (6) as

$$\max_{P^f_{H,t}} \hat{\mathbb{E}}_t \sum_{T=t}^{\infty}\theta^{T-t}\Lambda_{t,T}\left[P^f_{H,t} - P_T\frac{W_T}{z_t}\right]\left(\frac{P^f_{H,t}}{P_{H,T}}\right)^{\frac{\mu}{1-\mu}}\left[Y_{H,T} + Y^*_{H,T}\right]. \quad \text{(A.18)}$$

The first order condition is

$$\hat{\mathbb{E}}_t \sum_{T=t}^{\infty}\theta^{T-t}\Lambda_{t,T}\left[P^f_{H,t} - \mu P_T MC_T\right]\left(\frac{P^f_{H,t}}{P_{H,T}}\right)^{\frac{\mu}{1-\mu}}\left[Y_{H,T} + Y^*_{H,T}\right] = 0, \quad \text{(A.19)}$$

where $MC_t \equiv (W_t P_t)/(P_{H,t} z_t)$ is real marginal cost deflated by the producer price index.

As in a textbook closed economy case (see e.g. Galí, 2015), linearizing around the zero inflation steady state yields

$$\hat{P}^{\diamond}_{H,t} = (1-\beta\theta)\sum_{T=t}^{\infty}(\beta\theta)^{T-t}\hat{\mathbb{E}}_t\left\{\hat{\pi}_{H,t+1} + ... + \hat{\pi}_{H,T} + \hat{MC}_T\right\}, \quad \text{(A.20)}$$

where $\hat{P}^{\diamond}_{H,t} \equiv \log(P^f_{H,t}/P_{H,t})$, $\hat{MC}_t \equiv \log(MC_t/MC)$, $\hat{\pi}_{H,t} \equiv \log(P_{H,t}/P_{H,t-1})$ and where we used the result that all reoptimizing firms choose the same price to drop the f superscript. Since the subjective expectation operator now concerns only variables beyond individual firm control and all of them are expressed as deviations from steady state, we can apply the discounting formula (11) to obtain

$$\hat{P}^{\diamond}_{H,t} = (1-\beta\theta)\sum_{T=t}^{\infty}(\beta\theta)^{T-t}\mathbb{E}_t\left\{m\hat{\pi}_{H,t+1} + ... + m^{T-t}\hat{\pi}_{H,T} + m^{T-t}\hat{MC}_T\right\}. \tag{A.21}$$

Note that this step differs from Gabaix (2020), who discounts all terms in the curly bracket of Equation (A.20) by m^{T-t}. By doing so he implicitly applies myopia to nominal rather than real marginal cost, even though the former is not constant in the steady state (see also Benchimol and Bounader (2019) for a discussion).

After some algebra, this can be written recursively as

$$\hat{P}^{\diamond}_{H,t} - \beta\theta m\mathbb{E}_t\hat{P}^{\diamond}_{H,t+1} = (1-\beta\theta)\hat{MC}_t + \beta\theta m\mathbb{E}_t\left\{\hat{\pi}_{H,t+1}\right\}. \tag{A.22}$$

Note that the definition of the price index (A.17) implies

$$\hat{\pi}_{H,t} = (1-\theta)(\hat{P}^{\diamond}_{H,t} + \hat{\pi}_{H,t}) = \frac{1-\theta}{\theta}\hat{P}^{\diamond}_{H,t}. \tag{A.23}$$

Combining this with Equation (A.22) and rearranging yields

$$\hat{\pi}_{H,t} = m\beta\mathbb{E}_t\left\{\hat{\pi}_{H,t+1}\right\} + \frac{(1-\beta\theta)(1-\theta)}{\theta}\hat{MC}_t, \tag{A.24}$$

which is Equation (15) in the main text.

A.5. **Deriving the Marginal Cost Equation.** The optimal composition of the consumption basket (2) implies the following formula for the aggregate price index P_t

$$P_t = \left[(1-\alpha)\left(P_{H,t}\right)^{1-\eta} + \alpha\left(P_{F,t}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{A.25}$$

which leads to

$$\hat{P}_{H,t} = -\frac{\alpha}{1-\alpha}\hat{P}_{F,t} = -\frac{\alpha}{1-\alpha}\hat{Q}_t, \tag{A.26}$$

where $\hat{P}_{H,t} = \log(P_{H,t}/P_t)$, $\hat{P}_{F,t} = \log(P_{F,t}/P_t)$, and where the last equality follows from the definition of the real exchange rate $Q_t = \varepsilon_t P^*_t$ and the small open economy version of producer currency pricing $P_{F,t} = \varepsilon_t P^*_t$.

