

# INTEREST RATE UNCERTAINTY AS A POLICY TOOL\*

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## Abstract

We study a novel policy tool, interest rate uncertainty, against inefficient capital inflows and in affecting the composition of external account between short-term securities and FDI. We identify the tradeoffs that are faced in navigating external balance and price stability. The policy discourages short-term inflows mainly through *portfolio risk* and *precautionary saving* channels. A *markup channel* generates net FDI outflows under full exchange rate pass-through. We further investigate new channels under different assumptions on irreversibility of FDI, currency of export invoicing, risk aversion of outside agents, and effective-lower-bound in the rest of the world. Under every scenario, uncertainty policy is inflationary. Our analysis is both positive and normative.

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*Keywords:* International Financial Policy, Stochastic Volatility, Short-term and Long-term Capital Movements, Unconventional Monetary Policy.

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# 1 INTRODUCTION

Starting with the colonial pattern of foreign investment in 19<sup>th</sup> century,<sup>1</sup> emerging and developing nations have been subject to ebbs and flows of capital, affecting their economic management. However, the recent episode distinguishes itself with a surge in the size and volatility of flows with the development of financial markets and with the exceptionally expansionary policy in advanced economies after the Global Financial Crisis (GFC).<sup>2,3</sup> Figure 1 exhibits the change in portfolio flows to Emerging Markets Economies (EMEs) between 2006-2014. The recent surge in the size and volatility of inflows can cause dislocations —mainly, financial stability concerns and inflationary pressures (Obstfeld, 2015). Hence, the conduct of monetary policy in EMEs has become a very modern contrivance and intended to prevent the adverse effects of feast-famine order of capital flows.<sup>4,5</sup> The central bankers who are working under multiple mandates are forced to be even more “innovative” when facing similar challenges.

The recent unorthodox policy experiment of the Central Bank of the Republic of Turkey (CBRT) provides an example for the innovative policy response to changing nature of capital flows, while aiming to achieve its multiple mandates of contributing to financial strength and maintaining price stability:<sup>6</sup> In response to intense capital inflows, the interest rate corridor<sup>7</sup> widened from below to discourage carry trade and channel inflows towards long-term foreign direct investments (FDI), and in response to powerful capital outflows, the interest rate corridor was narrowed by raising overnight borrowing rates, with an aim of preventing excessive outflows (see Başçı, 2012). In Figure 2, the

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<sup>1</sup>See Nurkse (1954) for a comparison of 19<sup>th</sup> century vs early 20<sup>th</sup> century capital flows.

<sup>2</sup>Among others, see Ahmed and Zlate (2013) and Rajan (2013).

<sup>3</sup>The change in the size and volatility of capital flows recently raised eyebrows on the applicability of independent monetary policy (given flexible exchange rates) in recipient countries. On the one hand, Rey (2013) argues that independent monetary policy is not possible without capital controls, and on the other, Woodford (2010) implies financial globalization does not affect the ability of domestic monetary policy to control inflation. Besides, Taylor (2015) claims that the volatility of capital flows would be *ex-ante* lower, if there were no deviations from rules-based monetary policy, but Obstfeld (2015) provides a middle ground, and highlights that monetary authorities have multiple goals in reality, and the surge in the volatility of capital flows affect the trade-off that authorities face between macro objectives and other targets, instead of making monetary policy ineffective.

<sup>4</sup>See IMF (2013) for a summary on the policy responses of several EMEs to capital inflows.

<sup>5</sup>Calvo et al. (1996) also argue that the countries that had been the most successful in managing capital flows during the Tequila crisis introduced a set of policy options instead of relying on a single instrument.

<sup>6</sup>The Turkish Central Bank Law, which was amended in 2001, provides the Bank with the instrumental independence to contribute to financial stability, in addition to its primary mandate of achieving price stability.

<sup>7</sup>Interest rate corridor refers to the window between overnight lending and borrowing rates. The main policy rate of CBRT, one-week repo rate, fluctuates within this band and a widening of the corridor implies an increase in the uncertainty for the future path of main policy rate.

period between November 2010 and October 2011 coincides with the horizon of the above policy.<sup>8</sup> Although this unconventional experiment is relevant for many countries suffering from swings in international capital flows, there is no structural model that studies such unorthodox attempt.<sup>9</sup>

This paper fills this gap by providing a laboratory for assessing the effectiveness of the above policy in affecting the composition of capital account between bonds and FDI, and in navigating the trade-offs between internal objectives and external balance. We build a New Keynesian two-region macroeconomic model<sup>10</sup> (EME and the Rest of the World (RoW)) with incomplete international financial markets and deviations from PPP, in which we can decompose the current account into bond and FDI components very easily. The model features uncertainty shocks to the domestic policy interest rate<sup>11</sup>, which the EME's central bank uses to discourage inefficient capital flows and channel inflows toward FDI.

We differentiate from the early NOEM literature mainly by two aspects: *i*) introducing FDI<sup>12</sup>, and *ii*) a non-linear model solution that allows us to trace transmission and propagation of heteroskedastic volatility. Under incomplete international financial markets, there is a time-varying wedge over the ratio of marginal utilities of consumption across the border, violating perfect risk sharing. Movements in this wedge make the real exchange misaligned and distort the incentives to borrow and lend across the border (as in [Corsetti et al. \(2018\)](#) and [Costinot et al. \(2014\)](#)). The joint analysis of interest rate uncertainty and heterogenous capital flows in the presence of financial market distortions yields new insights on the transmission and propagation of interest rate uncertainty both within and across borders.

Simulations indicate that interest rate uncertainty policy is an effective tool in fighting against inefficient capital inflows. When there is an increase in the demand uncertainty for RoW bonds,

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<sup>8</sup>Figure 3 exhibits an increase in FDI inflows during the application of interest rate corridor policy, however it is uncertain that whether the increase is due to a mean reversion of inflows after the GFC, or due to the success of the policy.

<sup>9</sup>Turkey is a case study for such policy, but we provide analysis in a more general framework that is relevant for a greater set of countries.

<sup>10</sup>Among others, see [Bergin \(2006\)](#), [Kollmann \(2001\)](#), and [Obstfeld and Rogoff \(1995\)](#).

<sup>11</sup>The changes in the size of the interest rate corridor implies a change in the variance of domestic interest rate.

<sup>12</sup>We define FDI as the investment in physical capital that will be used in overseas production activity. Introducing FDI in this way is in line with the definition of FDI as it captures the transactions of capital and capital gains between countries. IMF definition is as follows: "The term describes a category of international investment made by a resident entity in one economy (direct investor) with the objective of establishing a lasting interest in an enterprise resident in an economy other than that of the investor (direct investment enterprise). ... Direct investment involves both the initial transaction between the two entities and all subsequent capital transactions between them and among affiliated enterprises, both incorporated and unincorporated." Link: <https://www.imf.org/external/np/sta/di/glossary.pdf>

deviations in the uncovered interest parity generates inflows into the EME (consistent with the cyclicity of UIP in [di Giovanni et al. \(2017\)](#)). An increase in the EME’s policy interest rate uncertainty discourages these capital inflows and induces a counteracting force on the wedge over the ratio of marginal utilities of consumption across the border.

Three key channels of uncertainty transmission operates in affecting the external account in our model. First, an international investor’s *portfolio risk channel* arises in affecting short-term capital flows. In response to increased risk in the EME, RoW investors shift away from holding EME debt, and smooth consumption using international securities. Real exchange rate appreciates to compensate for the fall in EME bond prices but only partially succeeds. Second, EME households mute consumption in response to rising interest rate uncertainty and increase their savings: a *precautionary savings channel* emerges. These savings go to the RoW, where risk is lower. It further contributes to the outflow in the bond component of the external account. Third, when production is subject to price frictions, a *markup channel* starts to operate. With nominal rigidities in place, firms cannot adjust to changes in demand efficiently and this inability depresses the output. Furthermore, under full exchange rate pass through, firms respond to rising uncertainty by rising their prices, which further depresses firms’ demand for inputs, including inward FDI. We show that this widely-known precautionary pricing behavior in the literature is heavily dependent on the level exchange rate pass through in an open economy setting. In fact, when there is no exchange rate pass through, firms respond by decreasing prices and demand more inward FDI.

We further compare the interest rate uncertainty with another “second-order” policy that does not complicate the conduct of monetary policy: capital control uncertainty. We calculate the welfare compensating variation in consumption for the EME household to be indifferent under two policy regimes. We find that EME household significantly suffers under the interest rate uncertainty policy. The main reason is that the interplay between controlling the external account and pursuing price stability does not work well when multiple duties are assigned to a single policy instrument. Our results suggest that EME households enjoy higher consumption when policymakers create uncertainty about foreign variables, instead of domestic policy interest rate.

We also study several other ingredients that are relevant for the effectiveness of using interest rate uncertainty as a policy tool. When FDI is irreversible through a time-to-build requirement, the fluctuations in the FDI component of the capital account are dampened through a *wait-and-see*

effect. When we introduce high degrees of risk aversion through Epstein-Zin-Weil preferences, we observe significantly more pronounced movements in higher order terms in transmission of interest rate uncertainty. Under this scenario, EME bond risk premium jumps high enough to compensate for the riskiness of EME bonds, inducing demand on these securities for consumption smoothing purposes. When the RoW policy interest rate is subject to an effective lower bound constraint and cannot respond to movements in the economy, EME interest rate uncertainty generates amplified responses.

Our contribution is three-fold. First, we contribute to the literature that studies macroprudential policies in response to inefficient capital flows by introducing a novel policy tool.<sup>13</sup> In our environment, we consider inefficiency through endogenous movements in relative prices instead of introducing an exogenous borrowing constraint. Moreover, we deviate from the perfect foresight framework and allow for the propagation of heteroskedastic volatility. A distinct feature of our analysis is that an increase in the policy interest rate uncertainty is successful in closing the wedge in the uncovered interest parity condition under incomplete markets against inefficient capital inflows.

We also contribute to the literature that study the effects of uncertainty shocks on economic activity.<sup>14</sup> This paper differentiates from this literature, first, by asking the implications of using uncertainty as a policy tool, instead of a taken-as-given phenomenon.<sup>15</sup> In addition, our paper is also the first that studies the effects of uncertainty on different types of capital flows. There is also very limited work on studying uncertainty in an open economy framework.<sup>16</sup> Our setting is the first that studies implications of uncertainty in an international macro model that exhibit incomplete international financial markets, deviations from PPP, price rigidities and investment dynamics. Moreover, this paper provides a laboratory to study FDI dynamics.

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<sup>13</sup>See [Benigno et al. \(2016\)](#), [Bianchi \(2011\)](#), [Bianchi and Mendoza \(2018\)](#), [Costinot et al. \(2014\)](#), [Farhi and Werning \(2014\)](#), [Farhi and Werning \(2016\)](#), and [Lorenzoni \(2008\)](#). [Aoki et al. \(2015\)](#) and [Corsetti et al. \(2018\)](#) study the interplay between monetary and macroprudential policies in a framework that allows for inefficient capital flows under perfect foresight.

<sup>14</sup>This is a recently growing literature with early papers by [Andreasen \(2012\)](#), [Bachmann and Bayer \(2013\)](#), [Basu and Bundick \(2017\)](#), [Bloom \(2009\)](#), [Born and Pfeifer \(2014a\)](#), [Born and Pfeifer \(2014b\)](#), [Cesa-Bianchi and Fernandez-Corugedo \(2014\)](#), [Fernández-Villaverde et al. \(2011\)](#), [Fernández-Villaverde et al. \(2015\)](#), and [Justiniano and Primiceri \(2008\)](#).

<sup>15</sup>A relevant interpretation emerges in [Nosal and Ordoñez \(2016\)](#), in which they show uncertainty about providing bank bailouts can generate a self-disciplining mechanism for banks by limiting their portfolio riskiness. We are also noted that [Akkaya \(2014\)](#) interpreted stochastic volatility shocks to the interest rate as forward guidance shocks.

<sup>16</sup>[Fernández-Villaverde et al. \(2011\)](#) introduce uncertainty in [Mendoza \(1991\)](#) and abstract from monetary features. [Benigno et al. \(2012\)](#) study the uncovered interest parity in a two-country endowment model under international complete markets with a model solution of second-order approximation. [Kollmann \(2016\)](#) studies the effects of output volatility in a similar setting as in [Benigno et al. \(2012\)](#) with third-order solution.

Finally, we contribute to the literature that study the global financial cycle and its interaction with global monetary policy.<sup>17</sup> We differentiate mainly from this literature by studying a policy tool against the impact of the global financial cycle, instead of direct implications of the global financial cycle.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 discusses calibration, model dynamics, and presents a welfare analysis. Section 4 introduces additional results when new ingredients are included in the baseline economy. Section 5 concludes.

## 2 THE MODEL

The world is composed of two regions, Home and the Rest of the World (RoW)<sup>18</sup>. The total measure of the world economy is normalized to unity, with Home and RoW having measures of  $n$  and  $1 - n$ , respectively. The model shares several basic features of those in the literature that are characterized by microeconomic foundations in combination with nominal rigidities. International financial markets are incomplete as only non-contingent assets are internationally traded. An additional important feature is that, in addition to international trade of short-term securities, RoW agents can invest in productive capital that will be used as an input in Home's production activity. RoW variables are denoted with an asterisk.

Households consume a basket of final goods which is an Armington aggregator of Home and RoW goods. Domestic intermediate goods are produced by monopolistically competitive firms which combine labor with real capital from domestic and foreign agents. The baseline setup assumes that the law of one price holds, firms engage in producer currency pricing, and the source of PPP deviations is home bias in preferences. Figure 4 exhibits the model architecture.

In what follows, we focus on Home economy, and otherwise indicated, RoW is symmetric.

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<sup>17</sup>The literature is still expanding on top of the contributions of [Ahmed and Zlate \(2013\)](#), [Aoki et al. \(2015\)](#), [Banerjee et al. \(2015\)](#), [Bruno and Shin \(2016\)](#), [di Giovanni et al. \(2017\)](#), [Gourinchas et al. \(2016\)](#), and [Rey \(2013\)](#).

<sup>18</sup>RoW can be treated as the cluster of countries which engage in international transactions with the Home economy. Alternatively, it can be thought as the main trading partner and the origin of major FDI received by the Home economy after adjusting for the respective country sizes.

## 2.1 HOUSEHOLDS

The economy is populated by atomistic households. Each household is a monopolistic supplier of a specific labor input. The representative household, indexed by  $h$ , maximizes the expected intertemporal utility from consumption,  $C_t(h)$ , net of disutility from supplying labor to intermediate good producers,  $L_t(h)$ :

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t(h), L_t(h)) \quad (1)$$

where  $U(C_t(h), L_t(h)) = \frac{C_t(h)^{1-\rho}-1}{1-\rho} - \chi \frac{L_t(h)^{1+\varphi}}{1+\varphi}$  and  $\beta \in (0, 1)$  is the discount factor.

Households also accumulate physical capital in Home and RoW consumption units, that are used in the respective region's production of intermediate goods,  $K$  and  $K_*$ .<sup>19</sup> They rent these two types of capital to intermediate firms at Home and RoW. The rental rate they receive from Home and RoW producers are also in Home and RoW consumption units, respectively. Investments in the respective physical capital stock,  $I$  and  $I_*$ , require use of same composite of goods as in the final goods,  $Y$  and  $Y^*$ . Law of motion of capital is as standard in the literature for both types of capital:

$$K_{t+1}(h) = (1 - \delta)K_t(h) + I_t(h), \quad (2)$$

$$K_{*,t+1}(h) = (1 - \delta)K_{*,t}(h) + I_{*,t}(h), \quad (3)$$

where  $\delta$  denotes the depreciation rate of capital.

Households supply differentiated labor input, which gives them some pricing power in setting their own wage. The composite labor index is in Dixit-Stiglitz form:  $L_t \equiv \left[ \int_0^1 L_t(h)^{\frac{\epsilon_W-1}{\epsilon_W}} dh \right]^{\frac{\epsilon_W}{\epsilon_W-1}}$  where  $\epsilon_W > 0$  is the elasticity of substitution between the differentiated labor inputs. The aggregate nominal wage index is  $W_t \equiv \left[ \int_0^1 W_t(h)^{1-\epsilon_W} dh \right]^{\frac{1}{1-\epsilon_W}}$ , where  $W_t(h)$  is the nominal wage received by household  $h$ . The optimization problem for the competitive labor packer yields the labor demand equation:

$$L_t(h) = \left( \frac{W_t(h)}{W_t} \right)^{-\epsilon_W} L_t. \quad (4)$$

The nominal wage,  $W_t(h)$ , is set by households subject to (4) when maximizing utility. There is

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<sup>19</sup>Similarly, RoW agents invest in physical capital that will be used in RoW,  $K_*$ , and in physical capital that will be rented to Home,  $K^*$ . As discussed in more detail later on, we interpret the transactions related with the latter as FDI into the EME.

quadratic cost of adjustment for the nominal wage rate between period  $t - 1$  and  $t$ , à la Rotemberg (1982):

$$\frac{\kappa^W}{2} \left( \frac{W_t(h)}{W_{t-1}(h)} - 1 \right)^2 W_t(h)L_t(h),$$

where  $\kappa^W \geq 0$  determines the size of adjustment cost (if  $\kappa^W = 0$ , then wages are flexible). The size of this cost is proportional in labor income.

Households can hold one-period non-contingent nominal bonds supplied by domestic and RoW agents,  $B$  and  $B_*$ . Nominal exchange rate is denoted by  $S$ . International asset markets are incomplete as only risk-free bonds are traded across countries. Home bonds are issued by Home households and are denominated in Home currency, whereas RoW bonds are issued by RoW households and denominated in foreign currency. There are convex adjustment costs that ensure that zero international bond holding is the unique steady state, and hence the economy goes back to their initial position after temporary shocks. These costs are rebated back to households in equilibrium in lump-sum fashion.

The period budget constraint of the household can be written as:

$$\begin{aligned} P_t C_t(h) + B_{t+1}(h) + S_t B_{*,t+1}(h) + \frac{\eta}{2} P_t \left( \frac{B_{t+1}(h)}{P_t} \right)^2 + \frac{\eta}{2} S_t P_t^* \left( \frac{B_{*,t+1}(h)}{P_t^*} \right)^2 + P_t I_t(h) + S_t P_t^* I_{*,t}(h) \\ = R_t B_t(h) + S_t R_t^* B_{*,t}(h) + P_t r_{K,t} K_t(h) + S_t P_t^* r_{K,*,t} K_{*,t}(h) + W_t(h)L_t(h) \\ - \frac{\kappa^W}{2} \left( \frac{W_t(h)}{W_{t-1}(h)} - 1 \right)^2 W_t(h)L_t(h) + d_t(h) + T_t(h), \end{aligned} \quad (5)$$

where  $\frac{\eta}{2} \xi_t(B_{*,t+1})^2$  is the cost of adjusting holdings of internationally traded securities,  $T_t(h)$  is a fee rebate, taken as given by the household.  $d_t(h)$  represents the profits obtained by household  $h$  from engagements in production.  $R_{t+1}$  and  $R_{t+1}^*$  are gross nominal interest rates on Home and RoW bond holdings between  $t$  and  $t + 1$ . Finally,  $d_t(h)$  is the profits from producers, and  $r_K$  and  $r_{K,*}$  are real rental rates for the capital produced by Home households and used in Home and RoW production functions.

The household maximizes (1) subject to (2), (3), (4), and (5). The Euler equations for bond holdings are as follows:

$$1 + \eta b_{t+1} = R_{t+1} \mathbb{E}_t \left[ \frac{\beta_{t,t+1}}{\Pi_{t+1}} \right], \quad (6)$$



$$1 + \eta b_{*t+1} = R_{t+1}^* \mathbb{E}_t \left[ \frac{\beta_{t,t+1} rert_{t+1}}{\Pi_{t+1}^* rert_t} \right], \quad (7)$$

where  $\beta_{t,t+s} \equiv \frac{\beta U_{C,t+s}}{U_{C,t}}$  is the discount factor with  $U_{C,t}$  denoting marginal utility from consumption in period  $t$ .  $\Pi_t$  and  $\Pi_t^*$  represent the gross inflation between  $t - 1$  and  $t$  in Home and RoW.  $b_{t+1} \equiv \frac{B_{t+1}(h)}{P_t}$  and  $b_{*t+1} \equiv \frac{B_{*,t+1}(h)}{P_t^*}$  are real holdings of Home and RoW bonds, and  $rer$  is the consumption-based real exchange rate (units of Home consumption per units of RoW).<sup>20</sup> We omit the transversality conditions for bond holdings. With  $\eta > 0$ , no-arbitrage condition<sup>21</sup> implies:

$$\frac{R_{t+1}}{R_{t+1}^*} = \frac{(1 + \eta b_{t+1}) \mathbb{E}_t \left[ \frac{\beta_{t,t+1} rert_{t+1}}{\Pi_{t+1}^* rert_t} \right]}{(1 + \eta b_{*,t+1}) \mathbb{E}_t \left[ \frac{\beta_{t,t+1}}{\Pi_{t+1}} \right]}.$$

The Euler equations for the accumulation of capital used in Home and RoW production of intermediate inputs are:

$$1 = \mathbb{E}_t [\beta_{t,t+1} (r_{K,t+1} + 1 - \delta)], \quad (8)$$

$$1 = \mathbb{E}_t \left[ \beta_{t,t+1} \frac{rert_{t+1}}{rert_t} (r_{K,*,t+1} + 1 - \delta) \right], \quad (9)$$

with real prices of each type of capital being

$$q_t = 1, \quad (10)$$

$$q_{*t} = rert_t. \quad (11)$$

Equations (9) and (11) imply that Home households' investment in capital that will go into RoW production is not only dependent on the rental rate but also on the fluctuations in real exchange rate. The benefit of an additional unit of new capital that will be used by foreign production is the present discounted stream of extra profits (marginal products). Equation (11) says that the cost is equal to the real exchange rate, and hence, for an additional unit of capital,  $K_{*,t+1}$ , investment will

<sup>20</sup>Real exchange rate is defined as  $rer = \frac{SP^*}{P}$ . A decrease in  $rer$  implies appreciation, whereas an increase indicates depreciation of the real exchange rate.

<sup>21</sup>As discussed in calibration, we will set  $\eta$  to a very small value that will minimally affect the model dynamics, and its sole implication will be on ensuring that zero international bond holding is the unique non-stochastic steady state of the model. However, our experiments with volatility shocks and the solution method of the model will imply that there will be deviations from the uncovered interest rate parity based on a time-varying risk component.

be adjusted by the movements in the real exchange rate such that future profits from renting the capital abroad will not be affected.

