On the Effectiveness of Sterilized Foreign Exchange Intervention Policy:
A Study of Economies with Imperfect Financial Markets

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Abstract

In recent literature, several theories have suggested that emerging markets (EMs) are exposed to spillovers from US monetary policy. There has also been a recent increase in Foreign Exchange Intervention implemented by EM policymakers such as those in Argentina, Chile, and Turkey. Yet, theory about such interventions has found no real effectiveness on the exchange rate or domestic variables. To explain the reasoning of such policymakers and the data, this paper develops a two-country New Keynesian model with imperfect financial markets, dollar-denominated debt and sterilized foreign exchange intervention policy. The model finds both short and long term effects of intervention on real exchange rates, PPI-inflation and trade balance with an interesting spill-back effect to US CPI-inflation.
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1 Introduction

During the recent US monetary tightening policy regime between 2016-2019, many emerging markets (EMs), including Argentina, Chile and Turkey, faced heightened volatility in their exchange rates with the dollar. Simultaneously, they faced high spikes in their inflation levels, tracking the pattern of the exchange rate. Alongside an inflation targeting Taylor rule to determine the policy rate, affected countries’ policymakers have found it useful to implement a foreign exchange intervention policy to stabilize prices and other domestic variables.

This evidence renews the interest in the foreign effects of US monetary policy actions. Recent works such as Giovanni et al. (2017), Kalemli-Özcan (2019) and Akinci and Queralto (2018) have emphasized the role of financial channels involving a deviation from the uncovered interest parity (UIP) fluctuating counter-cyclically, as the global financial markets tighten. Another avenue for explaining the strong linkage between foreign variables and inflation has been the dominant currency paradigm (DCP) suggested by Gopinath et al. (2016) where trade pricing is in dollar terms instead of producer currency pricing (PCP). With these recent developments in mind, there has been an ongoing debate about the appropriate monetary policy response of dollar dependent EMs to US monetary policy shifts.

A central bank can engage in foreign exchange markets by selling (or buying) official dollar reserves in exchange for domestic currency. This process increases the dollar supply and decreases the domestic money supply in the exchange market, thus reducing the exchange rate. If the intervention were to be unsterilized this would conclude the intervention. With unsterilized intervention, the domestic money supply decreases and therefore the intervention indirectly affects monetary policy. In order for the domestic money supply and the nominal interest rate to remain unchanged by intervention, the central bank engages in sterilization, i.e. buying back (or selling) an equivalent amount of government issued bonds only held by domestic institutions.

For example, in response to an exchange rate hike the central bank sells some of its dollar reserves to lower the exchange rate while indirectly shrinking the domestic money supply and increasing the policy rate. Simultaneously, the central bank buys back sterilized bonds\(^1\) from domestic banks thus counter-balancing the money supply and keeping nominal interest rates unchanged. Buying back sterilized bonds frees up the domestic banks’ budget constraint thus simulating lending to the private sector, and reducing production costs and domestic prices. This can also be viewed as a change in the composition of debt held by the banks.

Textbook open-economy New Keynesian models like that of Gali and Monacelli (2005) argue that monetary policy should focus on domestic objectives and allow the exchange rate to fluctuate freely under the framework of the 'divine coincidence'. This stands in

\(^1\)Sterilized bonds by definition can only be held by domestic institutions.
contrast with policies under which many EM central banks put substantial importance on exchange rate stabilization in order to control domestic variables. Thus, there exists a divergence between the theory and the intervention policy approach implemented by EM policymakers.

The aim of my paper is to close the gap between the policymakers’ incentives to engage in intervention policy and the economic theory. More precisely, under what conditions is a sterilized foreign exchange intervention policy an effective measure to control domestic prices?