Combining labor market clearing condition (9), with the firm-level production function (5), and the firm's demand conditions (A.16) yields

$$N_t = \frac{Y_{H,t} + Y^*_{H,t}}{z_t}\Delta_t, \tag{A.27}$$

where

$$\Delta_t \equiv \int_0^1 \left(\frac{P^f_{H,t}}{P_{H,t}}\right)^{\frac{\mu}{1-\mu}} \mathrm{d}f \tag{A.28}$$

is a measure of price dispersion. Defining aggregate output as the sum of domestic production and exports results in the following aggregate production function

$$Y_t \equiv Y_{H,t} + Y^*_{H,t} = \frac{z_t}{\Delta_t} N_t, \tag{A.29}$$

the linearized version of which is

$$\hat{Y}_t = \hat{z}_t + \hat{N}_t - \hat{\Delta}_t. \tag{A.30}$$

Given the problem of firms, their marginal cost deflated by producer prices is

$$\hat{MC}_t = \hat{W}_t - \hat{P}_{H,t} - \hat{z}_t, \tag{A.31}$$

where $\hat{P}_{H,t} = \log(P_{H,t}/P_t)$. Using Equation (A.26) to substitute in for $\hat{P}_{H,t}$, labor supply condition (A.4) to eliminate $\hat{W}_t$, Equation (A.30) to eliminate $\hat{N}_t$, and the well-known result that price dispersion is of second order (see, e.g., Woodford, 2003) yields

$$\hat{MC}_t = \sigma\hat{C}_t + \varphi\hat{Y}_t + \frac{\alpha}{1-\alpha}\hat{Q}_t - (1+\varphi)\hat{z}_t, \tag{A.32}$$

which is Equation (16) in the main text.

A.6. **Deriving the Goods Market Clearing Condition.** Our definition of aggregate output (A.29) together with market clearing conditions (10) imply

$$Y_t = C_{H,t} + \frac{1-\zeta}{\zeta} C^*_{H,t}. \tag{A.33}$$

Plugging in for the optimal composition of the consumption basket then results in

$$Y_t = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t + \frac{1-\zeta}{\zeta}\alpha^*\left(\frac{P^*_{H,t}}{P^*_t}\right)^{-\eta} C^*_t. \tag{A.34}$$

The small open economy assumption and producer currency pricing imply $C^*_t = Y^*_t$ and $P^*_{H,t} = P_{H,t}/\varepsilon_t$. This allows us to write

$$Y_t = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t + \frac{1-\zeta}{\zeta}\alpha^*\left(\frac{P_{H,t}}{P_t Q_t}\right)^{-\eta} Y^*_t. \tag{A.35}$$

Linearization then yields

$$\hat{Y}_t = (1-\alpha)\hat{C}_t - (1-\alpha)\eta\hat{P}_{H,t} + \alpha\hat{Y}^*_t - \alpha\eta(\hat{P}_{H,t} - \hat{Q}_t). \tag{A.36}$$

Using Equation (A.26) to eliminate $\hat{P}_{H,t}$ and rearranging terms results in

$$\hat{Y}_t = (1-\alpha)\hat{C}_t + \alpha\hat{Y}^*_t + \eta\frac{\alpha(2-\alpha)}{1-\alpha}\hat{Q}_t, \tag{A.37}$$

which is equation (18) in the main text.

Appendix B. Additional Derivations

B.1. **Deriving Equation** (36)**.** Eliminating consumption from Equation (13) using the resource constraint (18) results in

$$\hat{Y}_t = m\mathbb{E}_t\hat{Y}_{t+1} + \alpha\left(\hat{Y}_t^* - m\mathbb{E}_t\hat{Y}_{t+1}^*\right) + \eta\frac{\alpha(2-\alpha)}{1-\alpha}\left(\hat{Q}_t - m\mathbb{E}_t\hat{Q}_{t+1}\right) \\ - \frac{1-\alpha}{\sigma}\left(\hat{i}_t - m\mathbb{E}_t\hat{\pi}_{t+1}\right) + (1-m)(1-\alpha)\frac{1-\beta}{1+\frac{\sigma}{\mu\varphi}}\hat{B}_t^*, \quad \text{(B.1)}$$

and exploiting the UIP condition (14) then yields

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

When considering the effects of Home monetary policy, we can drop foreign variables as they are exogenous on account of the small open economy assumption. By rearranging and using the definition of the ex ante real interest rate $\hat{r}_t \equiv \hat{i}_t - m\mathbb{E}_t\hat{\pi}_{t+1}$ we then arrive at

$$\hat{Y}_t = m\mathbb{E}_t\hat{Y}_{t+1} - \left(\frac{1-\alpha}{\sigma} + \eta\frac{\alpha(2-\alpha)}{1-\alpha}\right)\hat{r}_t - \left[\eta\frac{\alpha(2-\alpha)}{1-\alpha}\phi - (1-m)(1-\alpha)\frac{1-\beta}{1+\frac{\sigma}{\mu\varphi}}\right]\hat{B}_t^*, \quad \text{(B.3)}$$

which is Equation (36) in the main text.