The first-order-condition with respect to  $W_t(h)$  shows that real wage,  $w_t$ , is a time-varying markup over the marginal rate of substitution between labor and consumption:

$$w_t = \mu_t^W \left( \frac{\chi L_t^\varphi}{C_t^{-\rho}} \right), \quad (12)$$

where  $\mu_t^W$  is the time-varying wage markup:

$$\mu_t^W \equiv \frac{\epsilon^W}{(\epsilon^W - 1) \left( 1 - \frac{\kappa^W}{2} (\Pi_t^W - 1)^2 \right) + \kappa^W \left( \Pi_t^W (\Pi_t^W - 1) - \mathbb{E}_t \left[ \frac{\beta_{t,t+1}}{\Pi_{t+1}} (\Pi_{t+1}^W - 1) (\Pi_{t+1}^W)^2 \frac{L_{t+1}}{L_t} \right] \right)},$$

with  $\Pi^W \equiv \frac{w_t}{w_{t-1}} \Pi_t$  being the gross nominal wage inflation. The response of output will be less than it would if wages were flexible, when markups move in response to shocks.

## 2.2 FIRMS

Final goods in the economy,  $Y_t$ , are produced by aggregating a variety of differentiated intermediate Home goods indexed by  $i \in [0, 1]$  along with a variety differentiated intermediate RoW goods indexed by  $j \in [0, 1]$ . The aggregation technology for producing final goods is

$$Y_t = \left( a^{\frac{1}{\omega}} Y_{H,t}^{\frac{\omega-1}{\omega}} + (1-a)^{\frac{1}{\omega}} Y_{F,t}^{\frac{\omega-1}{\omega}} \right)^{\frac{\omega}{\omega-1}},$$

where  $Y_{H,t} = \left( \int_0^1 Y_{H,t}(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}$  represents an aggregate of Home goods sold domestically, and  $Y_{F,t} = \left( \int_0^1 Y_{F,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}}$  is an aggregate of imported RoW goods. Home bias is denoted by  $a$ . The producer of final good is competitive and demand is allocated between Home and RoW goods according to:

$$Y_{H,t} = a \left( \frac{P_{H,t}}{P_t} \right)^{-\omega} Y_t, \quad (13)$$

$$Y_{F,t} = (1-a) \left( \frac{P_{F,t}}{P_t} \right)^{-\omega} Y_t, \quad (14)$$

where  $P_{H,t}$  and  $P_{F,t}$  are nominal prices of aggregate Home goods sold domestically, and aggregate imported goods from RoW.  $P_t$  is aggregate price index as

$$P_t = \left( aP_{H,t}^{1-\omega} + (1-a)P_{F,t}^{1-\omega} \right)^{\frac{1}{1-\omega}}. \quad (15)$$

Each differentiated intermediate Home good is produced by using capital rented from Home households,  $K_t(i)$ , capital rented from RoW households,  $K_t^*(i)$ , and homogenous labor input rented from Home households,  $L_t(i)$ :

$$Y_{H,t}(i) + \left( \frac{1-n}{n} \right) Y_{H,t}^*(i) = K_t(i)^{\alpha_1} K_t^*(i)^{\alpha_2} L_t(i)^{1-\alpha_1-\alpha_2},$$

where  $Y_H^*$  is the exported intermediate Home good, and  $\alpha_1, \alpha_2$  and  $\alpha_1 + \alpha_2 \in (0, 1)$ .<sup>22</sup>

The producer of each differentiated intermediate Home good is monopolistically competitive and faces demand curves for its product sold domestically,  $Y_{H,t}(i) = \left( \frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\epsilon} Y_{H,t}$ , and for its product sold in RoW,  $Y_{H,t}^*(i) = \left( \frac{P_{H,t}^*(i)}{S_t P_{H,t}^*} \right)^{-\epsilon} Y_{H,t}^*$ , where  $P_{H,t}(i)$  is the nominal price of domestically sold Home good  $i$ , and  $P_{H,t}^*(i)$  is the domestic currency price of the exported good  $i$  with the price in the foreign market being  $P_{H,t}^*(i) = \frac{P_{H,t}^*(i)}{S_t}$ . Finally,  $P_{H,t} = \left( \int_0^1 P_{H,t}(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}$  is the nominal price of domestically sold Home good bundle and  $P_{H,t}^* = \left( \int_0^1 P_{H,t}^*(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}$  is the nominal foreign currency price of the export bundle.

Let  $r_{K,t}$  be the rental price of capital rented from Home households, and  $r_{K,t}^*$  be the rental price of capital rented from RoW households. The real marginal cost of producing intermediate Home good is

$$mc_t = \frac{w_t^{1-\alpha_1-\alpha_2} r_{K,t}^{\alpha_1} \left( r_{K,t}^* \right)^{\alpha_2}}{(1-\alpha_1-\alpha_2)^{1-\alpha_1-\alpha_2} \alpha_1^{\alpha_1} \alpha_2^{\alpha_2}}. \quad (16)$$

The monopolistic producer  $i$  chooses a rule  $(P_{H,t}(i), P_{H,t}^*(i), Y_{H,t}(i), Y_{H,t}^*(i))$  to maximize the

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<sup>22</sup>Three input Cobb-Douglas production function implies RoW capital and domestically produced capital are neither substitutes nor complements, and hence can be treated as the general case for the complementarity of FDI.

expected discounted profit:

$$\mathbb{E}_t \left[ \sum_{s=t}^{\infty} \beta_{t,t+s} \left( \begin{array}{c} \left( 1 - \frac{\kappa}{2} \left( \frac{P_{H,t+s}(i)}{P_{H,t+s-1}(i)} - 1 \right)^2 \right) \frac{P_{H,t+s}(i)}{P_{t+s}} Y_{H,t+s}(i) \\ \left( 1 - \frac{1-n}{n} \right) \left( 1 - \frac{\kappa^*}{2} \left( \frac{P_{H,t+s}^{*h}(i)}{P_{H,t+s-1}^{*h}(i)} - 1 \right)^2 \right) \frac{P_{H,t+s}^{*h}(i)}{P_{t+s}} Y_{H,t+s}^*(i) \\ -mc_t \left( Y_{H,t+s}(i) + \left( \frac{1-n}{n} \right) Y_{H,t+s}^*(i) \right) \end{array} \right) \right],$$

where the quadratic terms are the adjustment costs of respective prices. From the first-order conditions with respect to  $P_{H,t+s}(i)$  and  $P_{H,t+s}^{*h}(i)$  evaluated under symmetric equilibrium, we obtain the real price of Home output for domestic sales (*i.e.*  $rp_H \equiv \frac{P_H}{P}$ ) as a time-varying markup,  $\mu_{H,t}$  over the marginal cost:

$$rp_{H,t} = \mu_{H,t} mc_t, \quad (17)$$

and the real price of Home output for export sales (in units of RoW consumption) as a time-varying markup,  $\mu_{H,t}^*$ , over the marginal cost

$$rp_{H,t}^* = \frac{\mu_{H,t}^* mc_t}{rer_t}, \quad (18)$$

where

$$\mu_{H,t} \equiv \frac{\epsilon}{(\epsilon - 1) \left( 1 - \frac{\kappa}{2} (\Pi_{H,t} - 1)^2 \right) + \kappa \left( \Pi_{H,t} (\Pi_{H,t} - 1) - \mathbb{E}_t \left[ \frac{\beta_{t,t+1}}{\Pi_{t+1}} (\Pi_{H,t+1} - 1) (\Pi_{H,t+1})^2 \frac{Y_{H,t+1}}{Y_{H,t}} \right] \right)},$$

$$\mu_{H,t}^* \equiv \frac{\epsilon}{(\epsilon - 1) \left( 1 - \frac{\kappa^*}{2} (\Pi_{H,t}^{*h} - 1)^2 \right) + \kappa^* \left( \Pi_{H,t}^{*h} (\Pi_{H,t}^{*h} - 1) - \mathbb{E}_t \left[ \frac{\beta_{t,t+1}}{\Pi_{t+1}} (\Pi_{H,t+1}^{*h} - 1) (\Pi_{H,t+1}^{*h})^2 \frac{Y_{H,t+1}^*}{Y_{H,t}^*} \right] \right)}.$$

with  $\Pi_{H,t} \equiv \frac{rp_{H,t}}{rp_{H,t-1}} \Pi_t$  and  $\Pi_{H,t}^{*h} \equiv \frac{rp_{H,t}^*}{rp_{H,t-1}^*} \frac{rer_t}{rer_{t-1}} \Pi_t$ .

Given the cost of adjusting prices in domestic and export markets, firms has to move their markups to smooth price changes over time.

## 2.3 EQUILIBRIUM

Under symmetric equilibrium, we also learn

$$Y_{H,t} + \left( \frac{1-n}{n} \right) Y_{H,t}^* = K_t^{\alpha_1} K_t^{*\alpha_2} L_t^{1-\alpha_1-\alpha_2}, \quad (19)$$

where  $K_t = \int_0^1 K_t(i)di$ ,  $K_t^* = \int_0^1 K_t^*(i)di$ , and  $L_t = \int_0^1 L_t(i)di$ . The cost minimization implies

$$\alpha_1 w_t L_t = (1 - \alpha_1 - \alpha_2) r_{K,t} K_t, \quad (20)$$

$$\alpha_2 r_{K,t} K_t = \alpha_1 r_{K,t}^* K_t^*. \quad (21)$$

Hence, the trade-off between domestic capital, RoW capital, and labor inputs depends on the relative cost of each.

Market clearing requires that final production equals consumption and investment received from Home and RoW agents, net of cost of adjusting nominal prices:

$$Y_t = C_t + I_t + I_t^* + \frac{\kappa^W}{2} (\Pi_t^W - 1)^2 w_t L_t + \frac{\kappa}{2} (\Pi_{H,t} - 1)^2 r p_{H,t} Y_{H,t} + \left( \frac{1-n}{n} \right) \frac{\kappa^*}{2} (\Pi_{H,t}^{*h} - 1)^2 r p_{H,t}^{*h} Y_{H,t}^* \quad (22)$$

Finally, bonds are in zero net supply, which implies  $b_{t+1} + b_{t+1}^* = 0$  and  $b_{*,t+1}^* + b_{*,t+1} = 0$  at all periods. The lump sum transfer is  $T_t = \frac{\eta}{2} \left[ P_t \left( \frac{B_{t+1}(h)}{P_t} \right)^2 + S_t P_t^* \left( \frac{B_{*,t+1}(h)}{P_t^*} \right)^2 \right]$ . We show in Appendix A that Home net foreign assets are determined by:

$$\begin{aligned} & b_{t+1} + r e r_t b_{*,t+1} + \left( \frac{1-n}{n} \right) r e r_t K_{*,t+1} - K_{t+1}^* \\ &= \frac{R_t}{\Pi_t} b_t + \frac{R_t^*}{\Pi_t^*} r e r_t b_{*,t} + \left( \frac{1-n}{n} \right) r e r_t (r_{K,*,t} + 1 - \delta) K_{*,t} - \left( r_{K,t}^* + 1 - \delta \right) K_t^* + T B_t \end{aligned} \quad (23)$$

where trade balance is given as follows:  $T B_t \equiv \left( \frac{1-n}{n} \right) \mu_{H,t}^* m c_t Y_{H,t}^* - r e r_t \mu_{F,t} m c_t^* Y_{F,t}$ .

The above equation differs from those in standard open-economy models by the terms that indicate the stock of physical capital received from RoW net of physical capital installed into RoW, and by the terms that indicate the respective rental gains from this transaction. The change in net foreign assets between  $t$  and  $t+1$  is determined by the current account,  $C A_t$ :

$$\underbrace{(b_{t+1} - b_t) + r e r_t (b_{*,t+1} - b_{*,t})}_{\text{Bond component}} + \underbrace{\left( \frac{1-n}{n} \right) r e r_t (K_{*,t+1} - K_{*,t}) - (K_{t+1}^* - K_t^*)}_{\text{FDI component}} \equiv C A_t$$

As shown under brackets, the current account is decomposed into short-term security flows component and FDI flows component.

## 2.4 MONETARY POLICY

The central bank sets the nominal interest rate according to a Taylor rule that reacts to inflation and output which displays stochastic volatility:

$$\frac{R_t}{R} = \left( \frac{R_{t-1}}{R} \right)^{\rho_R} \left( \frac{\Pi_t}{\Pi} \right)^{(1-\rho_R)\rho_\Pi} \left( \frac{Y_t}{Y} \right)^{(1-\rho_R)\rho_Y} e^{u_t}, \quad (24)$$

where  $\rho_R$  is a smoothing parameter to capture gradual movements in interest rates, and the parameters  $\rho_\Pi$  and  $\rho_Y$  are responsiveness of the nominal interest rate to deviations of inflation and output from their steady state values.

The monetary policy shock,  $u_t$ , represents unexpected deviations from the rules based policy, including the EME central bank's reactions to international factors. We allow this term to incorporate time-varying volatility in the form of stochastic volatility.

The monetary policy shock,  $u_t$ , follows an  $AR(1)$  process:

$$u_t = \rho^u u_{t-1} + e^{\sigma_t^R} \varepsilon_t, \quad (25)$$

where  $\varepsilon_t$  is a normally distributed shock with zero mean and unit variance. Moreover, the standard deviation,  $\sigma_t^R$ , follows an  $AR(1)$  process:

$$\sigma_t^R = (1 - \rho^{\sigma^R}) \sigma^R + \rho^{\sigma^R} \sigma_{t-1}^R + \varepsilon_t^\sigma, \quad (26)$$

where  $\varepsilon_t^\sigma$  is a normally distributed shock with zero mean and unit variance. Parameter  $\sigma^R$  controls the mean volatility of the exogenous component in the Taylor rule. An increase in the volatility of the exogenous process increases uncertainty about the future path of monetary policy.

## 2.5 SUMMARY

Table 1 summarizes the key equilibrium conditions of the model. The equations ((2), (3), (6), (7), (8), (9), (12), (13), (14), (15), (16), (17), (18), (19), (20), (21), (22), (24)) and their RoW counterparts, together with the net foreign asset condition in equation (23) determine 37 endogenous variables of interest:  $(Y_t, C_t, I_t, I_{*t}, K_t, K_{*,t}, L_t, Y_{H,t}, Y_{H,t}^*, mc_t, rp_{H,t}, rp_{H,t}^*, w_t, r_{K,t}, r_{K,*,t}, b_t,$

$R_t, \Pi_t$ ) and their foreign counterparts, and  $rer_t$ . Auxiliary variables and exogenous processes are described above.

### 3 MODEL CALIBRATION AND SIMULATIONS

In this section, we illustrate the model dynamics and highlight the role of using interest rate uncertainty in adjusting external capital account.

#### 3.1 CALIBRATION

We set the discount factor,  $\beta$ , to match 2% real rate, to 0.9804 as in the literature that focus on emerging markets. Relative risk aversion,  $\rho$ , relative weight of labor in the utility function,  $\chi$ , and Frisch elasticity,  $\varphi$ , are set to their conventional values in the literature as well. We set them to 2, 1, and 0.25, respectively. Regarding the convex adjustment costs of bond holdings to households,  $\eta$ , we use 0.0025 as in Ghironi and Melitz (2005). This value implies that the cost of adjusting has negligible impact on model dynamics, other than pinning down the non-stochastic steady state and ensuring mean reversion when shocks are transitory. Following Barattieri et al. (2018), we set  $\kappa^W$  to 116 for nominal wage stickiness being approximately equal to 3 periods on average. Moreover, we set the elasticity of substitution of differentiated labor inputs,  $\epsilon^W$ , to 11, which implies a wage markup of 10% under flexible prices.

For the parameters that are related with producer optimization, we set the home bias in final production to 0.65 as in Unsal (2013), and the shares for domestic and foreign capital in intermediate good productions,  $\alpha_1$  and  $\alpha_2$ , to 0.30 and 0.15 as in Aoki et al. (2015). Rotemberg price adjustment parameters for domestic and exported goods,  $\kappa$  and  $\kappa^*$ , are set to 116, as in Barattieri et al. (2018). We again set the elasticity of substitution of differentiated inputs,  $\epsilon$ , to 11, and replicate a 10% price markup in both sectors when prices are flexible.

Finally, our choice for the parameters in the Taylor rule is also in line with the previous literature, and we set the smoothing coefficient,  $\rho_R$ , the steady state response to inflation,  $\rho_\Pi$ , and the steady state response to output,  $\rho_Y$ , to 0.7, 1.5, and 0.5/4, respectively. We also set  $\sigma^R$ , the average standard deviation of an innovation to the interest rate shock, to hit 14 percentage point average

of 2002-2018,  $(100 \exp(-1.90))$ .<sup>23</sup>

Table 2 summarizes the parametrization of the model.

### 3.2 SOLUTION METHOD

We solve the model using third-order perturbation techniques. A first-order approximation will be certainty equivalent and will neglect higher order effects. A model solution under a second-order approximation will not be able to study the direct effects of a volatility change, as the model solution includes cross products of exogenous volatility and level variables. Hence, to single out the individual effects of volatility shocks, a third-order approximation of the model is needed (Fernández-Villaverde et al. (2011)).

As highlighted by Kim et al. (2008), solutions using higher-order perturbation techniques tend to yield explosive time-paths due to accumulation of terms of increasing order. To overcome this problem, Andreasen et al. (2013) uses pruning all higher order terms, and we integrate their method in our simulations.

Moreover, higher-order approximation solutions move the ergodic distribution of the model endogenous variables away from their non-stochastic steady state values (Fernández-Villaverde et al. (2011)). Therefore, calculating impulse responses from non-stochastic steady state is not informative. To overcome this difficulty, we follow the previous literature and calculate impulse responses as deviations from the stochastic steady states of the endogenous variables. In defining the stochastic steady state, we follow Born and Pfeifer (2014b) and Fernández-Villaverde et al. (2011), and characterize it as the fixed point of the third-order approximated policy functions in the absence of shocks. This is the point in which agents choose to remain with taking future uncertainty into account. Hence, this method allows us to study the effects of an increase in the uncertainty of the future path of interest rate without imposing any changes in the realized volatility of the interest rate *per se*.

### 3.3 EXPERIMENTS

First, we study how our model reacts to a 1% interest rate *level* shock, before studying the implications of interest rate uncertainty on capital flows. Then, we focus on our main experiment,

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<sup>23</sup>We start from 2002 to focus on the period after the 2001 economic crisis.



and show how interest rate uncertainty as a policy tool performs in response to inefficient capital inflows that induce an international wealth wedge. We also analyze the channels of transmission and propagation of interest rate uncertainty, and identify the repercussions of such unconventional policy. We, finally, provide a welfare analysis to evaluate the normative aspects of the policy.

### 3.3.1 INTEREST RATE LEVEL SHOCKS

Our first experiment is with an unexpected interest rate shock in EME, in order to compare our model with standard monetary open-economy models in the literature. We solve the model using a first-order approximation, and calculate impulse responses as deviations from the non-stochastic steady state values for model comparability purposes. Figure 5 exhibits impulse responses after a 1% increase in  $u_t$ .

The model reacts to a one-time exogenous increase in the interest rate reasonably. Upward movement in the level of the interest rate is contractionary with national absorption. Most of the collapse in output is due to fall in investment for domestic physical capital. There is downward pressure on prices, and markups fall accordingly. The fall in household demand on goods is followed by a fall in labor supply. Firms lower their demand on both types of physical capital. A decrease in the demand for RoW physical capital contributes to net FDI outflows from EME. Moreover, from uncovered interest parity (UIP) condition, real exchange rate appreciates and investment in Home economy becomes more expensive. Hence, RoW agents' investment in capital for Home production falls, and this leads to stronger FDI outflows.<sup>24</sup>

Finally, the fall in income negatively affects the demand on EME bonds and contributes to the outflow in the bond component of the current account. Most of the correction in the capital account is due to changes in the FDI component as investment dynamics are more volatile.

We conclude that our model passes the sanity check and move on to our main experiments.

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<sup>24</sup>Incomplete financial markets and convex adjustment costs for bond holdings imply deviations from the UIP, however given our calibration, the deviation is miniscule. UIP violations are much larger in magnitude when a third-order perturbation solution technique is applied.

### 3.3.2 INEFFICIENT CAPITAL INFLOWS AND INTEREST RATE UNCERTAINTY AS A POLICY TOOL

We turn to our main experiment and examine whether interest rate uncertainty is an effective policy against inefficient capital flows.

We consider the case in which inefficient capital inflows are generated due to risk premium shocks to Euler equations for bond holdings, in a similar fashion to [Smets and Wouters \(2007\)](#) and as in the subsequent literature. One of our distinct features is introducing risk premium shock as a second order shock, instead of a first order shock. A positive realization of these shocks can be interpreted as an increase in demand uncertainty for the respective financial asset. We do not attempt to model risk premium shocks endogenously. The Global Financial Crisis period exhibits significant movements in risk premium and we motivate our analysis from this episode (e.g. [di Giovanni et al. \(2017\)](#)).

Euler equations for the EME and the RoW households are modified accordingly:

$$\begin{aligned}
 1 + \eta b_{t+1} &= \frac{R_{t+1}}{e^{u_t^{SW}}} \mathbb{E}_t \left[ \frac{\beta_{t,t+1}}{\Pi_{t+1}} \right], \\
 1 + \eta b_{*t+1} &= \frac{R_{t+1}^*}{e^{u_t^{SW*}}} \mathbb{E}_t \left[ \frac{\beta_{t,t+1}}{\Pi_{t+1}^*} \frac{rer_{t+1}}{rer_t} \right], \\
 1 + \eta b_{*,t+1}^* &= \frac{R_{t+1}^*}{e^{u_t^{SW*}}} \mathbb{E}_t \left[ \frac{\beta_{t,t+1}^*}{\Pi_{t+1}^*} \right], \\
 1 + \eta b_{t+1}^* &= \frac{R_{t+1}}{e^{u_t^{SW}}} \mathbb{E}_t \left[ \frac{\beta_{t,t+1}^*}{\Pi_{t+1}} \frac{rer_t}{rer_{t+1}} \right].
 \end{aligned}$$

The Smets-Wouters shocks that apply to EME and RoW Euler equations,  $u_t^{SW}$  and  $u_t^{SW*}$ , follow an  $AR(1)$  process

$$u_t^x = \rho^x u_{t-1}^x + e^{\sigma_t^x} \varepsilon_t^x,$$

for  $x \in \{SW, SW*\}$ . The log of the standard deviation of the Smets-Wouters shock,  $\sigma_t^x$ , is random, and modeled as an  $AR(1)$  process

$$\sigma_t^x = (1 - \rho^{\sigma^x}) \sigma^x + \rho^{\sigma^x} \sigma_{t-1}^x + \varepsilon_t^{\sigma^x}.$$

We use the VIX index as a proxy for UIP risk premium and set the average standard deviation of an innovation to RoW Smets-Wouters shock,  $\sigma^{SW*}$ , to 34 percent.