I will focus specifically on sterilized intervention under imperfect financial markets since sterilization directly affects the domestic banking sector’s balance sheet and constraint. Due to a high correlation between inflation and exchange rates, the intervention policy’s efficiency will be tested under a dollar dependent economy with dollar-denominated debt, using a two-country medium-scale DSGE model based on the SIGMA model (this model is described in detail in Erceg, Guerrieri, Gust (2006)) and Akinci and Queralto (2018). Both papers are taken from the Fed Staff Reports as the goal of this model is to make a policy recommendation. Using Akinci and Queralto’s framework the model allows for an endogenous UIP deviation, thus possibly breaking the 'divine coincidence.' This creates an opportunity for central banks to control for exchange rates using intervention for price stability.

The key takeaways from the model are as follows: (1) The intervention policy is able to lower the real exchange rate volatility. On the objective of controlling domestic prices the answer is more nuanced: (2) when it comes to CPI-inflation the intervention doesn’t change the behavior of the model. This echoes previous findings on the effectiveness of sterilized intervention. (3) Regarding producer prices, i.e. PPI-inflation, the intervention policy is effective in reducing volatility in the short run.2 (4) The intervention comes at a cost of reduced net exports for the emerging economy since the benefit of currency depreciation to exports is muted. (5) It is important to note that after intervention, there is a permanent change in reserve levels. After repetitive intervention episodes, this could cause a problem regarding lack of reserve accumulation and low reserve levels. (6) There is an unexpected spill-back effect to US CPI-inflation where intervention further deflates the dollar from an initial US monetary tightening.

The model can be extended to incorporate dollar exposure in export pricing as described by Gopinath et al. (2016) to allow the emerging economy to be more dependent on exchange rate fluctuations in trade and pricing. This could change the results regarding CPI-inflation mentioned above as well as trade patterns.

The rest of the paper is outlined as follows. Section 2 is a discussion on the related literature to this paper. Section 3 describes the quantitative model in detail. Section 4 discusses the calibration of the model and analyzes simulated data and impulse response

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2 Producers are an important part of the economy since they directly affect the returns of the banking sector and thus the international credit market.
functions. Section 5 compares basic properties of the simulated model with data. Section 6 briefly introduces future expansions of the model.

1.1 Some Motivation from Data

During the recent US monetary tightening between 2016-2019, many emerging economies faced currency depreciation against the dollar while also facing continued increases in inflation. Some of these countries, such as Argentina, Chile, and Turkey, have repeatedly engaged in foreign exchange intervention. This suggests that when there exists a strong relationship between exchange rates and inflation countries have found value in exchange rate stabilization in the form of selling reserves.

Consider the following regressions with data from FRED between 2003-2019:

\[ \Delta N E R_t = \beta_0 + \beta_1 \pi_{EM} + \beta_2 \pi_{US} \]  

(1)

where \( \Delta N E R_t = \frac{NER_t - NER_{t-1}}{NER_{t-1}} \) is the change in nominal exchange rate, \( \pi_{EM} \) is the emerging market CPI-inflation, and \( \pi_{US} \) is the US CPI-inflation.

Running the above regression for Chile and Turkey, Table 1 describes the regression results. Notice that in both countries the estimated parameter \( \beta_1 \) is strongly positive while \( \beta_2 \) is strongly negative supporting the claim that currency depreciation in such countries where intervention is common is positively correlated with domestic price changes and negatively correlated with US price changes. This exercise does not explain all or even most of the variability of exchange rates. Instead this shows the strong relationship between EM inflation and exchange rates which might incentivize policymakers to want to control for the exchange rate as a supplementary policy measure to the Taylor rule during US monetary tightening periods.

2 Related Literature

This paper aims to develop an open economy New Keynesian macroeconomic model for policy analysis such as Gali and Monacelli (2005), and Erceg, Guerrieri, and Gust (2006), and Akinci and Queralto (2018). Additionally, the model is related to Gertler and Kiyotaki (2010) where the presence of financial market frictions and institutions allows to consider sterilized foreign exchange intervention as an "unconventional" policy instrument.