B.2. **Deriving Equations** (38) **and** (39)**.** By combining equations (15) and (16), and iterating forward on the outcome, we obtain

$$\hat{\pi}_{H,t} = \kappa\mathbb{E}_t\sum_{T=t}^{\infty}(\beta m)^{T-t}\left(\sigma\hat{C}_T + \varphi\hat{Y}_T + \frac{\alpha}{1-\alpha}\hat{Q}_T - \hat{z}_t\right), \quad \text{(B.4)}$$

Note that each of the three endogenous variables defining real marginal cost (last bracket above) can be expressed as a function of the current and expected future real interest rates, see in particular equations (35), (37) and (34). Ignoring terms associated with the net foreign asset position (as they are small), omitting productivity shocks (as we focus on the effects of domestic monetary policy), and consistently dropping foreign variables (on account of the the small open economy assumption) allows us to write

$$\sigma\hat{C}_t + \varphi\hat{Y}_t + \frac{\alpha}{1-\alpha}\hat{Q}_t \approx -a\mathbb{E}_t\sum_{T=t}^{\infty}m^{T-t}\hat{r}_T, \quad \text{(B.5)}$$

where $a \equiv \varphi\left(\frac{1-\alpha}{\sigma} + \eta\frac{\alpha(2-\alpha)}{1-\alpha}\right) + \frac{1}{1-\alpha}$. Plugging this into Equation (B.4) yields

$$\hat{\pi}_{H,t} \approx -\kappa a\mathbb{E}_t\left[\hat{r}_t + m(1+\beta)\hat{r}_{t+1} + ... + m^n(1+\beta+...+\beta^n)\hat{r}_{t+n} + ...\right] \\ = -\kappa a\mathbb{E}_t\sum_{T=t}^{\infty}\frac{m^{T-t+1} - (\beta m)^{T-t+1}}{m(1-\beta)}\hat{r}_T. \quad \text{(B.6)}$$

Recall that CPI inflation is given by Equation (17). Exploiting relationships (B.6) and (34), and again ignoring terms related to net foreign assets, yields

$$\hat{\pi}_t \approx -\frac{\kappa a}{m(1-\beta)}\mathbb{E}_t \sum_{T=t}^{\infty}\left[m^{T-t+1}-(\beta m)^{T-t+1}\right]\hat{r}_T - \frac{\alpha}{1-\alpha}\mathbb{E}_t\sum_{T=t}^{\infty} m^{T-t}\hat{r}_T - \frac{\alpha}{1-\alpha}\hat{Q}_{t-1}, \quad \text{(B.7)}$$

which is Equation (38) in the main text.

In the limit $\beta \to 1$ we also have $M \to m$, and Equation (B.6) becomes

$$\hat{\pi}_{H,t} = -\kappa a \mathbb{E}_t\left[\hat{r}_t + 2m\hat{r}_{t+1} + ... + (n+1)m^n\hat{r}_{t+n} + \dots\right], \quad \text{(B.8)}$$

which plugged into the definition of CPI (17) results in

$$\hat{\pi}_t = -\kappa a \mathbb{E}_t \sum_{T=t}^{\infty}(T-t+1)\, m^{T-t}\hat{r}_T - \frac{\alpha}{1-\alpha}\mathbb{E}_t\sum_{T=t}^{\infty} m^{T-t}\hat{r}_T - \frac{\alpha}{1-\alpha}\hat{Q}_{t-1}, \quad \text{(B.9)}$$

which is Equation (39) in the text.

Finally, the relative weight of the penultimate component in the formula above is

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

and so it is clearly increasing in the economy's openness α.

B.3. **Deriving Equation** (40) **and** (41)**.** Let us rearrange the output IS curve (B.1) as follows

$$\hat{Y}_t - \alpha\hat{Y}^*_t - \eta\frac{\alpha(2-\alpha)}{1-\alpha}\hat{Q}_t = m\mathbb{E}_t\left\{\hat{Y}_{t+1} + \alpha\hat{Y}^*_{t+1} + \eta\frac{\alpha(2-\alpha)}{1-\alpha}\hat{Q}_{t+1}\right\}$$
$$- \frac{1-\alpha}{\sigma}\mathbb{E}_t\sum_{T=t}^{\infty} m^{T-t}\hat{r}_T + (1-m)(1-\alpha)\frac{1-\beta}{1+\frac{\sigma}{\mu\varphi}}\hat{B}^*_t. \quad \text{(B.10)}$$

Iterating this forward yields

$$\hat{Y}_t = \alpha\hat{Y}^*_t + \eta\frac{\alpha(2-\alpha)}{1-\alpha}\hat{Q}_t - \frac{1-\alpha}{\sigma}\mathbb{E}_t\sum_{T=t}^{\infty} m^{T-t}\hat{r}_T + (1-m)(1-\alpha)\mathbb{E}_t\sum_{T=t}^{\infty} m^{T-t}\hat{B}^*_T, \quad \text{(B.11)}$$

which is Equation (40) in the main text.