The second order shocks contribute to the wedge in the relative value of wealth between EME and RoW under incomplete markets. To see this, we express the uncovered interest parity condition as a time-varying wedge over the ratio of marginal utilities of consumption across the border:

$$1 = \mu_{t+1}^{UIP} \frac{U_{C^*,t}}{U_{C,t}rer_t}, \quad (27)$$

where  $\mu_{t+1}^{UIP} \equiv \frac{1+\eta b_{t+1}^*}{1+\eta b_{t+1}} \frac{\mathbb{E}_t \left[ \frac{U_{C,t+1}}{P_{t+1}} \right]}{\mathbb{E}_t \left[ \frac{U_{C^*,t+1}}{P_{t+1}rer_{t+1}} \right]}$ .

Under complete markets, the marginal utilities of the EME and the RoW agents would be constant across all histories and dates, implying extensive risk sharing in terms of marginal utility (*i.e.*  $\mu_{t+1}^{UIP} = 1$ ). Under incomplete markets, stochastic volatility shocks to Smets-Wouters disturbances (henceforth, risk premium shocks) will induce movements in  $\mu_{t+1}^{UIP}$  and highlight the inefficient allocation of wealth across nations due to movements of relative prices that are not internalized by the agents across the border.

We are interested in the qualitative dynamics of the UIP wedge to understand whether interest rate uncertainty performs as a counteracting tool to inefficient capital inflows. When we generate dynamics with two standard deviation to the stochastic volatility processes of the RoW risk premium and EME interest rate, separately, we observe that the UIP wedge moves in opposite directions. Figure 6 shows the movement in  $\mu_{t+1}^{UIP}$  after this exercise. A RoW risk premium shock induces a negative wedge between the marginal value of wealth across the border. This is due to a dominant fall in RoW consumption in response to a RoW risk premium shock. On the other hand, using interest rate uncertainty as a policy tool (henceforth, IRUPT), generates an opposite movement in  $\mu_{t+1}^{UIP}$ . As we will study deeper below, the increase in UIP wedge in response to IRUPT is mainly due to a rise in prices and fall in consumption in EME. Inflationary effect of IRUPT has valuation effects on the EME debt similar to a capital inflow tax. These suggest us that IRUPT can be effective in tackling inefficient capital inflows that are generated in response to RoW risk premium shocks.

Having seen that interest rate uncertainty can be used against inefficient capital inflows, we now study the implications of unexpected policy uncertainty policy *in response to* inefficient capital

inflows. We conduct the following exercise: We generate dynamics by a two standard deviation increase in RoW risk premium (*i.e.*,  $\varepsilon_t^{\sigma^{SW*}}$ ) in  $t = 1$  and increase in the distribution of the exogenous component of the interest rate while there is no change in the level of the process (*i.e.*,  $\varepsilon_t^\sigma$ ) in  $t = 2$ . Figure 7 exhibits dynamics from this exercise. Blue lines indicate dynamics from the RoW risk premium shock in the absence of IRUPT, and purple lines indicate dynamics when IRUPT is in place in  $t = 2$  in response to inefficient capital inflows.

We observe that IRUPT is successful in discouraging capital inflows. There is a correction in the bond component of the current account as well as in the FDI component of the current account. Consumption fall significantly due to precautionary motives, and EME households shift their investments into the physical capital that will be used in RoW production, where risk is lower (a milder drop in investment for the RoW capital vis-à-vis to no policy case). The drops in consumption and investments are reflected as a sharp fall in output. Future uncertainty on marginal costs force firms to set higher prices, leading to amplification in price markups in both domestic and export markets. Markups rise because, for one reason, with consumption (demand) falling, prices do not fully accommodate the lower demand under rigidities. Markups also rise due to the shape of the profit function under producer currency pricing, which we discuss below. Rising markups contribute to the jump in inflation.

Increase in markups, combined with low rental payments to RoW for their capital in Home production, and the appreciation of real exchange rate (from the perspective of the EME) contribute to a decrease in FDI inflows, leading to an increase in the FDI component of the current account. Home agents' low consumption further decreases supply of Home bonds, leading to an increase in the short-term component of the current account. Households increase savings, but mostly with holding more RoW bonds. Due to combined effect of rising markups and real exchange rate appreciation, FDI component of the current account moves more significantly.

From here onwards, for the clarity of our analysis, we focus on the effect of IRUPT by analyzing the impulse responses to interest rate uncertainty as deviations from the stochastic steady state of the economy, instead of being in place in response to inefficient capital inflows in  $t = 2$ . Figure 8 shows how the model behaves under this exercise.<sup>25</sup>

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<sup>25</sup>Although the way IRUPT operates is the same in our exercise, it is important to note that the stochastic steady state of the economy is different in the absence of Smets-Wouters risk premium shocks.

### 3.3.3 PORTFOLIO RISK OF REST OF THE WORLD INVESTORS

How is the portfolio problem of the RoW investors affected under this scenario? To understand the RoW behavior in response to EME interest rate uncertainty, we further investigate the movements in the risk premia in RoW portfolio. After some algebra, the relative risk premia between the assets in the RoW portfolio can be written as:<sup>26</sup>

$$RR_{B^*,B^*,t+1} \equiv \frac{Cov_t \left( \beta_{t,t+1}^*, \frac{R_{t+1}^*}{\Pi_{t+1}^*} - \frac{R_{t+1}}{\Pi_{t+1}} \frac{rer_t}{rer_{t+1}} \right)}{\mathbb{E}_t \left[ \beta_{t,t+1}^* \right]},$$

$$RR_{K^*,K^*,t+1} \equiv \frac{Cov_t \left( \beta_{t,t+1}^*, R_{K^*,t+1} - \frac{rer_t}{rer_{t+1}} R_{K^*,t+1} \right)}{\mathbb{E}_t \left[ \beta_{t,t+1}^* \right]}$$

and

$$RR_{B^*,K^*,t+1} \equiv \frac{Cov_t \left( \beta_{t,t+1}^*, \frac{R_{t+1}}{\Pi_{t+1}} \frac{rer_t}{rer_{t+1}} - R_{K^*,t+1} \frac{rer_t}{rer_{t+1}} \right)}{\mathbb{E}_t \left[ \beta_{t,t+1}^* \right]}.$$

We denote the relative risk between RoW investors' holdings of RoW bonds and EME bonds, EME physical capital and RoW physical capital, EME bonds and EME physical capital by  $RR_{B^*,B^*}$ ,  $RR_{K^*,K^*}$ ,  $RR_{B^*,K^*}$ , respectively.<sup>27</sup> Applied to excess returns, these identities can be further expressed as:

$$\mathbb{E}_t \left[ \frac{R_{t+1}^*}{\Pi_{t+1}^*} - \frac{R_{t+1}}{\Pi_{t+1}} \frac{rer_t}{rer_{t+1}} \right] \approx -RR_{B^*,B^*,t+1},$$

$$\mathbb{E}_t \left[ R_{K^*,t+1} - \frac{rer_t}{rer_{t+1}} R_{K^*,t+1} \right] = -RR_{K^*,K^*,t+1},$$

and

$$\mathbb{E}_t \left[ \frac{rer_t}{rer_{t+1}} \left( \frac{R_{t+1}}{\Pi_{t+1}} - R_{K^*,t+1} \right) \right] \approx -RR_{B^*,K^*,t+1}.$$

If the relative risk between two specific assets of the RoW investor increases, there is a decrease in the expected excess return between those assets. RoW investors will drive up relative prices and push down the average relative return of assets that positively covary with their stochastic discount

<sup>26</sup>See Appendix B for derivations.

<sup>27</sup>We define  $R_{K,t+1} \equiv r_{K,t+1} + 1 - \delta$ .

factor.

We study how relative risk between the RoW investors' assets move in response to an increase in the uncertainty of the EME policy rate. Figure 9 shows the responses of the relative risk terms we defined above. We observe a very big decrease in the relative risk between holdings of RoW and EME bonds. As EME bonds are much riskier with the EME policy, RoW investors are more willing to hold RoW bonds. They drive down the prices of EME bonds and seek higher returns for exposure to EME bonds. Bond component of the EME current account responds by a positive jump, as RoW investors are less willing to finance the EME current account by holding EME bonds.

Second column exhibits the movement in the relative risk between the RoW physical capital and EME physical capital. The response to EME monetary policy is much less pronounced than in the previous case. The reaction also tells us that the relative risk of EME physical capital, which is important for the RoW investors' supply of FDI, falls with respect to investment in the RoW physical capital. However, we still observe an increase in the FDI component of the EME current account, which indicates an outflow of FDI. This behavior suggests us that FDI inflows into the EME decrease mainly due to a fall in demand for the RoW physical capital from the EME producers. Hence, repercussions of IRUPT have significant implications on the FDI component of the current account.

But why does the EME physical capital become less risky relative to the RoW physical capital in response to the EME policy? The reason is that the movement in real exchange rate provides a hedging mechanism to the RoW investor. The price of the EME physical capital to the RoW investor is  $q_t^* = \frac{1}{rer_t}$ . When the RoW investor shifts away from EME bonds, real exchange rate appreciates to compensate the jump in excess return between EME and RoW bonds. An appreciating real exchange rate also implies an increase in the real price of the EME capital, pushing the relative return (with respect to the RoW physical capital) down.

Finally, third column exhibits the movements in the relative risk of the EME bond with respect to the EME physical capital. As expected, bonds are much riskier vis-à-vis to the physical capital, and at a decision between holding bonds vs. physical capital, the RoW investor opts for the latter.

### 3.3.4 TRANSMISSION WITHIN THE EMERGING MARKET ECONOMY

In this subsection, we investigate how IRUPT propagates within the EME through different channels.

#### PRECAUTIONARY SAVINGS CHANNEL AND OI-HARTMAN-ABEL EFFECTS

Figure 10 shows dynamics after an increase in interest rate uncertainty as in the above experiment, but in the model version with no Rotemberg adjustment costs for the goods produced for domestic and export markets (*i.e.*  $\kappa = \kappa^* = 0$ ). For comparison purposes, we print the impulse responses from the baseline model (purple line) together with the impulse responses from the model with flexible prices (blue line). In the absence of adjustment costs in production, there are no time-varying inefficient wedges between relative prices and marginal costs. Flexible prices abstract from the effects of rising markups in production. However, inflation still goes up because of the rise in time-varying wage markup.

After an increase in uncertainty in the EME, we still observe a fall in consumption due to precautionary motives, but less pronounced with respect to the fall in consumption in the baseline model. This time savings go to domestic investment (instead of to the RoW), because demand in investment is not constrained due to rising markups in the production sector. Firms demand more FDI as well as domestic investment, and hence we see an inflow in the FDI component of the current account. Rising domestic investment has also positive effect on output. Labor supply still falls, but in a less pronounced manner vis-à-vis to the baseline model. This is, again, because of an upward movement in the markup over marginal substitution that contributes to inflation.

A contributing reason that there is an increase in net FDI inflows is because firms are more willing to expand production in response to uncertainty when it is easy to adjust inputs. In the absence of pricing frictions, factors of production are relatively more elastic and firms are willing to take advantage of volatility by increasing their production. This is known in the literature as Oi-Hartman-Abel effect (see [Oi \(1961\)](#), [Hartman \(1972\)](#), and [Abel \(1983\)](#)). In the absence of pricing frictions, hence, volatility can be positively affecting the EME production and increase the demand for incoming FDI.<sup>28</sup>

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<sup>28</sup>In a closed real economy absent from frictions, volatility can be welfare enhancing if this channel is dominant (e.g. [Lester et al. \(2014\)](#)).

IRUPT generates an outcome that is in line with the policymaker’s goal of attracting FDI and discouraging short-term inflows in the EME when the economy is not subject to pricing frictions.

### PRICE MARKUP CHANNEL

[Fernández-Villaverde et al. \(2015\)](#) studied the behavior of markups in response to uncertainty shocks in a closed economy and showed that firms move their prices upwards when production is subject to adjustment costs. A similar mechanism is at work in our model for FDI dynamics, but we show that having a divine coincidence with the closed economy results is crucially dependent on the level of exchange rate pass through. To single out the effects of pricing frictions in the production sector, in [Figure 11](#), we show model dynamics after removing wage adjustment frictions in the baseline economy. Black lines indicate dynamics when wages are flexible.

Firms cannot accommodate demand under rising uncertainty due to price stickiness. Markups go up and output goes down. Contraction in output contributes to a fall in demand for physical capital, implying a fall in domestic investment and in inward FDI. EME households shift their resources to rent capital to RoW agents, but this is relatively a small share of the EME and does not help output from going south. Through the relationship between factor prices, fall in rental rates of capital is more pronounced when wages are flexible.

Markups also rise because EME firms’ profits are asymmetric in response to price changes. We plot the period export profits of intermediate goods firms as in [Fernández-Villaverde et al. \(2015\)](#), but also taking real exchange rate into account as the third dimension (focusing on the steady state and abstracting from adjustment costs):

$$\left( r_{er} \frac{P_H^*}{P} \right)^\epsilon \left( \frac{P_H^{*h}(i)}{P} \right)^{1-\epsilon} Y_H^* - \left( \frac{\epsilon - 1}{\epsilon} \right) \left( r_{er} \frac{P_H^*}{P} \right)^\epsilon \left( \frac{P_H^{*h}(i)}{P} \right)^{-\epsilon} Y_H^*.$$

[Figure 12](#) Panel A shows how period profits respond to a change in prices at several levels of real exchange rate. The blue line coincides with the closed economy case. Profit function is asymmetric in the sense that an increase in price is yielding less profit loss than a decrease in price. When real exchange rate appreciates, the profit function becomes more asymmetric. When real exchange rate depreciates, it becomes also very costly to move prices upwards but not as much as decreasing prices. The reason is that under producer currency pricing, real exchange rate has symmetric effect



on both the revenue and cost parts of the profit function, due to full pass through. Hence, when firms engage in precautionary pricing they always increase prices. This result depends on the profit function having a smaller slope in absolute value for relative prices higher than one. That is, profit function being asymmetric in response to changes in relative prices, but symmetric in response to changes in real exchange rate. Figure 12 Panel B exhibits this property in three dimension. As we study later in this paper, under local currency pricing, profit function is asymmetric both in response to relative price and real exchange movements. Markups move in the opposite direction under that case.

IRUPT generates an outcome not in line with the policymaker’s objective of attracting FDI and discouraging short-term inflows, when the economy is subject to pricing frictions under full exchange rate pass through.

### 3.3.5 WELFARE ANALYSIS

Having exposed the transmission and propagation mechanisms, we now evaluate the performance of IRUPT in terms of welfare. We compare IRUPT to another “second-order” policy option that can be effective in tackling inefficient capital flows: capital control uncertainty (CCU). We first study CCU in affecting the current account, and then we compare CCU with IRUPT in terms of lifetime welfare and calculate the compensating variation –the percentage of consumption that has to be altered under IRUPT to generate same welfare as under CCU.

#### CAPITAL CONTROL UNCERTAINTY

Capital controls have been studied in the previous literature as a prudential policy for smoothing aggregate demand. However, these policies might not be always ideal during boom episodes (e.g. [Benigno et al. \(2016\)](#)). Hence, the policymaker can consider creating uncertainty on capital controls without actually introducing one, to mildly adjust the current account. We study CCU as follows.

We modify the EME household’s budget constraint to introduce capital controls as in the liter-

ature:

$$\begin{aligned}
& P_t C_t(h) + B_{t+1}(h) + S_t B_{*,t+1}(h) + \frac{\eta}{2} P_t \left( \frac{B_{t+1}(h)}{P_t} \right)^2 + \frac{\eta}{2} S_t P_t^* \left( \frac{B_{*,t+1}(h)}{P_t^*} \right)^2 + P_t I_t(h) + S_t P_t^* I_{*,t}(h) \\
& = R_t B_t(h) + S_t R_t^* (1 + \tau_{t-1}) B_{*,t}(h) + P_t r_{K,t} K_t(h) + S_t P_t^* r_{K,*,t} K_{*,t}(h) + W_t(h) L_t(h) \\
& \quad - \frac{\kappa^W}{2} \left( \frac{W_t(h)}{W_{t-1}(h)} - 1 \right)^2 W_t(h) L_t(h) + d_t(h) + T_t(h) + T_t^\tau(h).
\end{aligned}$$

The additional variables are highlighted in red.  $\tau$  is a capital inflow tax in the EME and the proceeds from this tax are rebated back to EME households period-by-period.

With capital inflow taxes in place, the international bond Euler of the EME household is modified accordingly:

$$1 + b_{*,t+1} = (1 + \tau_t) R_{t+1}^* \mathbb{E}_t \left[ \frac{\beta_{t,t+1}^* r e r_{t+1}}{\Pi_{t+1}^* r e r_t} \right].$$

The new equilibrium conditions tell us that after tax returns of EME and RoW bonds to EME households are  $R_{t+1}$  and  $\tilde{R}_{t+1}^* \equiv (1 + \tau_t) R_{t+1}^*$ , respectively. We further model capital control uncertainty as a stochastic volatility process for the gross rate of capital inflow tax:  $1 + \tau_t = e^{u_t}$ , where  $u_t = \rho^u u_{t-1} + e^{\sigma_t^R} \varepsilon_t$ , with the standard deviation,  $\sigma_t^R$ , following an  $AR(1)$  process,  $\sigma_t^R = (1 - \rho^{\sigma^R}) \sigma^R + \rho^{\sigma^R} \sigma_{t-1}^R + \varepsilon_t^\sigma$ .

We keep the notation the same as in the interest rate uncertainty process, because we exactly introduce the same rule of law with the same calibration to treat both policies fairly in comparison.

Capital control uncertainty can be willingly introduced by policymakers through communication (or lack thereof) with markets. From the perspective of our model, it will make the earnings from holding RoW bonds more uncertain (for EME household).

Figure 13 shows impulse responses to a two standard deviation increase in CCU. The most striking difference is that although the magnitude of the shocks are the same, CCU generates much milder fluctuations than those generated by IRUPT. The reason is that CCU acts similar to an increase in the RoW interest rate uncertainty rather than a more uncertain policy within the EME. Consumption falls due to precautionary savings behavior, and EME households tilt their portfolio towards savings in EME bonds. Hence, there is an outflow in the bond component of the current account. Another significant difference is that real exchange rate depreciates in response to CCU. Because it is the RoW bond which is riskier (from the perspective of EME investor), real exchange rate moves to compensate for the drop in RoW bond price. A depreciating real exchange

rate translates into a lower real price of physical capital in EME, generating inflows of FDI. Price markups still go up due to profit function being asymmetric to price movements but symmetric to real exchange rate movements, and depress the demand. But the effect of real exchange rate is more dominant in attracting FDI. Finally, in contrast with IRUPT, wage markup goes down. It is because the magnitude of the hike in inflation is not enough to generate an increase in nominal wages: nominal wages fall and labor demand increases.

In the end, although minuscule, CCU is successful in controlling the external account and in attracting FDI while discouraging bond inflows.<sup>29</sup>

### WELFARE COMPARISON

We compare IRUPT with CCU in terms of their effect on lifetime utility of the EME household and calculate a compensating variation welfare metric for the two different unconventional macro-prudential policy options. We take a third-order approximation of both the model and the utility function.

When calculating welfare, it is important whether a conditional or unconditional metric is used, and whether calculations are made when the steady state is efficient or inefficient. The unconditional metric measures welfare as the unconditional expectation of the value of the utility function and abstracts from the transition costs when policies are in effect. Hence, it is useful to evaluate the economy from a longer-term perspective. In addition, having distinct ergodic means under each policy option makes the comparison difficult. Hence, we focus more on the conditional metric –conditioned on the value of the deterministic steady state– in accounting for the transitional costs when uncertainty policies are in place.

Neither of these policies are introduced to replicate price stability or introduce perfect risk sharing in international financial markets. Hence, we focus on the simulations from inefficient steady state when evaluating welfare.

We calculate the conditional compensating variation as follows. Let's denote the expected

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<sup>29</sup>It is also possible to generate larger fluctuations with creating more uncertainty. Under both policy options the curvature of the profit functions (i.e. demand elasticity parameter), risk aversion of the agents, an effective-lower-bound in the RoW are all additional ingredients that contribute to much larger fluctuations. These ingredients are studied in the next section.

present discounted value of flow utility under each policy option as:

$$V_t^i = \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left( \frac{C_{t+j}^i 1^{-\rho} - 1}{1 - \rho} - \chi \frac{L_{t+j}^i 1^{+\varphi}}{1 + \varphi} \right) \quad i \in \{IRUPT, CCU\}.$$

Define  $\lambda$  as the percent of consumption that the EME household need each period under when IRUPT is in place to have a lifetime utility the same as when CCU is in place:

$$V_t^{CCU} = \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \frac{(1 + \lambda) C_{t+j}^{IRUPT 1-\rho} - 1}{1 - \rho} - \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \chi \frac{L_{t+j}^{IRUPT 1+\varphi}}{1 + \varphi}.$$

In the above identity, value functions are conditional on the same point. The derivation of the conditional and unconditional compensating variations is available in Appendix C. We calculate the unconditional metric by simulating the model with uncertainty shocks for 4,000 periods starting from the non-stochastic steady state and taking the average of the simulation.

Table 3 shows welfare under each policy and the compensating variation in consumption under both conditional and unconditional metric. We showed in the impulse response analysis that the fluctuations under CCU are much smaller because domestic repercussions of CCU is much limited than those of IRUPT. This is further being reflect in the welfare analysis. The conditional compensating variation shows that the EME household is desiring a level of consumption almost five times of the level of consumption under CCU to live under IRUPT. Welfare is larger under the unconditional metric in each policy regime, as it does not account for the transitional costs in the economy. EME households desires a level of consumption about 2.5 times of the level of consumption under CCU to be indifferent living under IRUPT.

The welfare analysis shows that complicating monetary policy has serious side effects and not desirable against more simple policy options. Furthermore, EME households are much better off when policymakers create uncertainty about foreign variables (e.g.  $\tilde{R}_{t+1}^* \equiv (1 + \tau_t) R_{t+1}^*$ ), rather than uncertainty about domestic variables.