More specifically, the model developed in this paper is based on Akinci and Queralto (2018) where there are financial market frictions and dollar-denominated debt leading to an endogenous uncovered interest parity (UIP) deviation and strong monetary spillovers from the US to an EM. Deviation from the UIP is defined as "the premium of the local safe rate over the expected dollar rate" (Akinci and Queralto, 2). This setup creates excess volatility in exchange rate dynamics compared to a setting when the UIP holds all the time. Additionally, dollar-denominated liabilities undesirably expose the borrowers' (i.e.
domestic banks) balance sheet to exchange rate fluctuations thus adding further volatility to the credit market. There has been other literature such as, Giovanni et al. (2017), Kalemli-Özcan (2019), examining the empirical deviations from the UIP and the financial channels leading to it.

Departing from Akinci and Queralto (2018) on how a central bank responds to international variables, the model allows for a separate policy instrument of sterilized intervention instead of adjusting the Taylor rule based on exchange rate movements. This is also in line with the findings of Gali and Monacelli (2005) suggesting that targeting international variables in a Taylor rule is not welfare maximizing. With this construction, intervention policy directly impacts the bank’s balance sheet through the size of sterilized bonds.

Literature on foreign exchange intervention policy mostly suggests that there are approximately no real effects from a sterilized intervention and considers such policy useless and irrelevant (Backus and Kehoe, 1989). Backus and Kehoe quantitatively establish that "...changes in the composition of debt do not affect equilibrium prices or quantities" (p. 2). Therefore they claim that portfolio balance approach fails as a theory of intervention since it ignores the feedback of government and private sector portfolio decisions. In my paper due to financial imperfections and UIP deviations, composition of debt can affect equilibrium prices. Additionally, the private sectors portfolio decisions are endogenous to my model thus consistent with the findings of Backus and Kehoe.

There is a new wave of literature trying to explain when intervention policy could be useful. Chang (2018) builds an intervention model with financial frictions similar to this paper. Chang (2018) finds that when financial constraints are occasionally binding under frictions, such interventions could be effective since it frees up bank resources. In this model I assume such constraints to be always binding. Departing from Chang (2018), the model has dollar-denominated debt and an endogenous UIP deviation, thus building on top of the US monetary spillover literature mentioned above, instead of a technology shock perspective that Chang implements.

Other recent intervention policy models include Alla, Espinoza, Ghosh (2017) where they argue ‘the divine coincidence’ may not hold and international capital markets can give rationale for sterilized intervention leading to credible effects for inflation targeting regimes. Their framework uses exogenous shocks to foreign risk premium thus creating deviations from the ‘divine coincidence’. This could be a possible future addition to this paper.

Additionally, there is other literature such as Gopinath et al. (2016) that investigates real effects of exchange rate movements on domestic variables and price levels under a dominant currency paradigm (DCP). A future extension of this model could include such a pricing scheme to amplify the dollar dependency of the model and the sizable effects of the exchange rate on domestic prices.
3 The Model

This section describes the baseline quantitative model in detail. The model is based on the framework of a two-country open-economy New Keynesian model similar to previous medium-scale models like Akinci and Queralto (2018) as well as the SIGMA model (Erceg, Guerrieri, and Gust, 2006) both published in the Fed Staff reports. Following Akinci and Queralto (2018) the model implements imperfect financial markets with dollar-denominated debt leading to "endogenous fluctuations in the domestic borrowing spread and in the UIP deviation" (Akinci and Queralto, 12). This allows for the endogenous UIP deviation to fluctuate with the exchange value of the domestic currency. Departing from this literature, the banking side also holds assets in the form of sterilized bonds thus altering the bank’s debt ratio in response to an exchange rate fluctuation.

A standard nominal price stickiness is implemented Calvo style, as well as adjustment costs in investment. These features, following previous literature, help generate empirically realistic effects of a US monetary policy shock.

There are two countries in the model: Home (any EM) and Foreign (the US) economy.