To derive Equation (41), we iterate forward on the foreign IS curve (21) and use the outcome to substitute for $\hat{Y}^*_t$ above, exploiting Equation 34 to substitute for $\hat{Q}_t$. After omitting the terms associated with net foreign assets, assuming constant real interest rate in the Home economy $\hat{r}_t = 0$, and rearranging we arrive at

$$\hat{Y}_t \approx \left(-\frac{\alpha}{\sigma} + \eta\frac{\alpha(2-\alpha)}{1-\alpha}\right)\mathbb{E}_t\sum_{T=t}^{\infty} m^{T-t}\hat{r}^*_T, \quad \text{(B.12)}$$

which is Equation (41) in the main text.

Appendix C. Complete Markets Case

C.1. **Deriving the IS Curve.** When markets are complete, the budget constraint (3) can be rewritten as

$$C_t^h + \hat{\mathbb{E}}_t q_{t,t+1} A_{t+1}^h = A_t^h + W_t N_t^h + D_t, \tag{C.1}$$

where A_t^h is real stochastic payoff of a portfolio of Arrow-Debreu securities purchased by household h at time $t-1$ and $q_{t,t+1}$ is the pricing kernel so that $\hat{\mathbb{E}}_t q_{t,t+1} A_{t+1}^h$ is the period-t price of a random payment A_{t+1}^h that occurs in period $t+1$ (see e.g. Woodford (2003) for a discussion). In a behavioral model like ours, $q_{t,t+1}$ can be interpreted as the price of a contingent claim that pays one unit of good in some state at time $t+1$, divided by the *subjective* probability of occurrence of that state given information at time t.

It then immediately follows that in the steady state we have $q = (1+r)^{-1} = \beta$. Linearizing around the zero asset holdings equilibrium yields

$$\hat{\mathbb{E}}_t \hat{A}_{t+1}^h = \beta^{-1}\left(\hat{A}_t^h + \mu^{-1}(\hat{W}_t + \hat{N}_t^h) + \hat{D}_t - \hat{C}_t^h\right). \tag{C.2}$$

Optimization by households still implies the same household-level Euler equation (A.2) and intratemporal optimality condition (A.4). This allows us to proceed exactly as in Appendix (A.2) to obtain an individual consumption function that is similar to equation (A.11), and which features expectations about aggregate variables only

$$\begin{aligned}\left(1+\frac{\sigma}{\mu\varphi}\right)\hat{C}_t^h &= (1-\beta)\hat{A}_t^h \\ &+ \hat{\mathbb{E}}_t \sum_{T=t}^{\infty} \beta^{T-t}\left[(1-\beta)\left(\frac{\varphi+1}{\mu\varphi}\hat{W}_T + \hat{D}_T\right) - \frac{\beta}{\sigma}\left(1+\frac{\sigma}{\mu\varphi}\right)\left(\hat{i}_T - \hat{\pi}_{T+1}\right)\right].\end{aligned} \tag{C.3}$$

The remaining derivations follows those presented in Appendix (A.3), except that we now need to apply behavioral discounting to the expected payoff of the aggregate portfolio of Arrow-Debreu securities $\hat{\mathbb{E}}_t \hat{A}_{t+1} = m\mathbb{E}_t \hat{A}_{t+1}$. This is the key step that makes the difference compared to the incomplete markets case, in which only risk-free bonds exist and so there is no uncertainty on the one-period asset return. As a result, we finally arrive at

$$\hat{C}_t = m\mathbb{E}_t \hat{C}_{t+1} - \frac{1}{\sigma}\left(\hat{i}_t - m\mathbb{E}_t \hat{\pi}_{t+1}\right), \tag{C.4}$$

which is equation (32) in the main text and which, unlike its incomplete markets version (13), does not feature the country's net foreign assets position.

C.2. **Implications.** The Fama regression coefficients for the complete markets case are shown in Table C.1. They are very similar to those reported in Table 2 that describes our baseline incomplete markets setup.