## 4 ADDITIONAL RESULTS

In this section, we discuss how our results react to introducing new relevant features to the baseline model. First, to capture the long-run nature of FDI, we introduce time-to-build capital for

investment in physical capital that will be used in overseas production. Second, due to central role of the real exchange rate in our results, we also study dynamics when firms engage in local currency pricing. Third, we look at the implications of using Epstein-Zin-Weil preferences, and deviate from time-separable utility. Finally, we study IRUPT when there is an effective-lower-bound (ELB) in the RoW monetary policy, because the episode in which Emerging Market Economies received large amount of capital inflows coincides with near zero interest rates in advanced economies.

#### 4.1 TIME-TO-BUILD FDI

Given the long-run nature of FDI, we also study dynamics under the condition that it requires multiple periods for Home and RoW agents to build the physical capital that will be used in the overseas production process. In doing so, equation (3) will be replaced by the following conditions:

$$\begin{aligned}
K_{*,t+1}(h) &= (1 - \delta)K_{*,t}(h) + I_{*,1,t}(h), \\
I_{*,j-1,t+1}(h) &= I_{*,j,t}(h); \quad j = 2, \dots, J. \\
I_{*,t}(h) &= \sum_{j=1}^J \frac{1}{j} I_{*,j,t}(h)
\end{aligned} \tag{28}$$

where  $\frac{1}{j}$  determines the fixed fraction of total investment expenditures allocated to projects that are  $j$  periods away from completion.  $I_{*,j,t}(h)$  is the project that is initiated in period  $t$  and  $j$  periods away from completion.

The conditions in (28) imply that, each period, households initiate projects that will be completed in  $J$  periods, and complete partially finished projects that are initiated in previous periods. Home households' optimization problem subject to above constraints lead to following Euler equation for Home capital that will be used in RoW and the respective pricing equation for the outgoing FDI:

$$q_{*,t+J-1} = \mathbb{E}_{t+J-1} [\beta_{t+J-1,t+J} (rer_{t+J} K_{*,t+J} + q_{*,t+J} (1 - \delta))], \tag{29}$$

$$\mathbb{E}_t [\beta_{t,t+J-1} q_{*,t+J-1}] = \frac{1}{J} (rer_t + \mathbb{E}_t [\beta_{t,t+1} rer_{t+1}] + \dots + \mathbb{E}_t [\beta_{t,t+J-1} rer_{t+J-1}]), \tag{30}$$

Equations (29) and (30) show that the period  $t + J - 1$  return of investment for the capital that will be completely built in period  $t + J$  depends on the rental rate (in foreign consumption units) and the expected fluctuations in real exchange rate. Equation (30) links the discounted marginal cost

of each project initiated in subsequent periods to the expected discounted one-period beforehand price of investment.

Furthermore, now the current account can be written as:

$$\underbrace{(b_{t+1} - b_t) + rert_t(b_{*,t+1} - b_{*,t})}_{\text{Bond component}} + \frac{1}{J} \underbrace{\left[ \left( \frac{1-n}{n} \right) rert_t(K_{*,t+J} - K_{*,t}) - (K_{t+J}^* - K_t^*) \right]}_{\text{FDI component}} \equiv CA_t$$

Appendix C shows the modifications in net foreign asset condition when FDI is subject to time-to-build.

Figure 14 shows the impulse responses to an increase in interest rate uncertainty when FDI is subject to 4-period time-to-build. Irreversibility of FDI contributes to a dampening in the net outflow of FDI from EME. EME households shift their investments toward the physical capital that will be used in RoW production, where risk is lower. However, because FDI takes 4-periods to be completed, they cannot generate immediate rental gains from shifting their investments, and instead, borrow instantaneously from international financial markets to prevent a further fall in their consumption. On the other hand, because EME debt is now riskier, RoW investors run away from EME debt and the bond outflows are observed two-periods after the rise in uncertainty in EME interest rate. Markups rise and contribute to an increase in inflation as before.

A comparison of current account dynamics under different periods of time-to-build is given in Figure 19. The figure shows that as the periods of time-to-build increase from two periods to four periods, net outflow of FDI becomes milder. However, as the sought rental gain from shifting investments is not received immediately under multiple periods being required to build the FDI, there is an instantaneous increase in short-term borrowing.

Dampening in net FDI outflows when FDI is subject to time-to-build is related with the “real options” argument that [Bernanke \(1983\)](#) highlighted: firms can evaluate their options as uncertainty increases. Having been more cautious, firms can prefer to wait and see until the resolution of uncertainty, before cutting down the demand for FDI.<sup>30</sup> The policymaker’s objective of attracting long-run and discouraging short-run flows is still not achieved under this version of the model. Moreover, irreversibility of FDI increases short-run inflows to the EME immediately after using

<sup>30</sup>See also [Stokey \(2016\)](#) for a more recent analysis.

interest rate uncertainty as a policy tool. The policy is, again, inflationary as in previous versions.

## 4.2 CURRENCY OF TRADE INVOICING

We assumed that domestic prices are always set in the currency of the consumer and the foreign price is set in the producer currency, in our baseline setting. Since the nature of price rigidity is central for the real effects of exchange rate fluctuations, in this subsection, we investigate the consequences when foreign price is set in the local currency, referred to as local currency pricing (LCP)<sup>31</sup>.

Under LCP, the cost of adjustment in changing prices for the export market is also dependent on the fluctuations in the nominal exchange rate in addition to price differentials. Therefore, the movements in the nominal exchange rates affect the relative price of the firm in domestic and foreign markets, violating the law of one price. Appendix D provides the details about firms' problem under LCP.

Figure 15 shows impulse response functions after an increase in interest rate uncertainty in a setting where firms engage in LCP. EME bond is again riskier with an increase in uncertainty and there is an outflow in the bond component of the current account. The most interesting observation is that LCP reverses the behavior of net FDI flows in response to interest rate uncertainty. A fall in export price markup implies cheaper exports under LCP. Cheaper exports contribute to an increase in export demand and a pressure on domestic firms to increase production. The latter generates a demand on capital, both from Home and RoW agents, contributing to an increase in net FDI inflows to the EME.

Why does the export price markup fall in response to IRUPT? It is because the profit function is asymmetric both in relative price and in real exchange rate. To see this, we write the steady state period profits abstracting from adjustment costs:

$$rer \left( \frac{P_H^*}{P} \right)^\epsilon \left( \frac{P_H^*(i)}{P^*} \right)^{1-\epsilon} Y_H^* - \left( \frac{\epsilon - 1}{\epsilon} \right) \left( \frac{P_H^*}{P^*} \right)^\epsilon \left( \frac{P_H^*(i)}{P^*} \right)^{-\epsilon} Y_H^*.$$

As can be seen from above, real exchange rate enters only the revenue side of the above identity, because when prices are set in local currency, only the revenues are converted to EME consumption

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<sup>31</sup>We focus on LCP and leave the analysis with dominant currency pricing (DCP) recently highlighted by [Gopinath \(2016\)](#) for future work.

units and there is no exchange rate pass-through. Figure 16 Panel A shows how period profits respond to a change in relative prices at several levels of real exchange rate. The blue line coincides with the closed economy case. For the values of real exchange rate after an appreciation, profits are asymmetric in the sense that increasing prices will be precautionary. However, for the values of real exchange rate after a depreciation, precautionary price setting is toward decreasing prices. Under flexible exchange rates, this contributes to a significant uncertainty about future profits and firms prefer to lower their prices as the gain from lower prices when real exchange rate depreciates is bigger than the gain from higher prices when real exchange rate appreciates. Hence, when profit function is asymmetric in both relative prices and real exchange rate, markups go down under local currency pricing. The asymmetrically in both arguments is clearer in Figure 16 Panel B.

If FDI is subject to time-to-build, the pass-through effect gets smaller over time due to long-run nature of FDI: real options channel dominates precautionary pricing. Figure 21 shows that the instant net inflow of FDI gets smaller as FDI is subject to longer periods to build. While the net-inflow is getting smaller, export revenues are diminishing. With the required rental gains are not delivered instantaneously, an immediate rise in the short-term current account deficit takes place, as in the case under PCP. When FDI is subject to four periods to build, it is observed from Figure 22 that short term component of the current account experiences a larger initial deficit.

### 4.3 EPSTEIN-ZIN-WEIL PREFERENCES

Computing the equilibrium with recursive preferences are being used to break the link between risk aversion and inverse of the elasticity of intertemporal substitution (EIS). Because the source of fluctuations is an increase in uncertainty of the central bank policy rate, it is informative to identify the trade-offs between agents' incentives on smoothing across states versus smoothing across time, in response to changes in interest rate risk. Therefore, in this subsection, we extend our analysis by assuming different degrees of risk aversion for the RoW agents and study their interaction with the EME.

We follow the literature and generalize equation (1) to an Epstein-Zin-Weil (Epstein and Zin (1989) and Weil (1989)) specification:

$$V_t \equiv (1 - \beta)U(C_t(h), L_t(h)) - \beta \left[ \mathbb{E}_t (-V_{t+1})^{1-\alpha} \right]^{1/(1-\alpha)}, \quad (31)$$



where  $\alpha \in \mathbb{R}$ .<sup>32</sup> When  $\alpha = 0$ , (31) reduces to the standard expected utility in (1). With  $U \leq 0$  everywhere, lower values of  $\alpha$  correspond to greater degrees of risk aversion.

Now, the discount factor of RoW agents,  $\beta_{t,t+1}^*$ , becomes

$$\beta_{t,t+1}^* \equiv \frac{\beta U_{C,t+1}^*}{U_{C,t}^*} \left( \frac{-V_{t+1}^*}{(\mathbb{E}_t[-V_{t+1}^{*1-\alpha^*}])^{1/(1-\alpha^*)}} \right)^{-\alpha^*}. \quad (32)$$

With Epstein-Zin-Weil preferences, the discount factor now has an additional term reflecting the early resolution of uncertainty. With  $\alpha^* < 0$ , unfavorable changes in utility imply a higher discount factor for RoW agents.

Using (32) and its Home counterpart we can express the no-arbitrage condition as:

$$\frac{R_{t+1}}{R_{t+1}^*} = \frac{(1 + \eta b_{t+1}^*) \mathbb{E}_t \left[ \frac{\beta U_{C,t+1}^*}{U_{C,t}^*} \left( \frac{-V_{t+1}^*}{(\mathbb{E}_t[-V_{t+1}^{*1-\alpha^*}])^{1/(1-\alpha^*)}} \right)^{-\alpha^*} \frac{1}{\Pi_{t+1}^*} \right]}{(1 + \eta b_{*,t+1}^*) \mathbb{E}_t \left[ \frac{\beta U_{C,t+1}^*}{U_{C,t}^*} \left( \frac{-V_{t+1}^*}{(\mathbb{E}_t[-V_{t+1}^{*1-\alpha^*}])^{1/(1-\alpha^*)}} \right)^{-\alpha^*} \frac{rer_t}{\Pi_{t+1} rer_{t+1}} \right]}.$$

Deviations from the uncovered interest parity is now additionally based on the discounted future utility stream and its time-varying risk component. Employing a third-order perturbation solution technique implies the covariance between the stochastic discount factor and the change in nominal exchange rates will be important to understand whether EME bonds are a better hedge with respect to RoW bonds, from the perspective of RoW agents.

Figure 23 compares the impulse responses to rising uncertainty in EME interest rate when RoW agents are becoming more risk averse. To highlight the role of RoW risk aversion on model dynamics, *w.l.o.g.*, we compare simulations with  $\alpha^*$  being equal to 0, -48, and -148. Our calibration implies an approximate risk aversion of 25, and 80 for the values of  $\alpha^*$  we set.<sup>33</sup>

As we increase RoW risk aversion, it is observed from the figure that there is a decrease in the investment made by RoW for the capital that is rented to Home economy, leading to an initial increase in the FDI component of the EME current account. The intuition is similar as in the baseline

<sup>32</sup>Because our utility kernel employs an elastic intertemporal substitution (*i.e.*  $\rho = 2$ ),  $U \leq 0$  everywhere and recursion is formulated as in (31). As highlighted by Rudebusch and Swanson (2012), when  $U \geq 0$  everywhere, it is natural to reformulate the recursion as  $V_t \equiv (1 - \beta)U(C_t(h), L_t(h)) + \beta [\mathbb{E}_t (V_{t+1})^{1-\alpha}]^{1/(1-\alpha)}$ .

<sup>33</sup>Swanson (2018) calculates risk aversion in models with flexible labor margin and we follow his calculations in setting risk aversion.

version of the model: Precautionary pricing of Home firms lead to higher markups, contributing to a decrease in profits. However, markups increase milder than in baseline model because a change in EME production prices have a more dominant effect on RoW investment behavior as RoW agents are more risk averse now. The change in prices is transformed into lower rental rates for the capital that is rented from RoW. The rental rate decreases quicker for higher degrees of RoW risk-aversion, reflecting the desire for the early resolution of uncertainty. In return, agents in RoW cut their investment in a more pronounced manner vis-à-vis to the behavior in the baseline model.

International linkages with EME imply a decrease in RoW consumption and increase in RoW savings. Lower rental gains of RoW agents from investing in EME capital is transformed into a noticeable increase in the real exchange rate appreciation (from EME perspective). Through the uncovered interest parity condition, a more pronounced increase in real exchange rate combined with higher RoW discount factor induces a lower short-term return from holding RoW bonds vis-à-vis to holding EME bonds. Although the source of risk is in EME interest rate, RoW agents increase their holdings of EME bonds, causing an inflow to EME. Hence, the behavior of the bond component of the current account is reversed with more risk-averse RoW agents.

The jump in markups is lower and they are transformed into a lower hike in EME inflation. The increase in EME policy uncertainty leads to short-term inflows together with long-term outflows and an increase in inflation.

#### 4.4 EFFECTIVE-LOWER-BOUND IN THE REST OF THE WORLD

The period of interest for our exercise coincides with the phase in which advanced economies were constrained from using their conventional monetary policy tool, nominal interest rate. Capital flows in an interdependent economy are heavily related with the monetary policy in the RoW, and therefore, we study the implications of such case under this subsection.

To provide analysis, we introduce the inability of monetary policy response in the RoW embodied in an interest rate peg. Although there is no explicit effective-lower-bound on the RoW nominal interest rate, this exercise enables us to approximate the effects, because what matters in our analysis is making the RoW rate unresponsive to economic conditions.<sup>34</sup>

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<sup>34</sup>Sims and Wolff (2018) use a similar methodology to study the effects of government spending shocks during the zero-lower-bound episodes.

In our experiment, we consider that the RoW nominal interest rate is pegged at its steady state value for four periods,<sup>35</sup> and we hit the economy with an unexpected EME interest rate uncertainty shock in period one. The impulse responses from our experiment are available in Figure 25. For each variable we plot the responses in terms of percent deviations from the stochastic steady state.

We observe that in each panel the responses are heavily magnified. The bond component and the FDI component of the current account both exhibit a positive reaction, implying outflows. Net FDI outflow is much more pronounced than in previous cases due to big appreciation of real exchange rate, making investment to the rest of the world much cheaper. Using interest rate uncertainty as a policy tool is still increasing markups, but this time with opposite effects on output and inflation: unlike the previous cases, interest rate uncertainty is now expansionary and deflationary.

The reason behind the change in qualitative responses of output and inflation is due to the trade effect. RoW monetary policy being constrained from moving south, relative prices in the RoW decrease in a more pronounced manner in response to real exchange rate movements. A fall in the RoW relative prices amplify the demand for imports in the EME, contributing to an increase in final good production. Similarly, because the decrease in the RoW produced goods prices is more pronounced than the increase in EME produced good prices, consumer price index falls down.

The importance of the trade share is clearly observable when we move the home bias parameter,  $a$ , to 0.90. Figure 26 shows impulse responses for the same exercise under new calibration. First of all, setting a smaller share of foreign intermediate goods in production of final output leads to a fall in the magnitude of responses. This is because the trade is more limited, and the fall in the RoW prices affect the EME variables relatively low. The most stark difference from the previous exercise is the qualitative change in the responses of output and inflation. The model behaves more in line with the previous versions, and the markup channel and the precautionary savings channel still dominate the trade effect generated by the fall in RoW prices. Our interpretation is that the responses from Figure 26 is more meaningful for two reasons. First, because of the fact that EME countries also do trade in-between each other, and during the implementation of the interest rate uncertainty as a policy tool, EMEs were not constrained by the lower bound. Second, advanced economies have also stronger ties between each other and EME policies do not heavily affect their

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<sup>35</sup>Fernández-Villaverde et al. (2015) also conduct a zero-lower-bound exercise under tax uncertainty shocks. In their setting, they introduce a combination of exogenous innovations to keep the interest rate at zero for a fixed amount of time.

good prices. Hence, we conclude that using interest rate as a policy tool is still discouraging bond inflows at the expense of FDI inflows, lower output, and higher inflation.

## 5 CONCLUSIONS

We examined the hypothesis that using interest rate uncertainty as an unconventional macroprudential policy tool is effective in dampening inefficient capital inflows and adjusting the composition of the external account between bonds and FDI. We further investigated the transmission and propagation channels in affecting the current account and compared interest rate uncertainty policy with capital control uncertainty policy.

We find that IRUPT can be used as a macroprudential tool against inefficient capital inflows. A rise in EME interest rate uncertainty makes EME debt riskier and RoW investors shift away from EME debt when smoothing consumption. EME households also prefer holding RoW bonds due to precautionary saving motives in response to IRUPT. A real exchange rate appreciation partly compensates for the fall in the EME bond price and acts as a hedging mechanism.

When production is subject to price rigidities and there is full exchange rate pass through, firms adjust their prices to higher levels than they would otherwise do. This is due to profit function being asymmetric to price changes but symmetric to real exchange rate fluctuations. Increase in markups together with a fall in consumption imply lower rental rate paid to RoW households for their investment in EME capital, and contributes to a fall in FDI received by the EME. When profit function is asymmetric in both price and real exchange rate fluctuations –as in the case under local currency pricing–, markups go down, generating an opposite effect in the FDI component of the current account.

Introducing irreversibility to FDI through a time-to-build assumption generates a wait-and-see effect, dampening FDI outflows. Having a RoW interest rate that is unresponsive to economic conditions as in the Great Recession era significantly amplifies the effect of uncertainty shocks. Furthermore, the direction of the bond component of the current is also dependent on the degree of risk aversion of RoW agents. At very high risk premium, holding EME bonds can be preferred by international investors.

The results are relevant because emerging economy central banks are concerned with adjusting

the external account and its composition when there are ample capital flows. We provide a rigorous analysis of a novel policy tool that is already experimented by an EME central bank. When inflation is below the central bank target rate and there are political constraints in implementation of economic policy, IRUPT can be used as a macroprudential tool against capital inflows. However, we also argue that complicating monetary policy is not desirable with respect to introducing conventional policy that can be effective in taming capital inflows.

An extension of the model that introduces an imperfect banking sector in the EME is a natural extension of our model. Under this setting, increased uncertainty in the policy rate can aggravate financial frictions in the banking sector, contributing to a new channel in affecting capital flows. We leave this extension for future work.