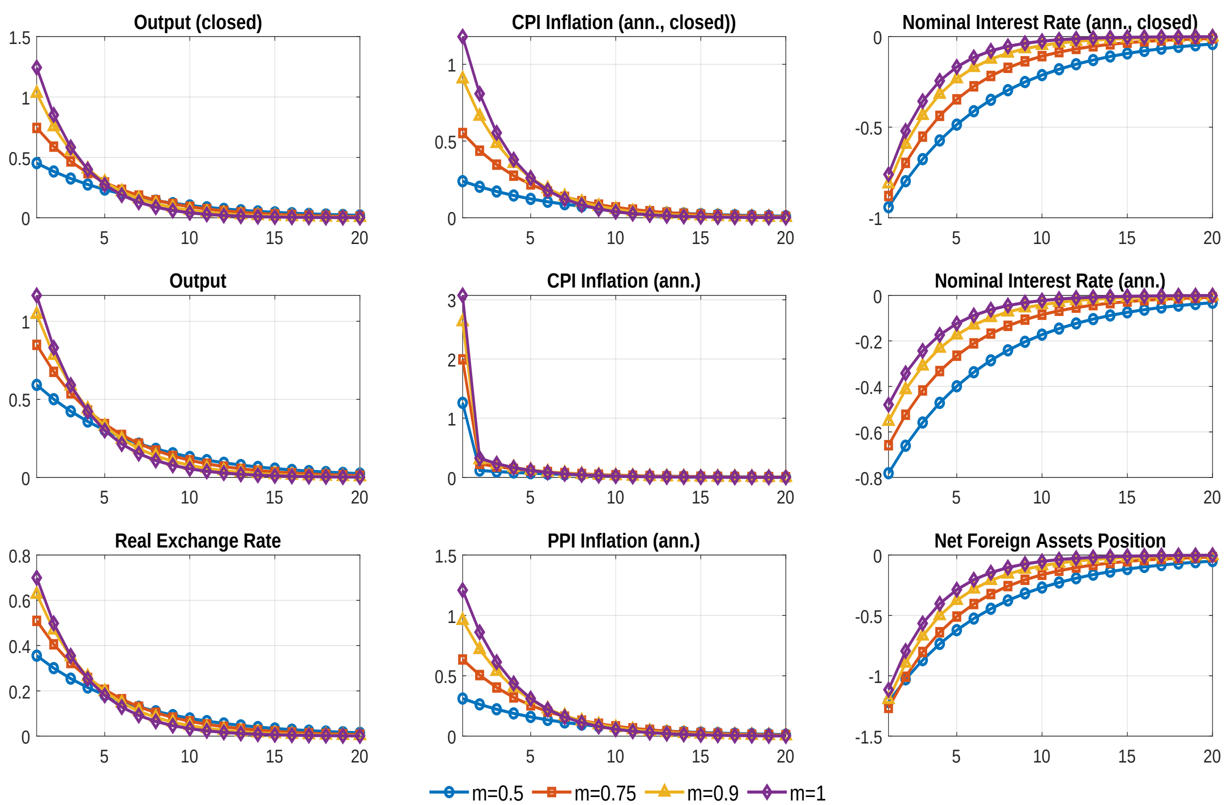
Figure 10 presents the dynamic responses to monetary easing under complete markets. It shows that behavioral discounting generates a very similar degree of attenuation in the short-term response

Table C.1. **Fama Regression Coefficients – Complete Markets Model**

Parameter	m =0.50	m =0.75	m =0.90	m =1.00
$\rho = 0.95$	-0.12	-0.17	0.25	1.00
$\rho = 0.90$	0.13	0.28	0.60	1.00
$\rho = 0.75$	0.49	0.66	0.83	1.00
$\rho = 0.50$	0.74	0.84	0.93	1.00

of output, inflation and the real exchange rate to that presented in Figure 6 that corresponds to our baseline model with incomplete markets.

Figure 10. **Dynamic Responses to a Monetary Easing – Complete Markets Model**



Note: This figure shows the impulse response functions to a 25bp (100 bp annualized) negative monetary policy shock for the model variant assuming complete markets. The first row depicts responses of output, CPI inflation and the nominal interest rate for the closed economy. The second and the third rows show IRFs for variables in the open economy. Responses of inflation and the interest rate are in annualized percentage points. In all the rows, purple lines correspond to no discounting, i.e., $m = 1$, while the blue, red and yellow lines indicate values of m equal to 0.5, 0.75 and 0.9 respectively.

Appendix D. Optimal Monetary Policy

D.1. **Deriving a Welfare Loss Function.** The goal of the social planner is to maximize

$$\mathbb{U}_t = \mathbb{E}_t \sum_{T=t}^{\infty} \beta^{T-t} \left[\frac{(C_T)^{1-\sigma}}{1-\sigma} - \frac{(N_T)^{1+\varphi}}{1+\varphi}) \right], \tag{D.1}$$

which differs from an individual household's objective (1) in that it uses rational instead of behavioral expectations. Denoting period utility (term in the square bracket) by u_t, its second order Taylor expansion around the steady state is

$$u_t \approx u + u_C C \left(\hat{C}_t + \frac{1-\sigma}{2} \hat{C}_t^2 \right) + u_N N \left(\hat{N}_t + \frac{1+\varphi}{2} \hat{N}_t^2 \right), \tag{D.2}$$

where $u_C$and u_N are the steady state partial derivatives of u with respect to consumption and labor. As shown by Gali and Monacelli (2005)), optimal steady state allocation for a small open economy that takes world output and consumption as given implies $-\frac{u_N}{u_C} = (1-\alpha)\frac{C}{N}$, which allows us to write

$$\frac{u_t - u}{u_C C} \approx \left(\hat{C}_t + \frac{1-\sigma}{2} \hat{C}_t^2 \right) - (1-\alpha) \left(\hat{N}_t + \frac{1+\varphi}{2} \hat{N}_t^2 \right). \tag{D.3}$$

When markets are complete so that the risk sharing condition (31) holds, the market clearing (18) condition can be rewritten as

$$\hat{Y}_t = (1-\alpha)\hat{C}_t + \alpha \hat{Y}_t^* + \eta \frac{\alpha(2-\alpha)}{1-\alpha} \sigma \left(\hat{C}_t - \hat{C}_t^* \right), \tag{D.4}$$

which simplifies to

$$\hat{C}_t = (1-\alpha)\hat{Y}_t + \alpha \hat{Y}_t^*, \tag{D.5}$$

when $\sigma = \eta = 1$, which we will use henceforth, and where we also use the small open economy implication $C_t^* = Y_t^*$. This allows us to rewrite Equation (D.3) as

$$\frac{u_t - u}{u_C C} \approx (1-\alpha) \left(\hat{Y}_t - \hat{N}_t - \frac{1+\varphi}{2} \hat{N}_t^2 \right) + t.i.p., \tag{D.6}$$

where $t.i.p.$ stands for terms independent of policy.

Let us now use the aggregate production function (A.30) to eliminate $\hat{N}_t$

$$\frac{u_t - u}{u_C C} \approx -\frac{1-\alpha}{2} \left(2\hat{\Delta}_t + (1+\varphi) \left(\hat{Y}_t - \hat{z}_t \right)^2 \right) + t.i.p., \tag{D.7}$$

where we again exploited the fact that price dispersion Δ_t is of second order. Note that, when markets are complete so that Equations (31) and (D.5) hold, real marginal cost formula (16) can be rewritten as

$$\hat{MC}_t = (1+\varphi)(\hat{Y}_t - \hat{z}_t), \tag{D.8}$$

which implies that flexible price output is proportional to productivity, i.e., we have that

$$\frac{u_t - u}{u_C C} \approx -\frac{1-\alpha}{2} \left(2\hat{\Delta}_t + (1+\varphi)\hat{x}_t^2 \right) + t.i.p., \tag{D.9}$$

where $\hat{x}_t \equiv \log(Y_t/\bar{Y}_t)$ is the output gap.

As the last step, we can use Lemma 1 and 2 in Gali and Monacelli (2005), originally proved by Woodford (2003)

$$\sum_{T=t}^{\infty} \beta^{T-t} \hat{\Delta}_T = \frac{\mu}{2(\mu-1)} \sum_{T=t}^{\infty} \beta^{T-t} \mathbb{V}\mathrm{ar} \hat{P}^f_{H,T} = \frac{\mu}{2\kappa(\mu-1)} \sum_{T=t}^{\infty} \beta^{T-t} \hat{\pi}^2_{H,T}, \tag{D.10}$$

where $\mathbb{V}\mathrm{ar}\hat{P}^f_{H,t}$ is the cross-sectional variance of relative prices charged by Home producers. As a result, we can finally write

$$\mathbb{U}_t \approx -\frac{1-\alpha}{2} \mathbb{E}_t \sum_{T=t}^{\infty} \beta^{T-t} \left[\frac{\mu}{\kappa(\mu-1)} \hat{\pi}^2_{H,T} + (1+\varphi)\hat{x}^2_T \right] + t.i.p., \tag{D.11}$$

which is Equation (43) in the main text.

D.2. **Optimal Stabilization.** The optimization problem is to minimize the welfare loss function (43), subject to (44). The Lagrangian for this problem is

$$\mathbb{E}_t \sum_{T=t}^{\infty} \beta^{T-t} \left[\frac{\mu}{\kappa(\mu-1)} \hat{\pi}^2_{H,T} + (1+\varphi)\hat{x}^2_T + \delta_T \left(\hat{\pi}_{H,T} - m\beta \hat{\pi}_{H,T+1} - \kappa(1+\varphi)\hat{x}_T - \xi_T \right) \right] \tag{D.12}$$

and the associated first-order conditions under commitment are

$$2\hat{x}_t - \kappa \delta_t = 0, \tag{D.13}$$

$$\frac{2\mu}{\kappa(\mu-1)} \hat{\pi}_{H,t} + \delta_t - m\delta_{t-1} = 0. \tag{D.14}$$

Combining these two equations results in

$$\hat{\pi}_{H,t} + \frac{\mu-1}{\mu} (\hat{x}_t - m\hat{x}_{t-1}) = 0, \tag{D.15}$$

which is the formulation reported in the main text.