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## TABLES

Table 1: Model Summary (Baseline)

Euler equation, domestic bonds	$1 + \eta b_{t+1} = R_{t+1} \mathbb{E}_t \left[ \frac{\beta_{t,t+1}}{\Pi_{t+1}} \right]$
Euler equation, RoW bonds	$1 + \eta b_{*,t+1} = R_{t+1}^* \mathbb{E}_t \left[ \frac{\beta_{t,t+1}}{\Pi_{t+1}^*} \frac{rer_{t+1}}{rer_t} \right]$
Law of motion of capital (Home)	$K_{t+1}(h) = (1 - \delta)K_t(h) + I_t(h)$
Law of motion of capital (FDI)	$K_{*,t+1}(h) = (1 - \delta)K_{*,t}(h) + I_{*,t}(h)$
Euler equation, Home capital	$1 = \mathbb{E}_t [\beta_{t,t+1} (r_{K,t+1} + 1 - \delta)]$
Euler equation, FDI	$1 = \mathbb{E}_t \left[ \beta_{t,t+1} \frac{rer_{t+1}}{rer_t} (r_{K,*,t+1} + 1 - \delta) \right]$
Real wage	$w_t = \mu_t^W \left( \frac{\chi L_t^\varphi}{C_t^{1-\rho}} \right)$
Demand functions	$Y_{H,t} = a \left( \frac{P_{H,t}}{P_t} \right)^{-\omega} Y_t$ $Y_{F,t} = (1 - a) \left( \frac{P_{F,t}}{P_t} \right)^{-\omega} Y_t$
Price index	$1 = \left( a \cdot r p_{H,t}^{1-\omega} + (1 - a) r p_{F,t}^{1-\omega} \right)^{\frac{1}{1-\omega}}$
Marginal cost of intermediate good production	$mc_t = \frac{w_t^{1-\alpha_1-\alpha_2} r_{K,t}^{\alpha_1} (r_{K,t}^*)^{\alpha_2}}{(1-\alpha_1-\alpha_2)^{1-\alpha_1-\alpha_2} \alpha_1^{\alpha_1} \alpha_2^{\alpha_2}}$
Relative price of goods sold at Home	$r p_{H,t} = \mu_{H,t} mc_t$
Relative price of exports	$r p_{H,t}^* = \frac{\mu_{H,t}^* mc_t}{rer_t}$
Intermediate good production	$Y_{H,t} + \left( \frac{1-n}{n} \right) Y_{H,t}^* = K_t^{\alpha_1} K_t^* \alpha_2 L_t^{1-\alpha_1-\alpha_2}$
Factors of production	$\alpha_1 w_t L_t = (1 - \alpha_1 - \alpha_2) r_{K,t} K_t$ $\alpha_2 r_{K,t} K_t = \alpha_1 r_{K,t}^* K_t^*$
Resource constraint	$Y_t = C_t + I_t + I_t^* + \frac{\kappa}{2} (\Pi_t^W - 1)^2 w_t L_t$ $+ \frac{\kappa}{2} (\Pi_{H,t} - 1)^2 r p_{H,t} Y_{H,t}$ $+ \left( \frac{1-n}{n} \right) \frac{\kappa}{2} (\Pi_{H,t}^* - 1)^2 r p_{H,t}^* Y_{H,t}^*$
Net foreign assets	$b_{t+1} + rer_t b_{*,t+1} + \left( \frac{1-n}{n} \right) rer_t K_{*,t+1} - K_{t+1}^*$ $= \frac{R_t}{\Pi_t} b_t + \frac{R_t^*}{\Pi_t^*} rer_t b_{*,t} + \left( \frac{1-n}{n} \right) rer_t (r_{K,*,t} + 1 - \delta) K_{*,t}$ $- (r_{K,t}^* + 1 - \delta) K_t^* + T B_t$
Monetary policy	$\frac{R_t}{R} = \left( \frac{R_{t-1}}{R} \right)^{\rho_R} \left( \frac{\Pi_t}{\Pi} \right)^{(1-\rho_R)\rho_\Pi} \left( \frac{Y_t}{Y} \right)^{(1-\rho_R)\rho_Y} e^{u_t}$

Table 2: Calibration

<i>Parameter</i>		<i>Value</i>	<i>Comments</i>
Discount factor	$\beta$	0.9804	2% Real Rate
Relative risk aversion	$\rho$	2	Literature
Relative weight of labor in utility	$\chi$	1	Literature
Frisch elasticity	$\varphi$	0.25	Literature
Bond adjustment	$\psi$	0.0025	Literature
Rotemberg wage adjustment	$\kappa^W$	116	Barattieri et al. (2018)
Elasticity of substitution of differentiated labor	$\epsilon^W$	11	Wage markup of 10%
Home bias	$a$	0.65	Unsal (2013)
Share of domestic capital	$\alpha_1$	0.30	Aoki et al. (2016)
Share of foreign capital	$\alpha_2$	0.15	Aoki et al. (2016)
Rotemberg domestic price adjustment	$\kappa$	116	Barattieri et al. (2018)
Rotemberg export price adjustment	$\kappa^*$	116	Barattieri et al. (2018)
Elasticity of substitution of differentiated goods	$\epsilon$	11	Price markup of 10%
Interest rate smoothing coefficient	$\rho_R$	0.7	Literature
Steady state response to inflation	$\rho_\Pi$	1.5	Literature
Steady state response to output	$\rho_Y$	0.5/4	Literature

Table 3: Welfare

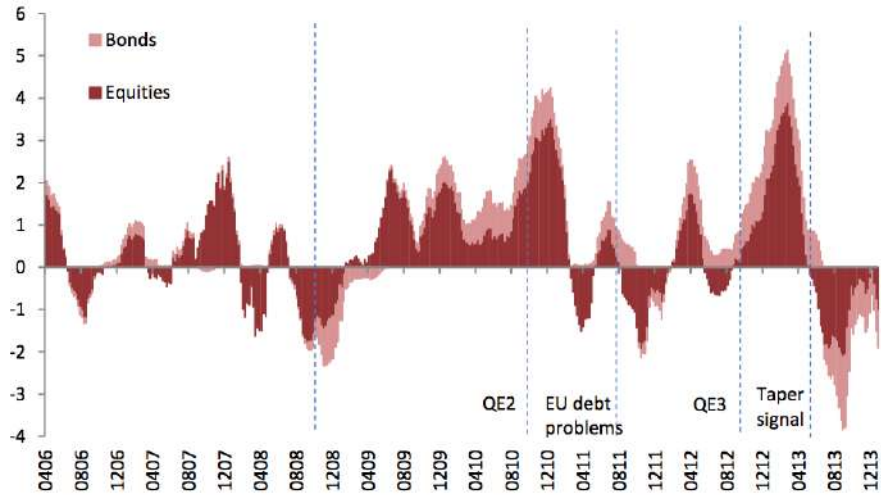
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	<i>Welfare under IRUPT</i>	<i>Welfare under CCU</i>	<i>Welfare Cost, <math>\lambda</math></i>
Conditional	-3090.040	-276.425	4.757
Unconditional	-1927.126	-142.779	2.416

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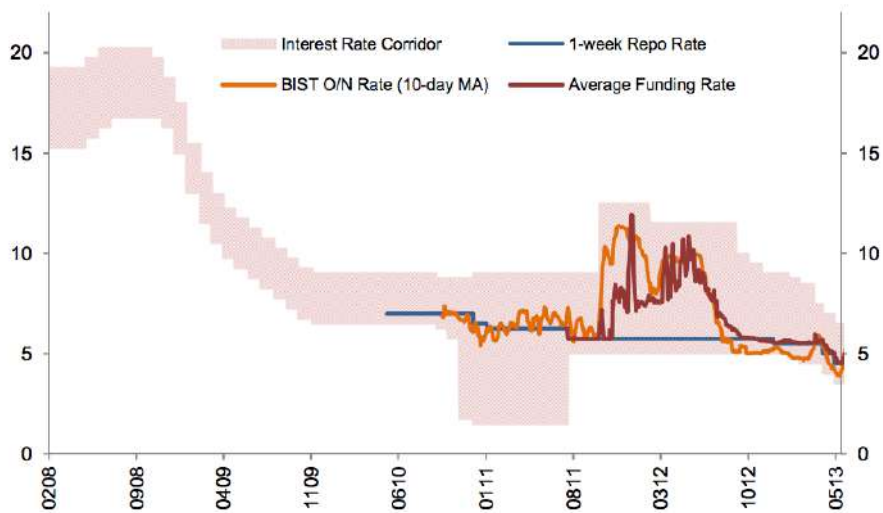
## FIGURES

Figure 1: Portfolio Flows to EMEs (13-week moving average, bn USD)



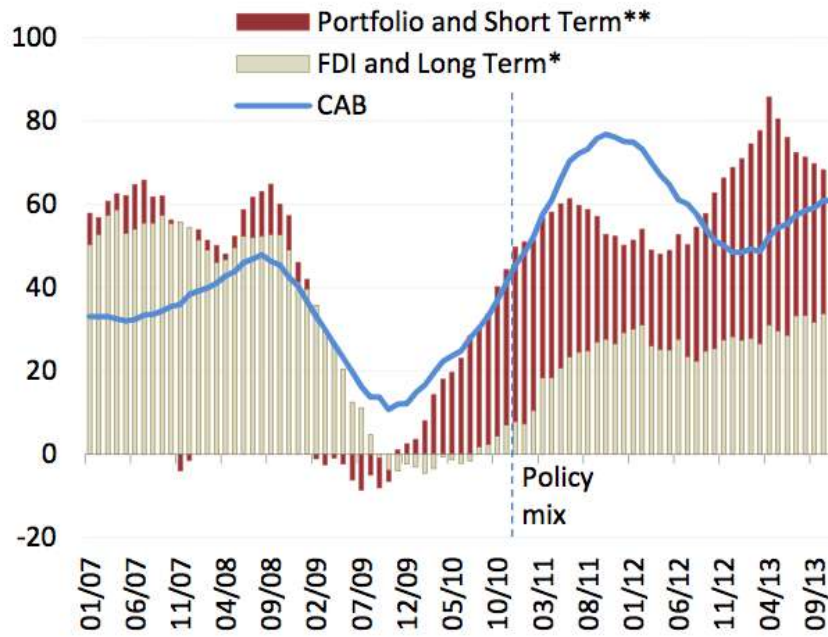
Source: Central Bank of the Republic of Turkey

Figure 2: Interest Rate Corridor and Average Funding Cost, Turkey



Source: Central Bank of the Republic of Turkey

Figure 3: Financing the Current Account, Turkey (12-month cumulative, bn USD)



Source: Central Bank of the Republic of Turkey

Figure 4: Model Architecture

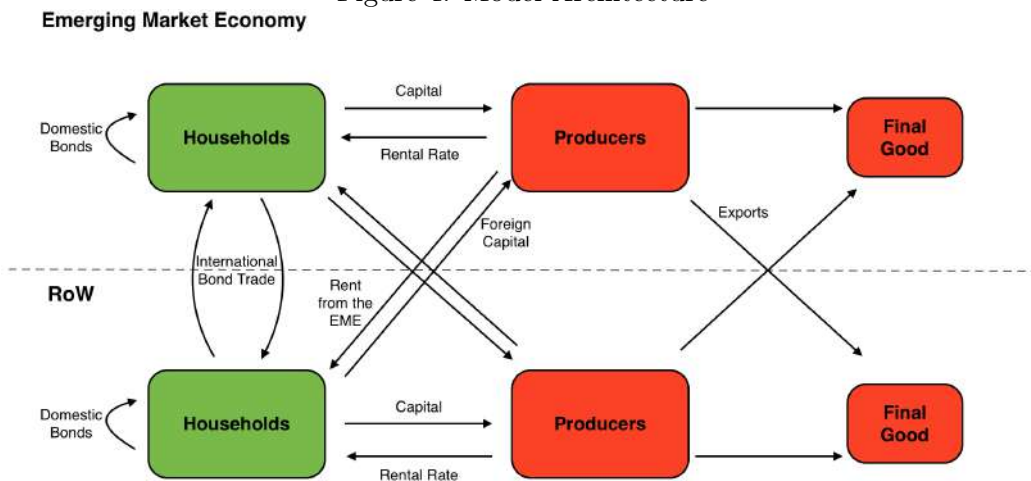






Figure 6: Movements in the UIP “Wedge”  
 $\mu^{UIP}$

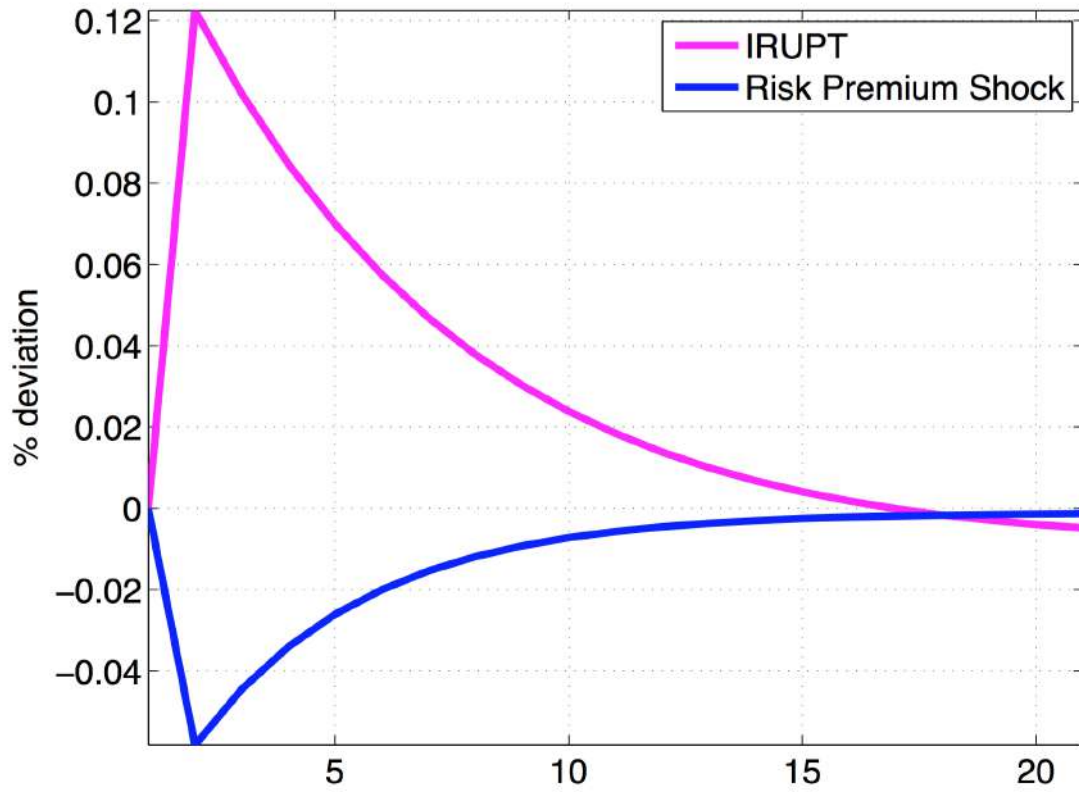


Figure 7: Inefficient capital inflows and IRUPT

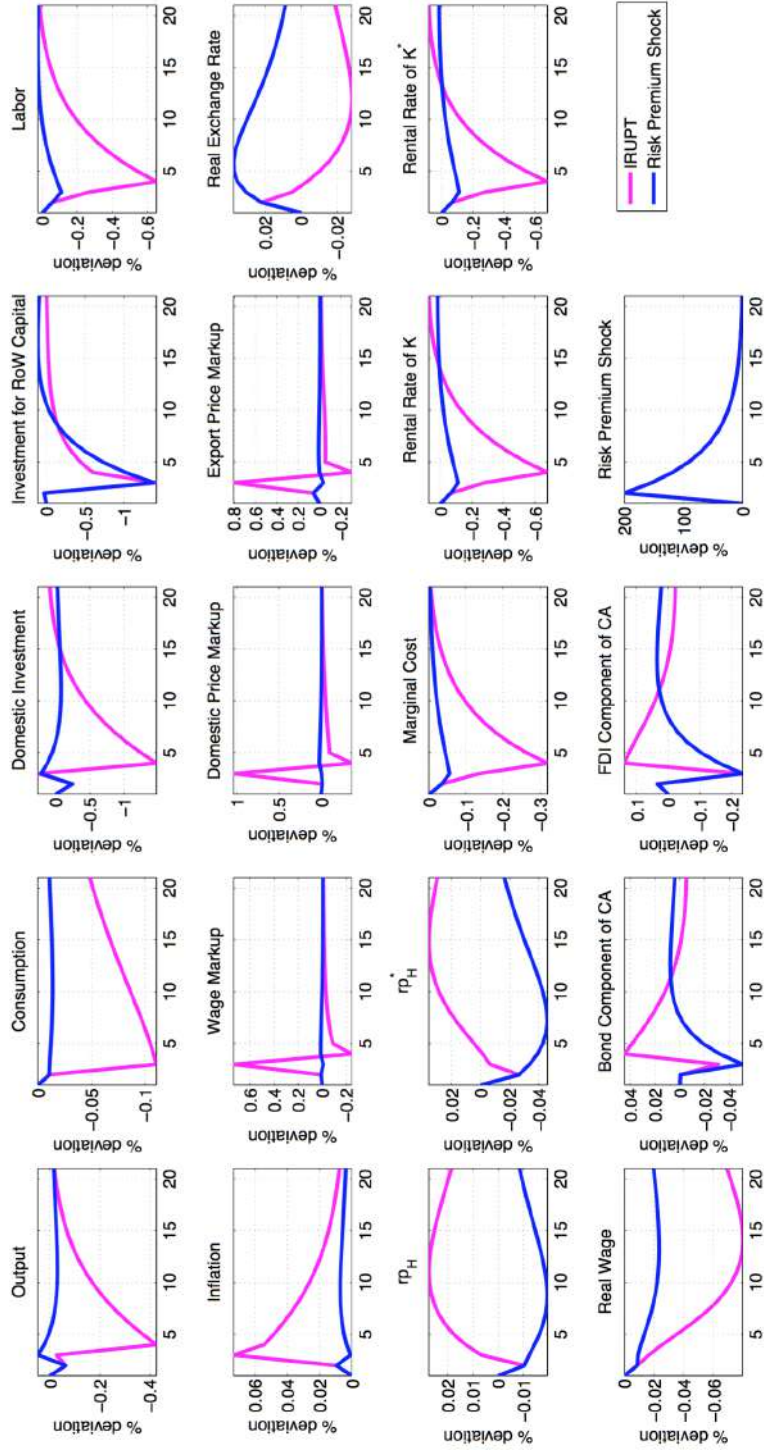


Figure 8: Impulse Responses to an Increase in Interest Rate Uncertainty (baseline)

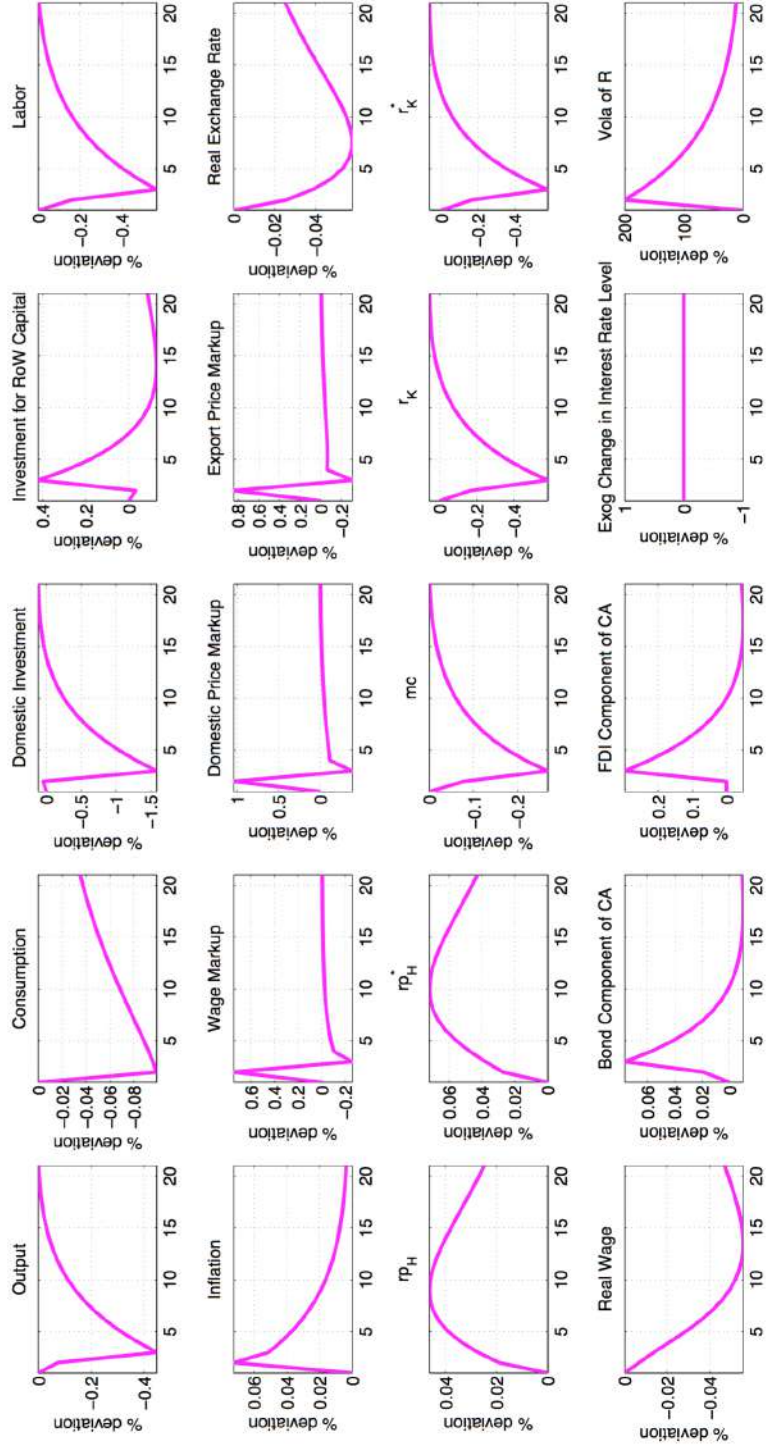


Figure 9: Decomposition of RoW Portfolio Risk

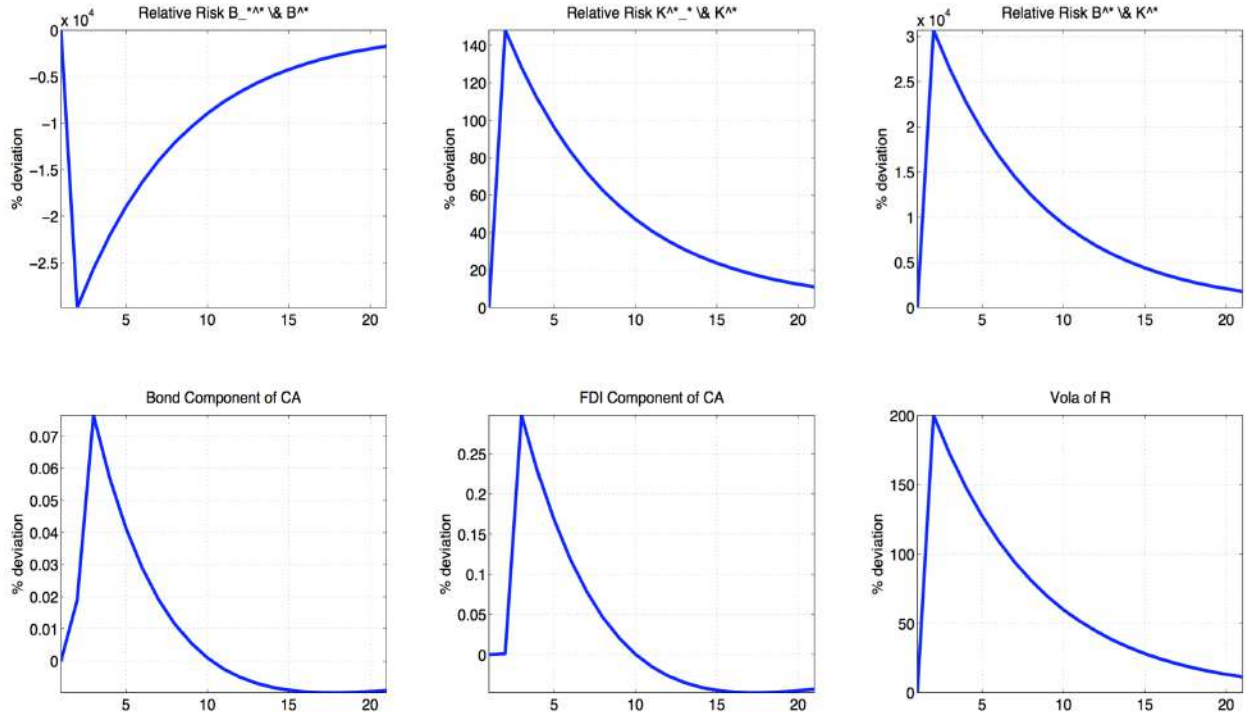


Figure 10: Impulse Responses to an Increase in Interest Rate Uncertainty ( $\kappa = \kappa^* = 0$ )