Appendix E. Bayesian Estimation Results

E.1. **Data.** The domestic block of our model is represented by Canada and the foreign block, which is essentially a closed economy, is represented by the US. For these two countries, the estimation uses quarterly data on output, inflation and interest rates, as well as the bilateral exchange rate. All time series are taken from the Federal Reserve Economic Data (FRED) and transformed as follows:

(1) Per-Capita Real Output Growth (y^{obs}_t): We use the real GDP series labeled as NGDPRSAXDCCAQ and quarterly population estimates 17-10-0009-01 (formerly CANSIM 051-0005)

$$y^{obs}_t = 100 \left[\ln\left(\frac{\mathrm{GDP}_t}{\mathrm{Pop}_t} \right) - \ln\left(\frac{\mathrm{GDP}_{t-1}}{\mathrm{Pop}_{t-1}} \right) \right] \tag{E.1}$$

(2) Inflation (π_t^{obs}): GDP deflator CANGDPDEFQISMEI

$$\pi_t^{obs} = 100 \ln \left[\frac{\text{Def}_t}{\text{Def}_{t-1}} \right] \tag{E.2}$$

(3) Interest Rate (i_t^{obs}): 3-Month rate IR3TIB01CAM156N

$$i_t^{obs} = \frac{R_t}{4} \tag{E.3}$$

(4) Foreign Per-Capita Real Output Growth ($y_t^{obs,*}$): We take real GDP GDPC1 and population level CNP16OV

$$y_t^{obs,*} = 100 \left[\ln \left(\frac{\text{GDP}_t^*}{\text{Pop}_t^*} \right) - \ln \left(\frac{\text{GDP}_{t-1}^*}{\text{Pop}_{t-1}^*} \right) \right] \tag{E.4}$$

(5) Foreign Inflation ($\pi_t^{obs,*}$): Implicit price deflator GDPDEF

$$\pi_t^{obs,*} = 100 \ln \left[\frac{\text{Def}_t^*}{\text{Def}_{t-1}^*} \right] \tag{E.5}$$

(6) Foreign Interest Rate ($r_t^{obs,*}$): Effective federal fund rate FEDFUNDS

$$r_t^{obs,*} = \frac{R_t^*}{4} \tag{E.6}$$

(7) Exchange Rate (e_t^{obs}): Canadian Dollar to US Dollar Exchange Rate CCUSMA02CAQ618N

$$\Delta e_t^{obs} = 100 \ln \left[\frac{\text{RER}_t}{\text{RER}_{t-1}} \right] \tag{E.7}$$

The measurement equations linking the data to the model variables are

$$
\begin{aligned}
y_t^{obs,*} &= \hat{Y}_t^* - \hat{Y}_{t-1}^* + y^* && \text{(E.8)}\\
\pi_t^{obs,*} &= \hat{\pi}_t^* + \pi^* && \text{(E.9)}\\
i_t^{obs,*} &= \hat{i}_t^* + \pi^* + r^* && \text{(E.10)}\\
y_t^{obs} &= \hat{Y}_t - \hat{Y}_{t-1} + y && \text{(E.11)}\\
\pi_t^{obs} &= \hat{\pi}_{H,t} + \pi && \text{(E.12)}\\
i_t^{obs} &= \hat{i}_t + \pi + r && \text{(E.13)}\\
e_t^{obs} &= Q_t - Q_{t-1} + \hat{\pi}_t + \pi - \hat{\pi}_t^* - \pi^* && \text{(E.14)}
\end{aligned}
$$

so that, rather than demeaning data prior to estimation, we use intercepts y, π, r, y^*, π^*, r^* to capture trend growth rate of output, average inflation and average real interest rate.

Our baseline sample runs from 1972:Q1 to 2007:Q4. However, for robustness, we also estimate the model over the periods 1982:Q2–2007:Q4 and 1972:Q1–2019:Q4. In the latter case, which captures the period when the US policy rate was constrained by the zero lower bound and asset purchase programs were conducted, we replace the interest rate with the shadow rate estimated by Wu and Xia (2016).

E.2. **Shocks.** The model features seven stochastic shocks affecting monetary policy (ν_t and ν_t^*), firm cost (ξ_t and ξ_t^*) and household intertemporal preferences (g_t and g_t^*) in each of the two countries, as well as an international risk premium shock (ϱ_t). Monetary shocks show up in the Taylor rule (see Equation 20) while cost-push shocks enter the Phillips curve as in Equation (44). Preference shocks are introduced as shifters in the subjective discount factor β, resulting in the following modification of the IS curve (13)

$$\hat{C}_t = m\mathbb{E}_t\hat{C}_{t+1} - \frac{1}{\sigma}\left(\hat{i}_t - m\mathbb{E}_t\hat{\pi}_{t+1}\right) + (1-m)\frac{1-\beta}{1+\frac{\sigma}{\mu\varphi}}\hat{B}_t^* + g_t - m\mathbb{E}_t\hat{g}_{t+1}. \tag{E.15}$$

Finally, the risk premium shock modifies the UIP condition (14)

$$\hat{i}_t - m\mathbb{E}_t\left\{\hat{\pi}_{t+1}\right\} = \hat{i}_t^* - m\mathbb{E}_t\left\{\hat{\pi}_{t+1}^* - \hat{Q}_{t+1}\right\} - \hat{Q}_t - \phi\hat{B}_t^* + \varrho_t \tag{E.16}$$

All shocks are defined as independent AR(1) processes, except for the monetary policy shocks that we assume to be white noise.