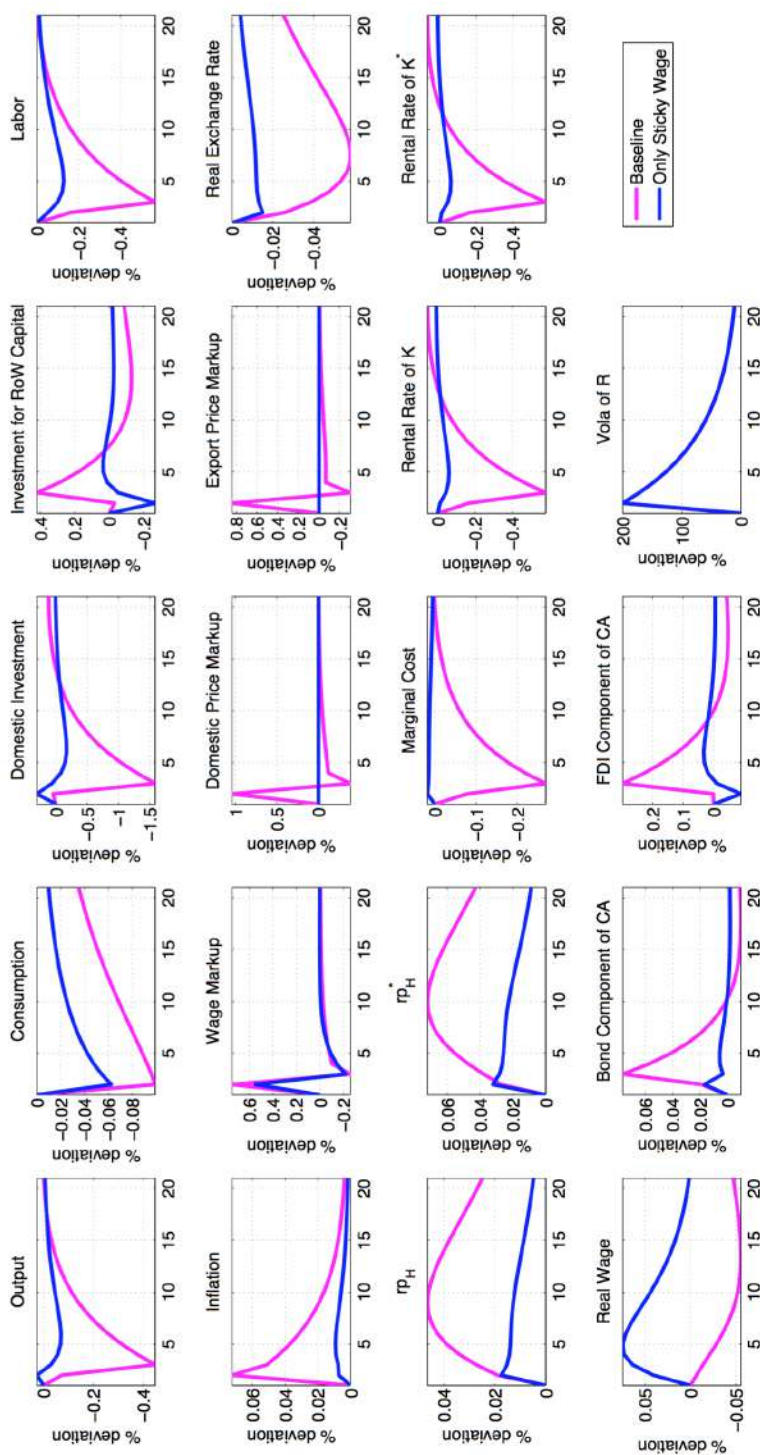


Figure 11: Impulse Responses to an Increase in Interest Rate Uncertainty ( $\kappa^W = 0$ )

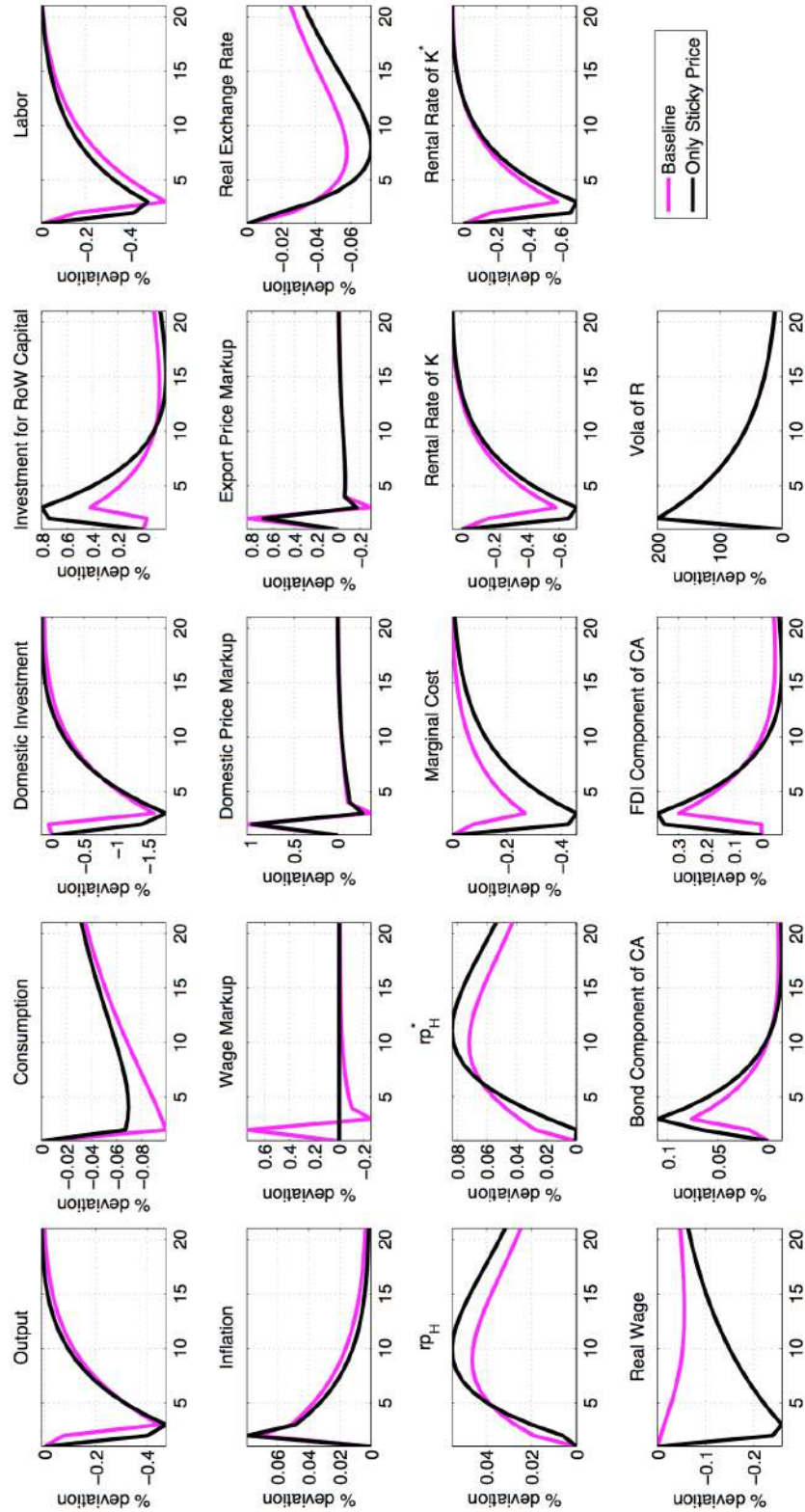


Figure 12: Period Profit (PCP)

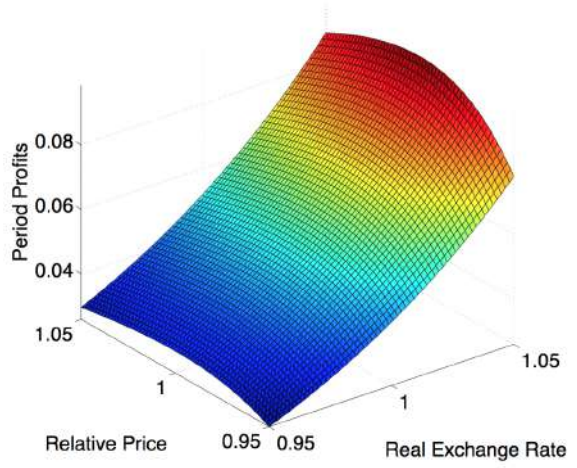
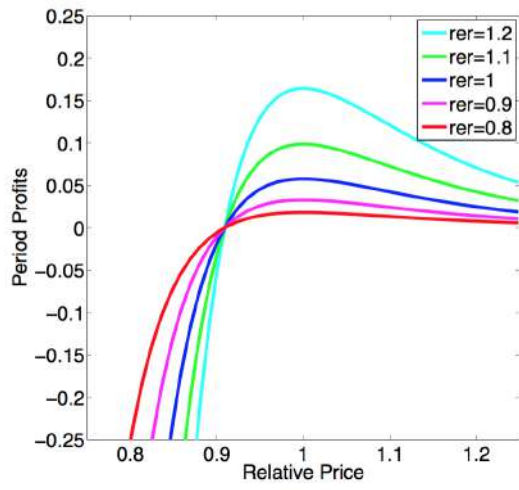




Figure 13: Impulse Responses to an Increase in Capital Control Uncertainty (CCU)

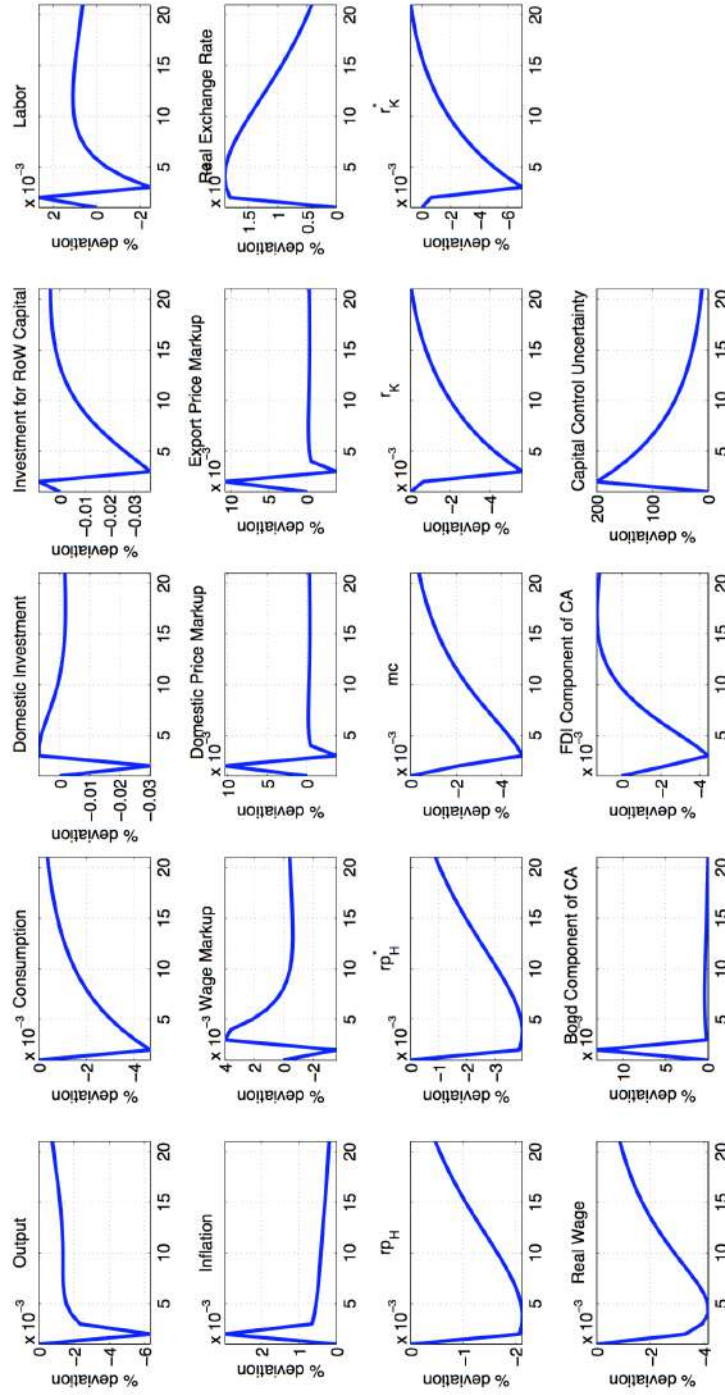


Figure 14: Impulse Responses to an Increase in Interest Rate Uncertainty (4-period time-to-build FDI)

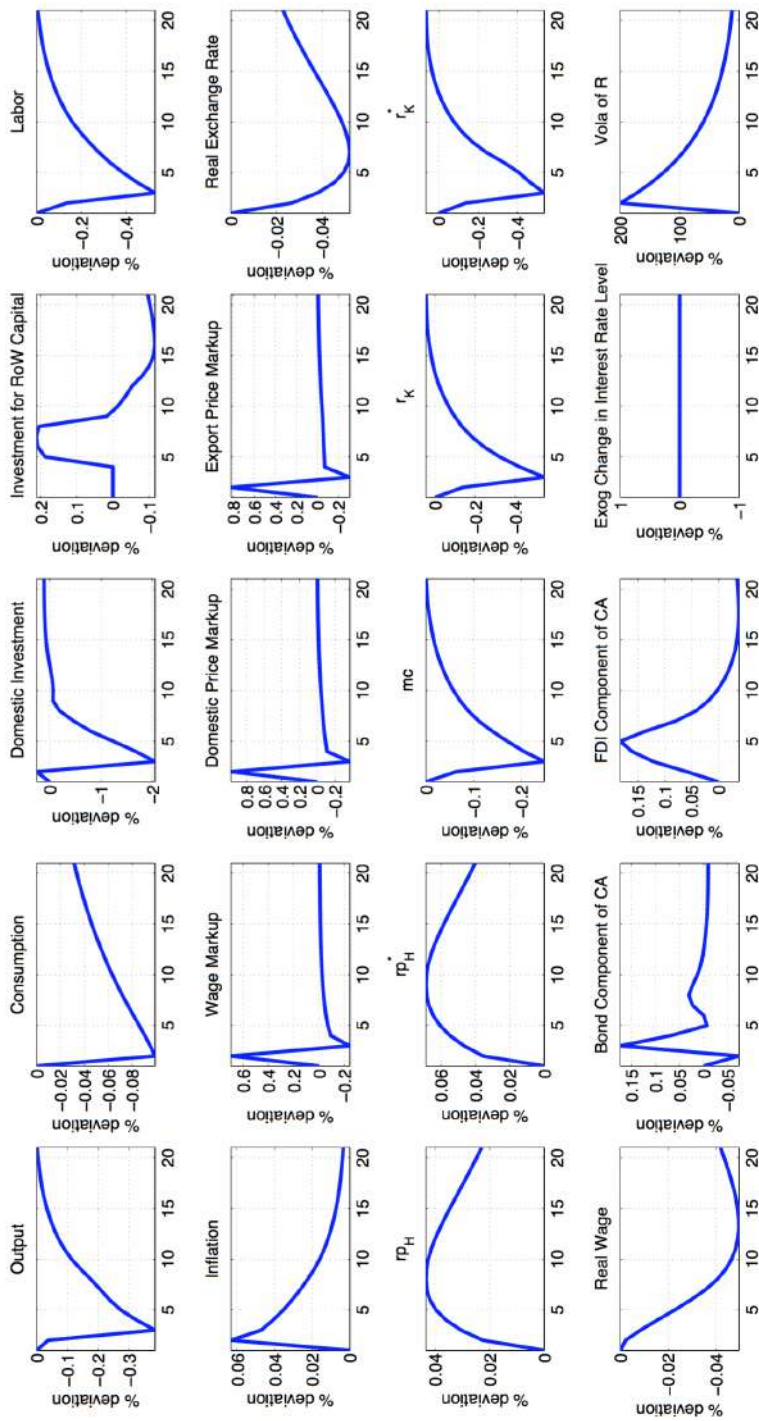


Figure 15: Impulse Responses to an Increase in Interest Rate Uncertainty (LCP)

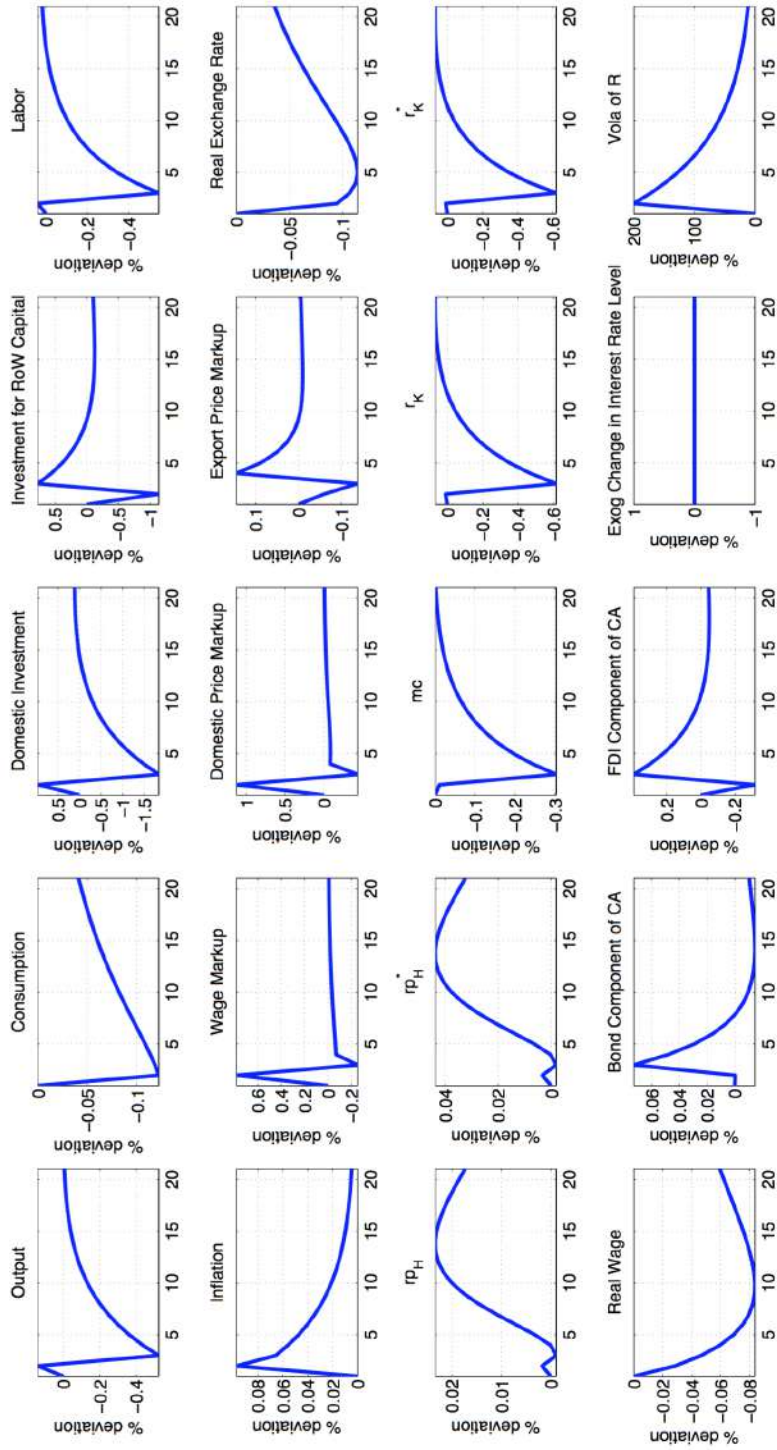


Figure 16: Period Profit (LCP)

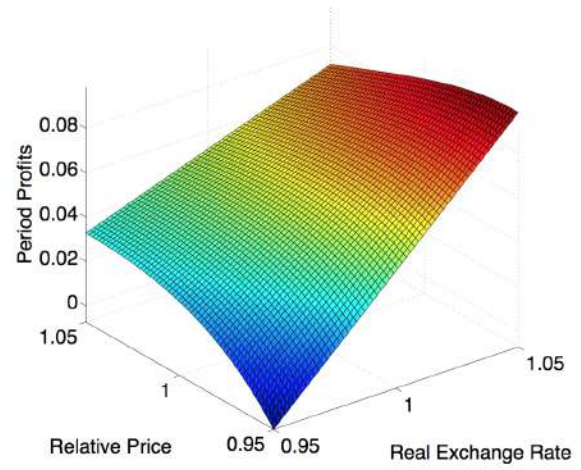
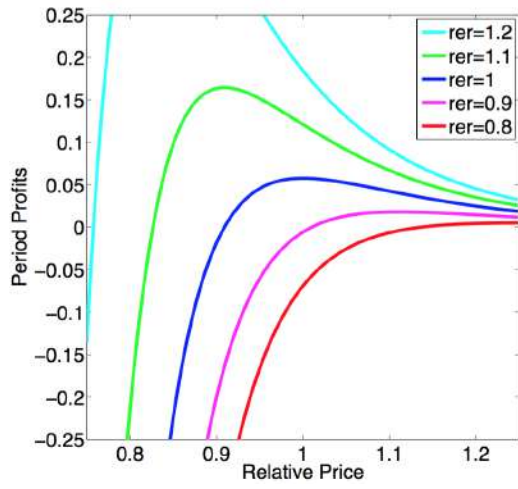


Figure 17: Impulse Responses to an Increase in Interest Rate Uncertainty (LCP, 4-period time-to-build FDI)