E.3. **Priors and Estimation Method.** As is common practice in the DSGE literature, we fix values of some of the parameters that are weakly identified when relying on standard macroeconomic time series. This includes the openness parameter α, the discount factor β, elasticity of substitution between domestic and foreign goods η and sensitivity of intermediation costs to the level of foreign debt ϕ. All of them are set to the baseline calibration values presented in Table 1.

The remaining parameters are estimated jointly using Bayesian methods. We center the prior distributions at values chosen in our baseline calibration, while their tightness is motivated by the literature. Most importantly, the cognitive discounting parameter m is assumed to follow a beta distribution with mean 0.85 (as chosen by Gabaix, 2020) and standard deviation of 0.05. The Markov Chain Monte Carlo (MCMC) jump size in the Metropolis-Hastings algorithm is scaled to ensure a target acceptance rate of around 25 percent. We use 4 parallel chains of 250,000 draws each and a burn-in phase of 100,000, with convergence of the MCMC chains verified using diagnostic tests based on trace plots and potential scale reduction factors. Estimation is conducted using Dynare 4.6.4 (Adjemian et al., 2021).

E.4. **Estimation Results.** We report the posterior estimates obtained for the baseline sample 1972:Q2–2007:Q4. The results for the other two samples are very similar and available upon request. Table E.1 presents the characteristics of the prior and posterior distributions for structural parameters and constants in the measurement equations while estimated shock properties are presented in Table E.2.

Table E.1. **Estimation: Structural Parameters**

Parameter	Description	Prior			Posterior	
		Dist.	Mean	SD	Mean	[5, 95]
m	Cognitive Discounting	B	0.85	0.05	0.53	[0.44, 0.62]
ϕ_π	H Taylor Rule, Inflation	N	1.50	0.30	1.63	[1.23, 2.01]
ϕ_π^*	F Taylor Rule, Inflation	N	1.50	0.30	1.39	[1.07, 1.72]
ϕ_y	H Taylor Rule, Output	N	0.125	0.13	0.13	[0.04, 0.23]
ϕ_y^*	F Taylor Rule, Output	N	0.125	0.13	0.09	[0.006, 0.18]
ρ	H Interest Rate Smoothing	B	0.90	0.05	0.84	[0.80, 0.87]
ρ^*	F Interest Rate Smoothing	B	0.90	0.05	0.80	[0.74, 0.86]
θ	Calvo Probability	B	0.875	0.10	0.95	[0.93, 0.97]
φ	Inverse Frisch Elasticity	G	3.00	0.75	2.74	[1.58, 3.83]
σ	Intertemporal El. of Substitution	G	1.00	0.40	3.11	[2.27, 3.91]
r	SS H Real Rate	N	0.50	0.25	0.23	[-0.16, 0.62]
r^*	SS F Real Rate	N	0.50	0.25	0.68	[0.43, 0.92]
π	SS H Inflation	N	1.00	0.25	1.07	[0.91, 1.24]
π^*	SS F Inflation	N	1.00	0.25	0.79	[0.64, 0.95]
y	SS H Output Growth	N	0.50	0.25	0.44	[0.38, 0.49]
y^*	SS F Output Growth	N	0.50	0.25	0.44	[0.41, 0.46]

Note: B stands for Beta, G stands for Gamma and N stands for Normal distribution. H and F indicates Home and Foreign, respectively. SS denotes the steady state and SD the standard deviation.

Table E.2. **Estimation: Shocks**

Parameter	Description	Prior			Posterior	
		Dist.	Mean	SD	Mean	[5, 95]
ρ_g	AR H Preference	B	0.70	0.10	0.97	[0.96, 0.98]
ρ_g^*	AR F Preference	B	0.70	0.10	0.92	[0.89, 0.96]
ρ_ξ	AR H Cost-Push	B	0.70	0.10	0.46	[0.36, 0.55]
ρ_ξ^*	AR F Cost-Push	B	0.70	0.10	0.89	[0.85, 0.93]
ρ_ϱ	AR Risk Premium	B	0.70	0.10	0.98	[0.97, 0.99]
σ_ν	SD H Monetary Policy	IG	0.25	Inf.	0.32	[0.28, 0.35]
$\sigma_{\nu*}$	SD F Monetary Policy	IG	0.25	Inf.	0.36	[0.32, 0.39]
σ_g	SD H Preference	IG	0.25	Inf.	4.46	[3.19, 5.65]
σ_{g*}	SD F Preference	IG	0.25	Inf.	2.80	[2.07, 3.50]
σ_ξ	SD H Cost-Push	IG	0.25	Inf.	0.50	[0.43, 0.56]
$\sigma_{\xi*}$	SD F Cost-Push	IG	0.25	Inf.	0.13	[0.11, 0.16]
σ_ϱ	SD Risk Premium	IG	0.25	Inf.	0.37	[0.31, 0.43]

Note: B stands for Beta and IG stands for Inverted Gamma distribution. AR indicates AR(1) coefficient and SD the standard deviation of innovation. H and F denote Home and Foreign, respectively.