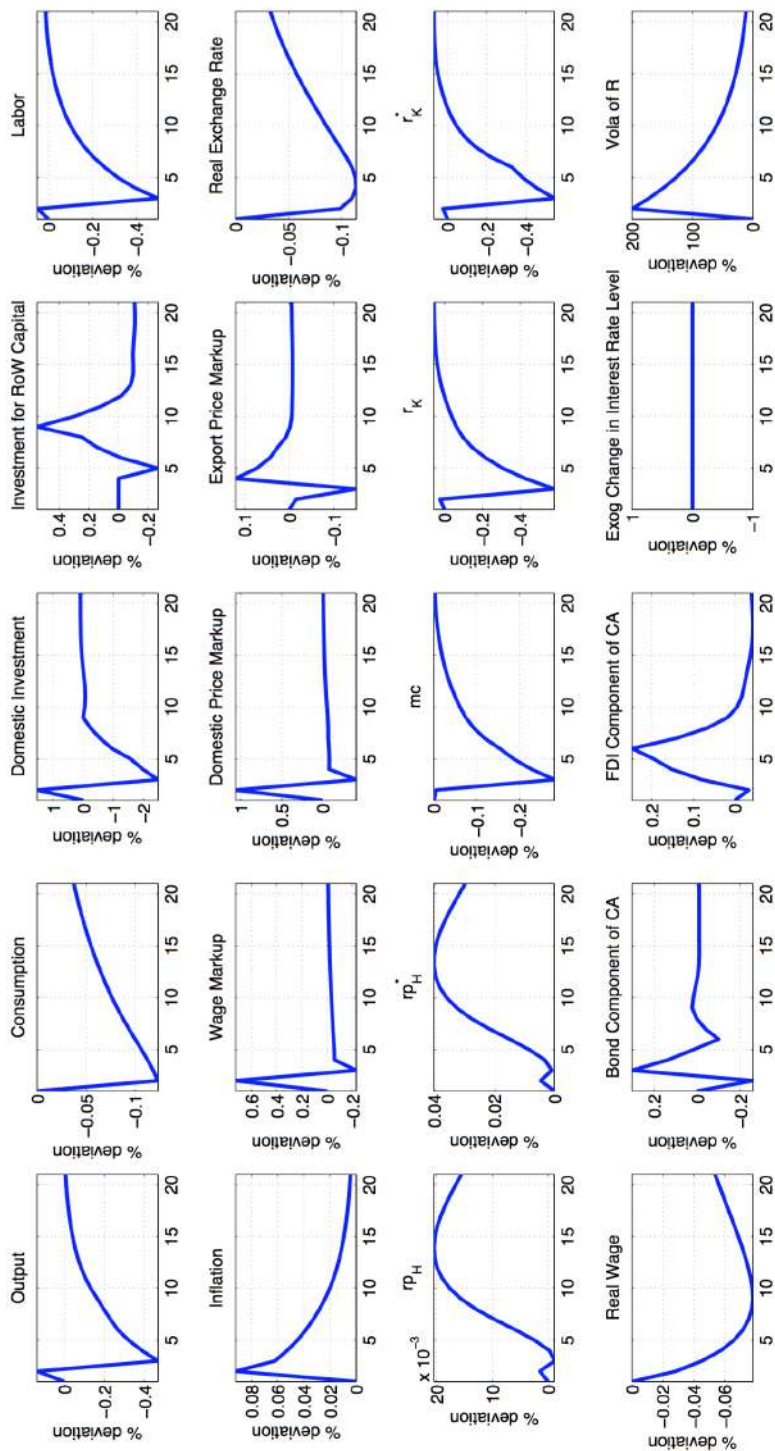


Figure 18: Comparison of Current Account Dynamics I

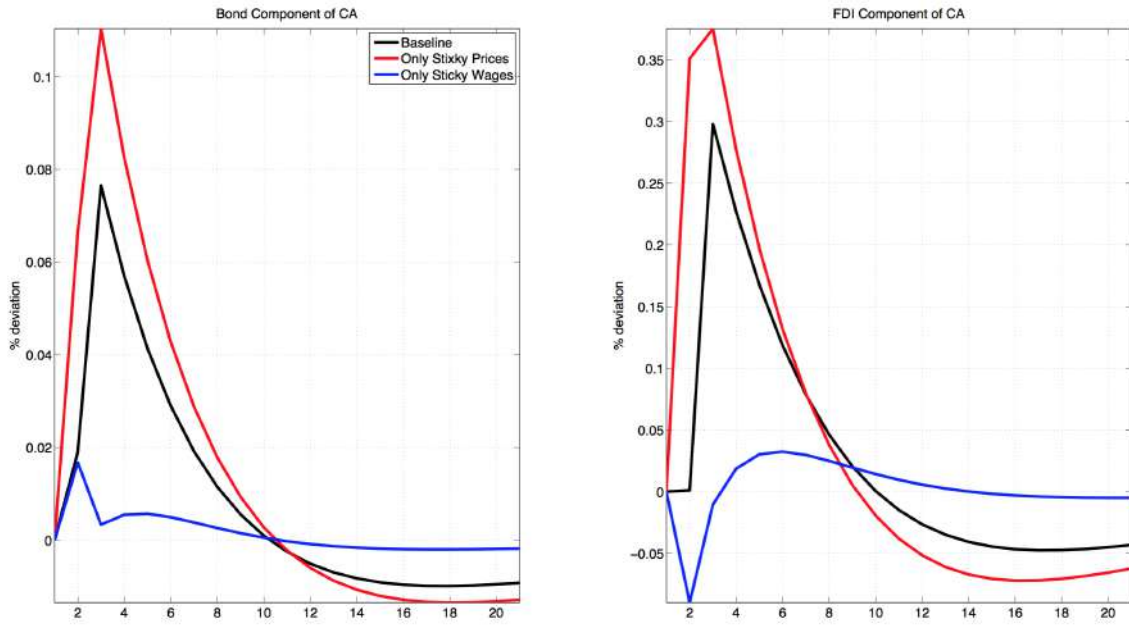


Figure 19: Comparison of Current Account Dynamics II

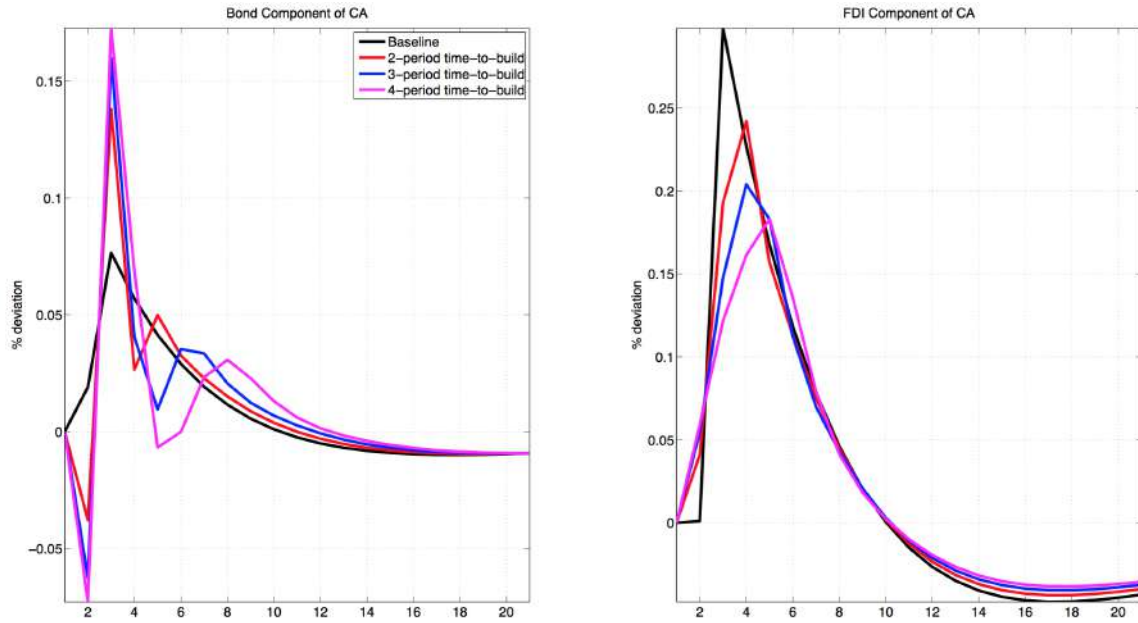


Figure 20: Comparison of Current Account Dynamics III

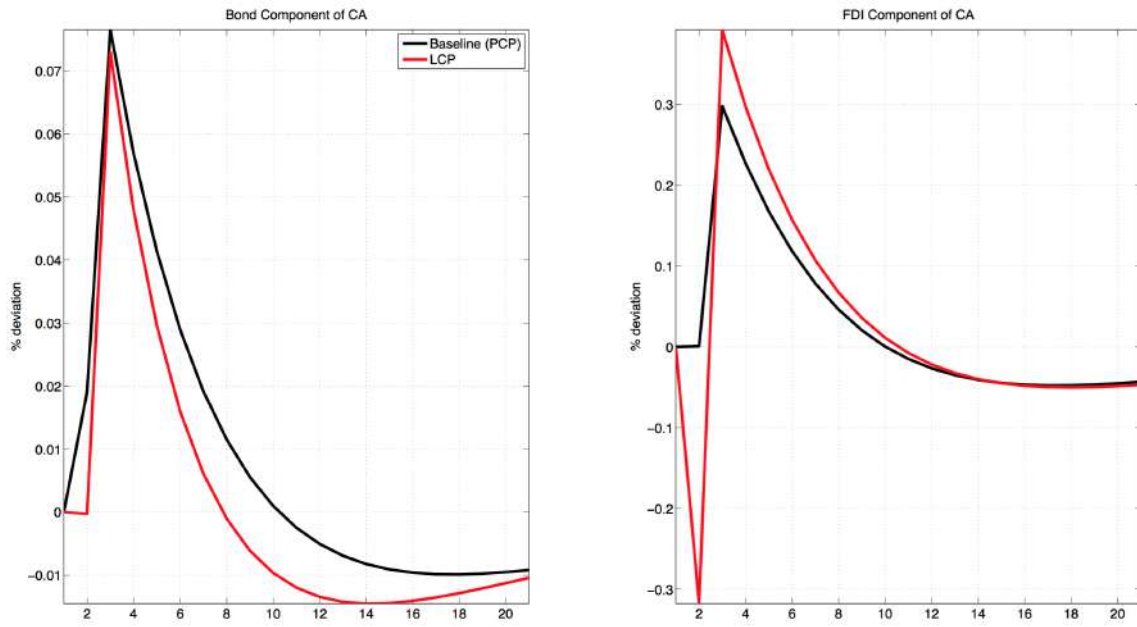


Figure 21: Comparison of Current Account Dynamics IV

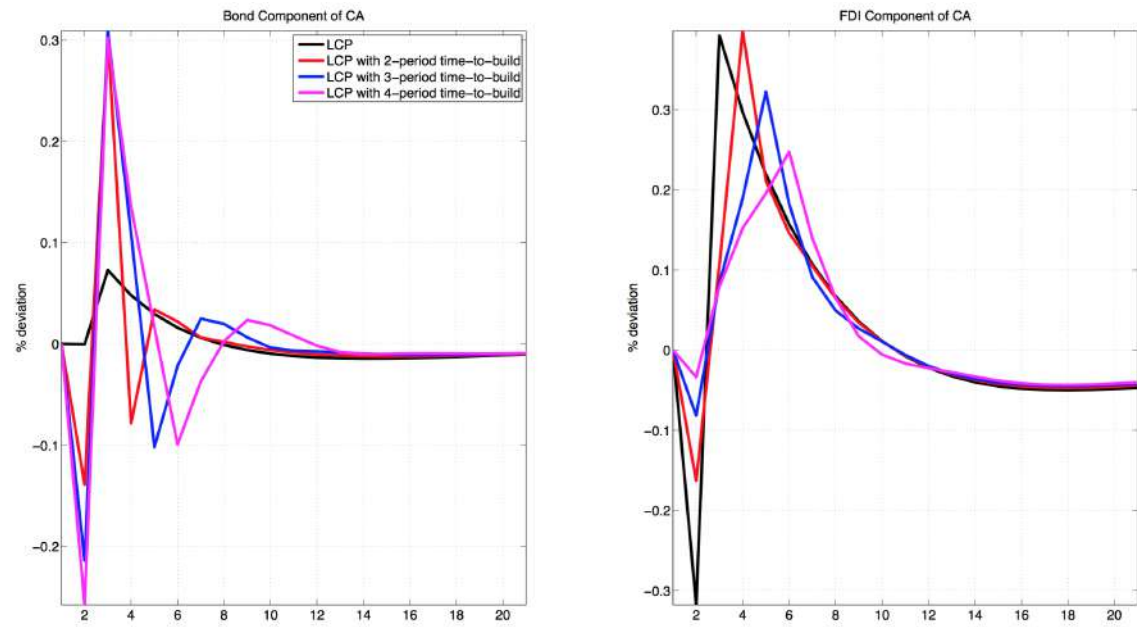


Figure 22: Comparison of Current Account Dynamics V

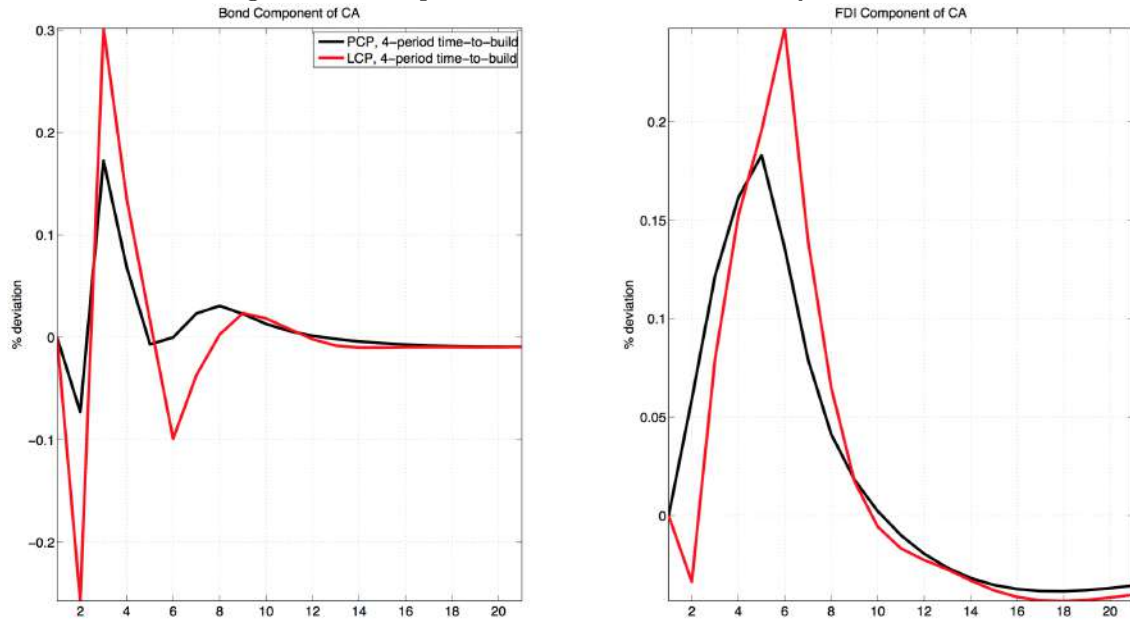




Figure 23: Impulse Responses to an Increase in Interest Rate Uncertainty (Recursive Preferences)

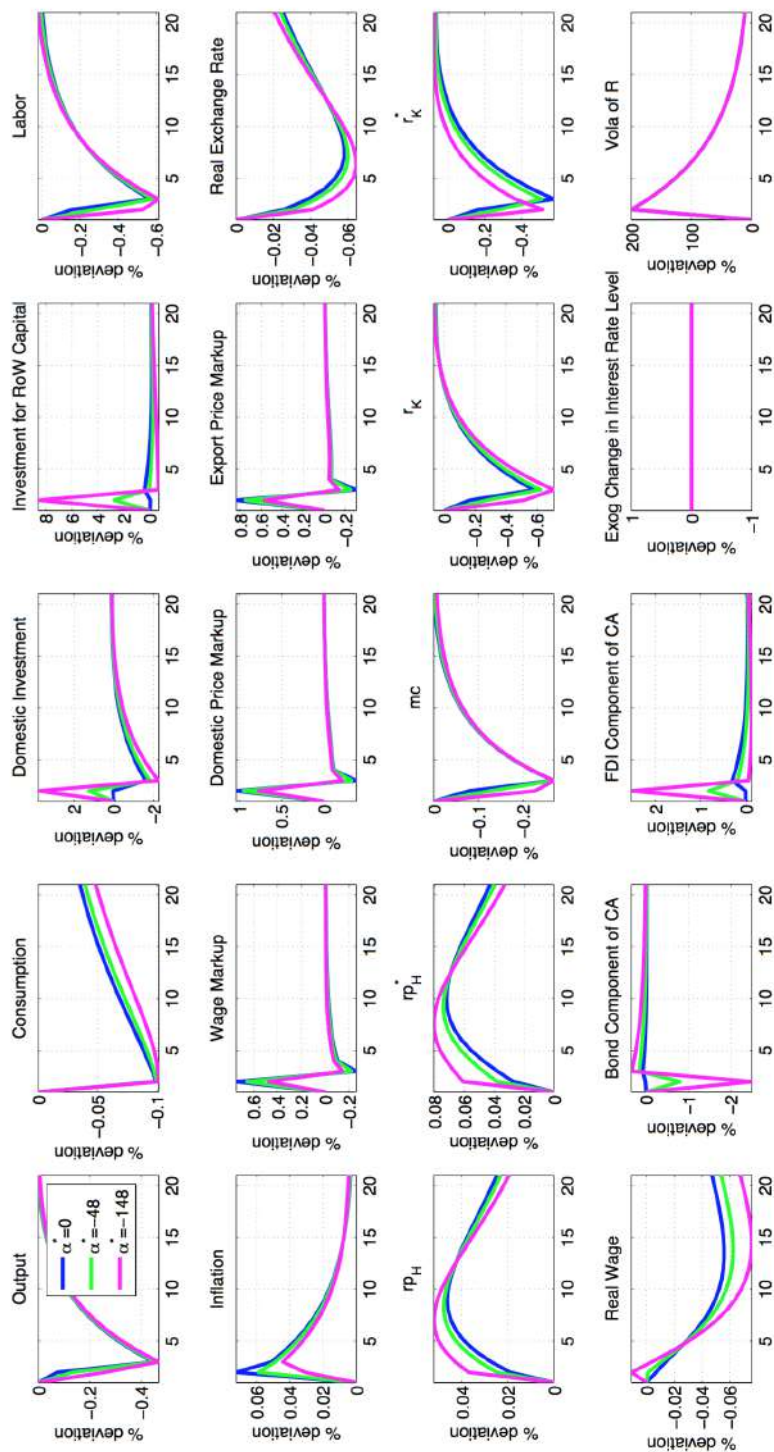


Figure 24: Impulse Responses to an Increase in Interest Rate Uncertainty (Recursive Preferences, same degree of risk aversion in EME and RoW)

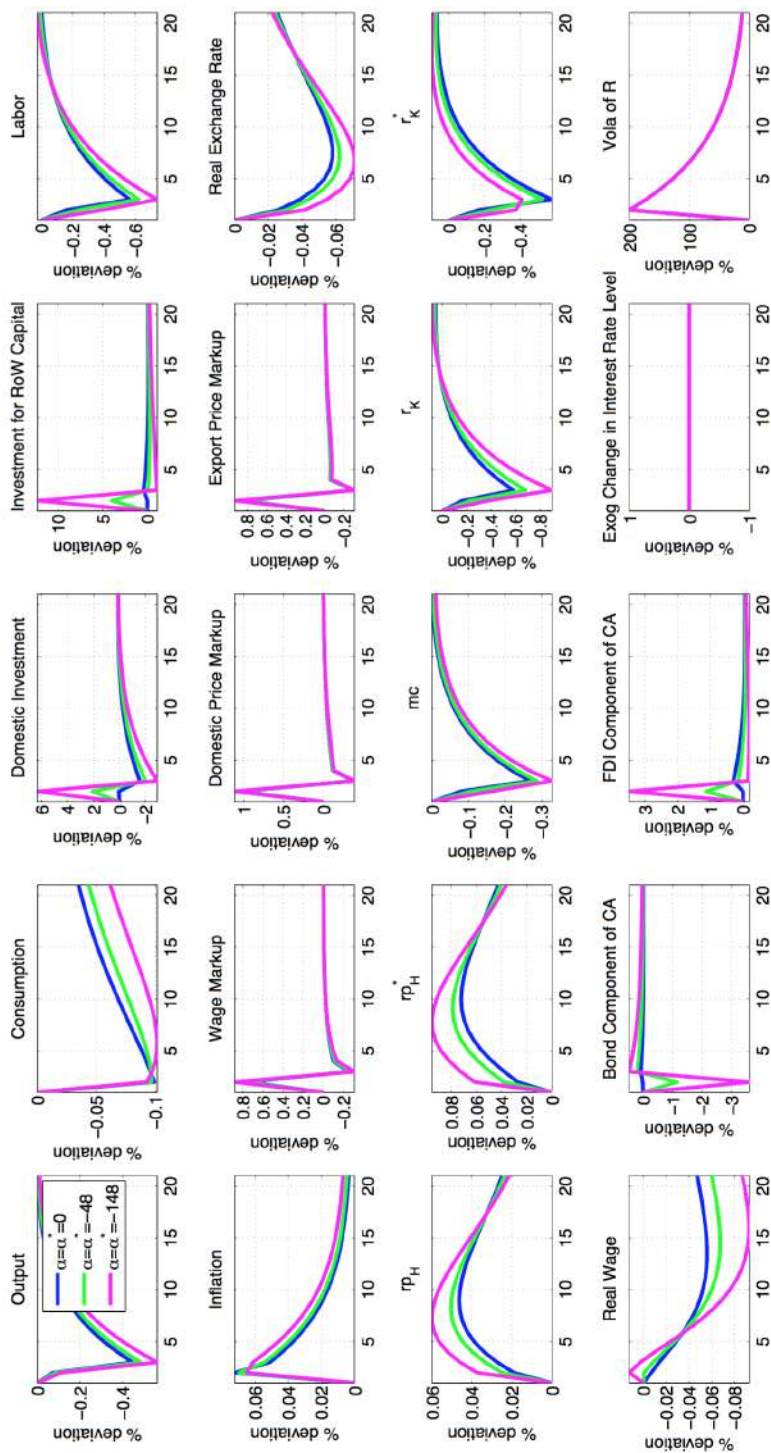


Figure 25: Impulse Responses to an Increase in Interest Rate Uncertainty (ELB in the RoW)

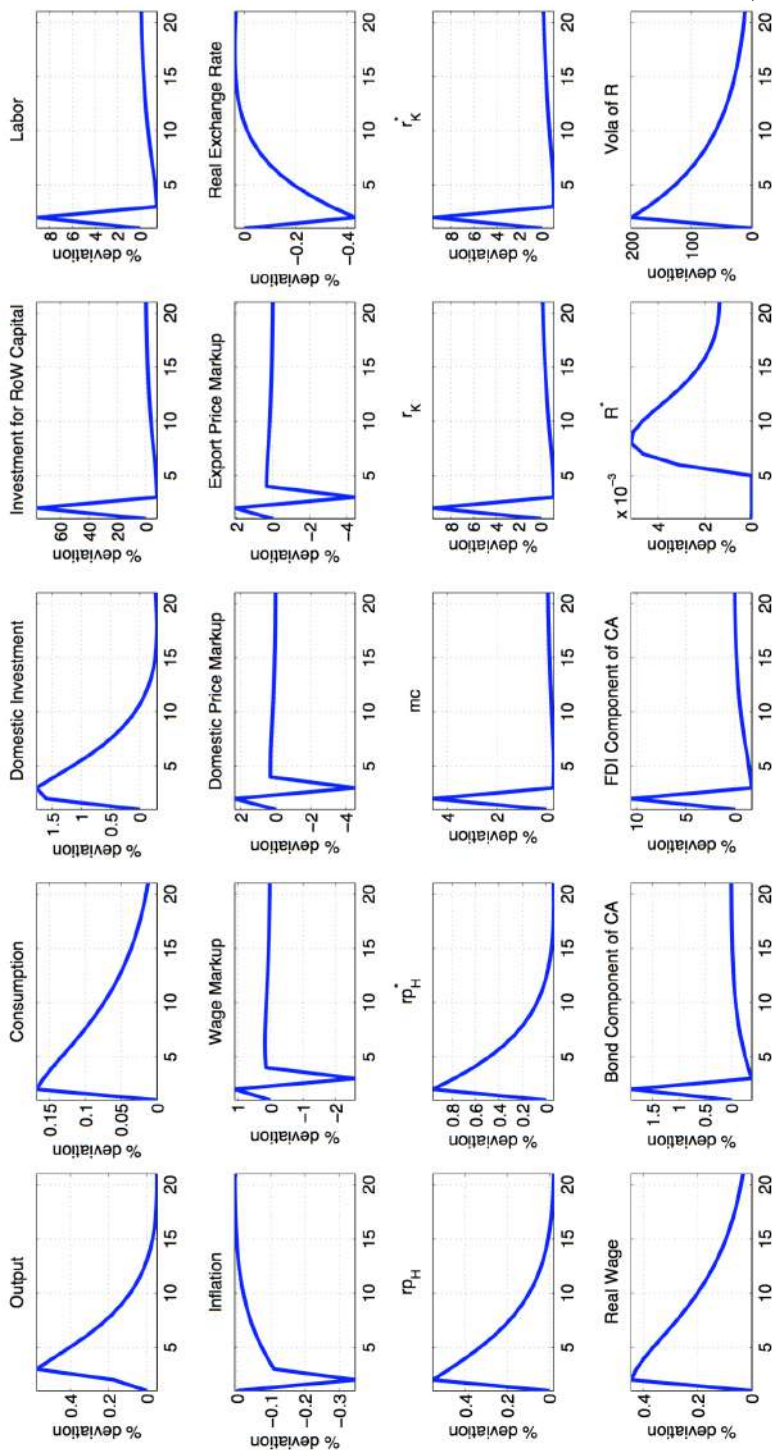
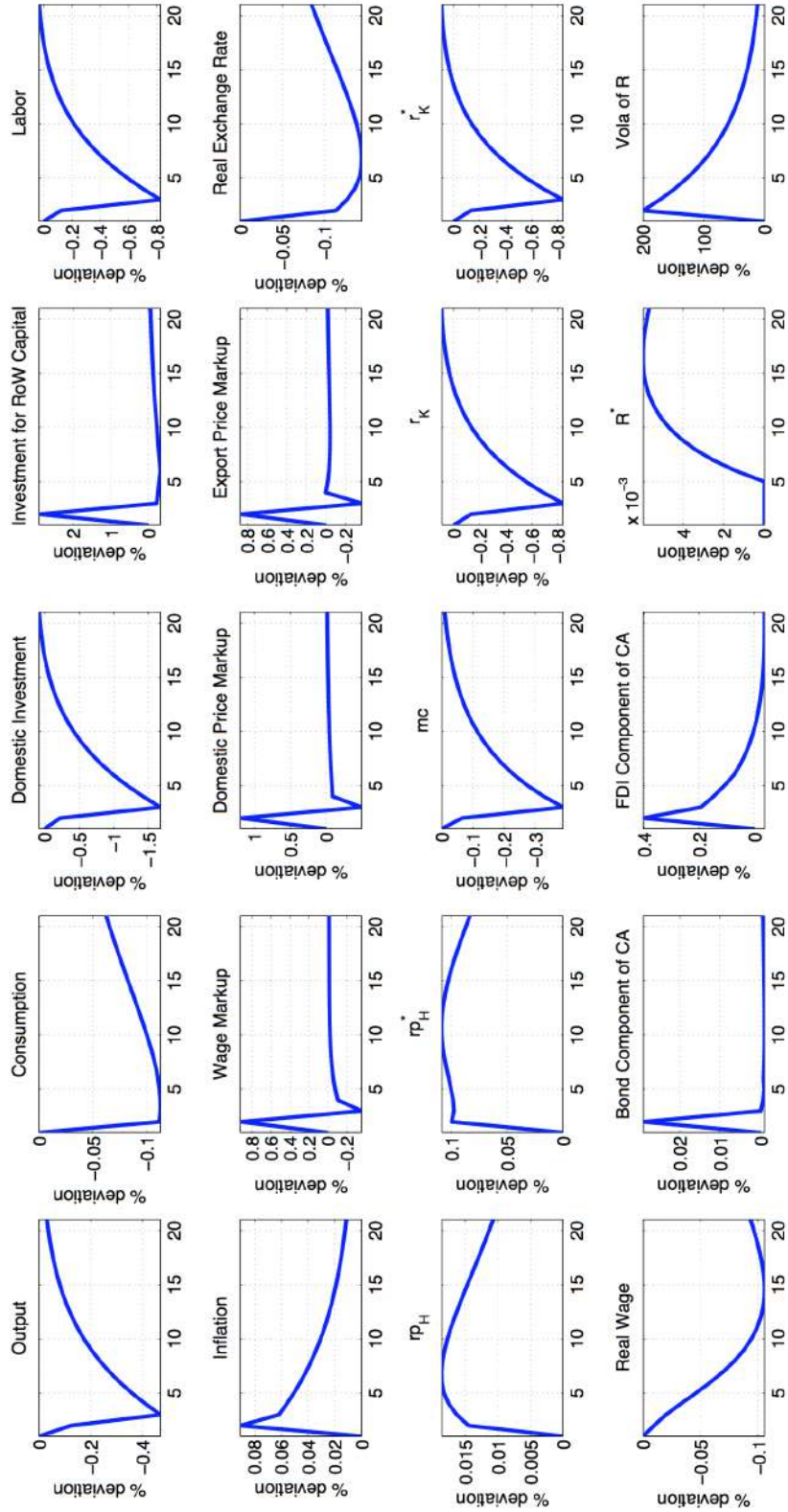


Figure 26: Impulse Responses to an Increase in Interest Rate Uncertainty (ELB in the RoW, strong home bias ( $a = 0.9$ ))



# INTEREST RATE UNCERTAINTY AS A POLICY TOOL

## ONLINE APPENDIX

Fabio Ghironi & Galip Kemal Ozhan

August 26, 2019

### A: DERIVATION OF NET FOREIGN ASSETS

Start with Home households' budget constraint, equation (5), divide it by  $P_t$ , and impose  $T_t = \frac{\eta}{2} \left[ P_t \left( \frac{B_{t+1}(h)}{P_t} \right)^2 + S_t P_t^* \left( \frac{B_{*,t+1}(h)}{P_t^*} \right)^2 \right]$  and equation (22) to obtain:

$$b_{t+1} + rer_t b_{*,t+1} + \left( \frac{1-n}{n} \right) rer_t I_{*,t} = \frac{R_t}{\Pi_t} b_t + \frac{R_t^*}{\Pi_t^*} rer_r b_{*,t} + w_t L_t + r_{K,t} K_t + \left( \frac{1-n}{n} \right) rer_t r_{K,*,t} K_{*,t} + I_t^* + (\mu_{H,t} - 1) mc_t Y_{H,t} + \left( \frac{1-n}{n} \right) \left( \mu_{H,t}^* - 1 \right) mc_t Y_{H,t}^* - Y_t.$$

Now, use  $w_t L_t + r_{K,t} K_t = mc_t \left( Y_{H,t} + \left( \frac{1-n}{n} \right) Y_{H,t}^* \right) - r_{K,t}^* K_t^*$  to get:

$$b_{t+1} + rer_t b_{*,t+1} + \left( \frac{1-n}{n} \right) rer_t I_{*,t} - I_t^* = \left( \frac{R_t}{\Pi_t} \right) b_t + \left( \frac{R_t^*}{\Pi_t^*} \right) rer_t b_{*,t} + \left( \frac{1-n}{n} \right) rer_t r_{K,*,t} K_{*,t} - r_{K,t}^* K_t^* + \left( \frac{1-n}{n} \right) \mu_{H,t}^* mc_t Y_{H,t}^* - rer_t \mu_{F,t} mc_t^* Y_{F,t}. \quad (33)$$

Use isomorphic equations for the RoW to obtain:

$$b_{*,t+1}^* + \frac{b_{t+1}^*}{rer_t} + \left( \frac{n}{n-1} \right) \frac{I_t^*}{rer_t} - I_{*,t} = \left( \frac{R_t^*}{\Pi_t^*} \right) b_{*,t}^* + \left( \frac{R_t}{rer_t \Pi_t} \right) b_{*,t} - r_{K,*,t} K_{*,t} + \left( \frac{n}{1-n} \right) \left( \frac{r_{K,t}^* K_t^*}{rer_t} \right) + \left( \frac{n}{1-n} \right) mc_t^* \mu_{F,t} Y_{F,t} - \frac{mc_t}{rer_t} \mu_{H,t}^* Y_{H,t}^*. \quad (34)$$

Now, multiply equation (33) with  $rer_t(1-n)$ , subtract it from equation (34) and impose the bond market clearing conditions,  $nb_{t+1} + (1-n)b_{t+1}^* = 0$  and  $nb_{*,t+1} + (1-n)b_{*,t+1}^* = 0$ :

$$2n(b_{t+1} + rer_t b_{*,t+1}) + 2((1-n)rer_t I_{*,t} - nI_t^*) = 2n \left( \left( \frac{R_t}{\Pi_t} \right) b_t + \left( \frac{R_t^*}{\Pi_t^*} \right) rer_t b_{*,t} \right) + 2(1-n)rer_t r_{K,*,t} K_{*,t} - 2nr_{K,t}^* K_t^* + 2(1-n)\mu_{H,t}^* mc_t Y_{H,t}^* - 2nrer_t \mu_{F,t} mc_t^* Y_{F,t}. \quad (35)$$

Finally, divide the above equation with  $2n$ , and impose law of motion of capital for  $K^*$  and  $K_*$

to obtain equation (23):

$$\begin{aligned}
& b_{t+1} + rer_t b_{*,t+1} + \left(\frac{1-n}{n}\right) rer_t K_{*,t+1} - K_{t+1}^* \\
= & \frac{R_t}{\Pi_t} b_t + \frac{R_t^*}{\Pi_t^*} rer_t b_{*,t} + \left(\frac{1-n}{n}\right) rer_t (r_{K,*,t} + 1 - \delta) K_{*,t} - \left(r_{K,t}^* + 1 - \delta\right) K_t^* + TB_t,
\end{aligned}$$

where  $TB_t \equiv \left(\frac{1-n}{n}\right) \mu_{H,t}^* mc_t Y_{H,t}^* - rer_t \mu_{F,t} mc_t^* Y_{F,t}$ .

## B: DERIVATION OF THE RELATIVE RISK TERMS IN THE RoW PORTFOLIO

Using the Euler equations of bond holdings and capital accumulation, we derive relative risk of each asset from the RoW portfolio problem. The equations we focus are as follows:

$$1 + \eta b_{*,t+1}^* = R_{t+1}^* \mathbb{E}_t \left[ \frac{\beta_{t,t+1}^*}{\Pi_{t+1}^*} \right], \quad (36)$$

$$1 + \eta b_{t+1}^* = R_{t+1} \mathbb{E}_t \left[ \frac{\beta_{t,t+1}^* \frac{rer_t}{rer_{t+1}}}{\Pi_{t+1}^* \frac{rer_t}{rer_{t+1}}} \right], \quad (37)$$

$$1 = \mathbb{E}_t \left[ \beta_{t,t+1}^* \left( \underbrace{r_{K_{*,t+1}^*} + 1 - \delta}_{\equiv R_{K_{*,t+1}^*}} \right) \right], \quad (38)$$

$$1 = \mathbb{E}_t \left[ \beta_{t,t+1}^* \frac{rer_t}{rer_{t+1}} \left( \underbrace{r_{K_{*,t+1}^*} + 1 - \delta}_{\equiv R_{K_{*,t+1}^*}} \right) \right]. \quad (39)$$

Let's focus on the relative risk between RoW bonds held by RoW agents and EME bonds held by RoW agents. One can express equations (36) and (37) as follows:

$$1 + \eta b_{*,t+1}^* = \mathbb{E}_t [\beta_{t,t+1}^*] \mathbb{E}_t \left[ \frac{R_{t+1}^*}{\Pi_{t+1}^*} \right] + Cov_t \left( \beta_{t,t+1}^*, \frac{R_{t+1}^*}{\Pi_{t+1}^*} \right) \quad (40)$$

$$1 + \eta b_{t+1}^* = \mathbb{E}_t [\beta_{t,t+1}^*] \mathbb{E}_t \left[ \frac{R_{t+1} \frac{rer_t}{rer_{t+1}}}{\Pi_{t+1}^* \frac{rer_t}{rer_{t+1}}} \right] + Cov_t \left( \beta_{t,t+1}^*, \frac{R_{t+1} \frac{rer_t}{rer_{t+1}}}{\Pi_{t+1}^* \frac{rer_t}{rer_{t+1}}} \right) \quad (41)$$

Subtracting equation (41) from (40), we obtain:

$$\frac{\eta (b_{*,t+1}^* - b_{t+1}^*)}{\mathbb{E}_t [\beta_{t,t+1}^*]} = \mathbb{E}_t \left[ \frac{R_{t+1}^*}{\Pi_{t+1}^*} \right] - \mathbb{E}_t \left[ \frac{R_{t+1} \frac{rer_t}{rer_{t+1}}}{\Pi_{t+1}^* \frac{rer_t}{rer_{t+1}}} \right] + \underbrace{\frac{Cov_t \left( \beta_{t,t+1}^*, \frac{R_{t+1}^*}{\Pi_{t+1}^*} \right) - Cov_t \left( \beta_{t,t+1}^*, \frac{R_{t+1} \frac{rer_t}{rer_{t+1}}}{\Pi_{t+1}^* \frac{rer_t}{rer_{t+1}}} \right)}{\mathbb{E}_t [\beta_{t,t+1}^*]}}_{\text{Relative Risk between } B_{*}^* \text{ and } B^*}.$$

We call the last term the relative risk between holding RoW bonds and EME bonds, and denote it as  $RR_{B_{*}^*, B^*, t+1}$ .

Proceeding in this fashion, we further define:

$$RR_{K^*,K^*,t+1} \equiv \frac{Cov_t \left( \beta_{t,t+1}^*, R_{K^*,t+1} \right) - Cov_t \left( \beta_{t,t+1}^*, \frac{rer_t}{rer_{t+1}} R_{K^*,t+1} \right)}{\mathbb{E}_t \left[ \beta_{t,t+1}^* \right]}$$

and

$$RR_{B^*,K^*,t+1} \equiv \frac{Cov_t \left( \beta_{t,t+1}^*, \frac{R_{t+1}}{\Pi_{t+1}} \frac{rer_t}{rer_{t+1}} \right) - Cov_t \left( \beta_{t,t+1}^*, \frac{rer_t}{rer_{t+1}} R_{K^*,t+1} \right)}{\mathbb{E}_t \left[ \beta_{t,t+1}^* \right]}.$$



## C: CONSUMPTION EQUIVALENT WELFARE

Define two auxiliary value functions:

$$V_t^{i,C} = \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \frac{(C_{t+j}^i)^{1-\rho} - 1}{1-\rho}, \quad V_t^{i,L} = -\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \frac{(L_{t+j}^i)^{1+\varphi}}{1+\varphi}.$$

Set the compensating variation in consumption under IRUPT to generate the same welfare as under CCU:

$$V_t^{CCU} = \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \frac{(1 + \lambda^{cond}) (C_{t+j}^{IRUPT})^{1-\rho} - 1}{1-\rho} - \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \chi \frac{(L_{t+j}^{IRUPT})^{1+\varphi}}{1+\varphi}.$$

Express the above equation using auxiliary value functions defined above:

$$V_t^{CCU} = (1 + \lambda^{cond})^{1-\rho} \left[ V_t^{IRUPT,C} + \frac{1}{(1-\beta)(1-\rho)} \right] - \frac{1}{(1-\beta)(1\rho)} + V_t^{IRUPT,N}.$$

Hence,

$$\lambda^{cond} = \left( \frac{V_t^{CCU} - V_t^{IRUPT,N} + \frac{1}{(1-\beta)(1-\rho)}}{V_t^{IRUPT,C} + \frac{1}{(1-\beta)(1-\rho)}} \right)^{\frac{1}{1-\rho}} - 1.$$

For the unconditional compensating variation, we follow the same steps using the unconditional expectation:

$$\lambda^{uncond} = \left( \frac{\mathbb{E} [V_t^{CCU}] - \mathbb{E} [V_t^{IRUPT,N}] + \frac{1}{(1-\beta)(1-\rho)}}{\mathbb{E} [V_t^{IRUPT,C}] + \frac{1}{(1-\beta)(1-\rho)}} \right)^{\frac{1}{1-\rho}} - 1.$$

## D: MODIFICATIONS WITH TIME-TO-BUILD

Starting from Equation (35), let's impose bond market clearing conditions and First combine the conditions in (28) and their RoW counterpart to obtain:

$$I_{*,t} = \frac{1}{J} [(K_{*,t+1} - (1 - \delta)K_{*,t}) + \dots + (K_{*,t+J} - (1 - \delta)K_{*,t+J-1})]$$

$$I_t^* = \frac{1}{J} [(K_{t+1}^* - (1 - \delta)K_t^*) + \dots + (K_{t+J}^* - (1 - \delta)K_{t+J-1}^*)]$$

Now, starting from Equation (35), let's impose the bond market clearing conditions and the conditions above to obtain the modified net foreign asset equation:

$$b_{t+1} + rer_t b_{*,t+1} + \left(\frac{1-n}{n}\right) rer_t \frac{1}{J} (K_{*,t+J} + \delta K_{*,t+J-1} + \dots + \delta K_{*,t+1}) - \frac{1}{J} (K_{t+J}^* + \delta K_{t+J-1}^* + \dots + \delta K_{t+1}^*)$$

$$= \frac{R_t}{\Pi_t} b_t + \frac{R_t^*}{\Pi_t^*} rer_t b_{*,t} + \left(\frac{1-n}{n}\right) rer_t \left(r_{K,*,t} + \frac{1}{J} (1 - \delta)\right) K_{*,t} - \left(r_{K,t}^* + \frac{1}{J} (1 - \delta)\right) K_t^* + TB_t,$$

(42)

## E: LOCAL CURRENCY PRICING

The export price is set in RoW currency under LCP. The cost of adjusting the export price is given as follows:

$$\left(\frac{1-n}{n}\right) \frac{\kappa^*}{2} \left(\frac{P_{H,t+s}^*(i)}{P_{H,t+s-1}^*(i)} - 1\right)^2 \frac{S_{t+s} P_{H,t+s}^*(i)}{P_{t+s}} Y_{H,t+s}^*.$$

The monopolistic producer  $i$  chooses a rule  $(P_{H,t}(i), P_{H,t}^{*h}(i), Y_{H,t}(i), Y_{H,t}^*(i))$  to maximize the expected discounted profit:

$$\mathbb{E}_t \left[ \sum_{s=t}^{\infty} \beta_{t,t+s} \left( \begin{array}{l} \left(1 - \frac{\kappa}{2} \left(\frac{P_{H,t+s}(i)}{P_{H,t+s-1}(i)} - 1\right)^2\right) \frac{P_{H,t+s}(i)}{P_{t+s}} Y_{H,t+s}(i) \\ + \left(\frac{1-n}{n}\right) \left(1 - \frac{\kappa^*}{2} \left(\frac{P_{H,t+s}^*(i)}{P_{H,t+s-1}^*(i)} - 1\right)^2\right) \frac{S_{t+s} P_{H,t+s}^*(i)}{P_{t+s}} Y_{H,t+s}^*(i) \\ - mc_t \left(Y_{H,t+s}(i) + \left(\frac{1-n}{n}\right) Y_{H,t+s}^*(i)\right) \end{array} \right) \right].$$

From the first-order-conditions with respect to  $P_{H,t+s}(i)$  and  $P_{H,t+s}^*(i)$  evaluated under symmetric equilibrium, we obtain the real price of Home output for domestic sales (*i.e.*  $rp_H \equiv \frac{P_H}{P}$ ) as a time-varying markup,  $\mu_{H,t}$  over the marginal cost:

$$rp_{H,t} = \mu_{H,t} mc_t,$$

and the real price of Home output for export sales (in units of RoW consumption) as a time-varying markup,  $\mu_{H,t}^*$ , over the marginal cost

$$rp_{H,t}^* = \frac{\mu_{H,t}^* mc_t}{rer_t},$$

where

$$\mu_{H,t} \equiv \frac{\epsilon}{(\epsilon - 1) \left(1 - \frac{\kappa}{2} (\Pi_{H,t} - 1)^2\right) + \kappa \left(\Pi_{H,t} (\Pi_{H,t} - 1) - \mathbb{E}_t \left[ \frac{\beta_{t,t+1}}{\Pi_{t+1}^*} (\Pi_{H,t+1} - 1) (\Pi_{H,t+1})^2 \frac{Y_{H,t+1}}{Y_{H,t}} \right]\right)},$$

$$\mu_{H,t}^* \equiv \frac{\epsilon}{(\epsilon - 1) \left(1 - \frac{\kappa^*}{2} (\Pi_{H,t}^* - 1)^2\right) + \kappa^* \left(\Pi_{H,t}^* (\Pi_{H,t}^* - 1) - \mathbb{E}_t \left[ \frac{\beta_{t,t+1}}{\Pi_{t+1}^*} (\Pi_{H,t+1}^* - 1) (\Pi_{H,t+1}^*)^2 \frac{rer_{t+1}}{rer_t} \frac{Y_{H,t+1}^*}{Y_{H,t}^*} \right]\right)}.$$

with  $\Pi_{H,t} \equiv \frac{rp_{H,t}}{rp_{H,t-1}} \Pi_t$  and  $\Pi_{H,t}^* \equiv \frac{rp_{H,t}^*}{rp_{H,t-1}^*} \Pi_t$ .