3.1 Households

Consider the Home country consumption bundle defined as follows:

\[
C = \left( \omega \frac{1}{\theta} C_H^\frac{\theta-1}{\theta} + (1 - \omega) \frac{1}{\theta} C_F^\frac{\theta-1}{\theta} \right)^{\frac{\theta}{\theta-1}}, \theta > 0
\]  
(2)

where \( C_H \) and \( C_F \) refer to the Home consumption of Home produced good and Foreign produced good respectively, with \( \theta > 0 \) being the elasticity of intratemporal substitution and \( \omega \in (0, 1) \), the weight given to Home produced good in aggregator \( C \).

The associated consumption based price of \( C \) is:

\[
P = \left[ \omega P_H^{1-\theta} + (1 - \omega) P_F^{1-\theta} \right]^{\frac{1}{1-\theta}}
\]  
(3)

where \( P_H \) is the price of Home-produced good expressed in Home currency and \( P_F \) is the price of Foreign-produced good expressed in Home currency.

The law of one price holds for the same goods: \( P_H = E P_H^* \) and \( P_F = E P_F^* \), where \( E \) is the nominal exchange rate (price of Foreign currency in terms of Home currency), \( P_H^* \) is the price of Home-produced good expressed in Foreign currency, and \( P_F^* \) is the price of Foreign-produced good expressed in Foreign currency. Notice \( P \neq E P^* \), where \( P^* \) is the associated consumption based price with \( C^* \). Unless \( \omega = \omega^* \), the purchasing power parity (PPP) doesn’t hold due to the differences in preferences of agents across countries. To measure deviations from PPP define the real exchange rate (RER) as \( Q \equiv P^*/P \). Also define the terms of trade (ToT) for the home country as \( T \equiv P_F/P_H \).
The representative household solves:

$$\max_{\{C_{t+j}, D_{t+j}, W_{t+j}, L_{t+j}\}} \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \beta^j \frac{C_{t+j}^{1-\sigma}}{1-\sigma} - \chi_0 \frac{L_{t+j}^{1+\chi}}{1+\chi} \right\}$$

subject to

$$P_t C_t + P_t D_t + B_t \leq W_t L_t + P_t R_t D_{t-1} + R^n_t B_{t-1}, \forall t$$

where $L_t$ is the amount of labor the household devotes with the associated wage $W_t$, $D_t$ is deposits made to the bank, and $B_t$ is the riskless one-period bond. $R^n_t$ is the nominal interest rate and $R_t$ is the real interest rate.

### 3.2 Firms and Price Setting

Following Akinci and Queralto (2018), a continuum of retail firms produce domestic output using intermediate goods as inputs. Final output $Y_t$ is a CES composite of retailers’ output:

$$Y_t = \left( \int_0^1 Y_{it} \frac{1}{1+\theta_p} \, di \right)^{1+\theta_p}$$

where $Y_{it}$ is output by retailer $i \in [0, 1]$. For the price set by home retailer $i$, $P_{Hint}$, the price level of domestic final output is $P_{Ht} = \left( \int_0^1 P_{Hint} \frac{1}{1+\theta_p} \, di \right)^{-\theta_p}$. Cost minimization by final output users yields the demand for firm $i$’s output:

$$Y_{it} = \left( \frac{P_{Hint}}{P_{Ht}} \right)^{-\frac{1+\theta_p}{\theta_p}} Y_t$$

with the production function:

$$Y_{it} = K_{it}^\alpha L_{it}^{\gamma-\alpha}$$

and pays real wage $w_t$ and capital rent $r_{Kt}$.

Assuming a Calvo-style price stickiness, firm $i$ can reset price optimally with respect to producer price inflation, $\pi_t \equiv \frac{P_{Hint}}{P_{Ht-1}}$, with probability $1 - \xi_p$ at each time period and otherwise must follow the lagged indexation rule:\footnote{This mechanism introduces inflation inertia into producer price setting.}

$$P_{Hint} = P_{Hint-1} \pi_{t-1}$$
3.3 Capital Producers

The representative capital producer generates new capital goods subject to adjustment costs of investment $I_t$:

$$\phi_{It} = \frac{\psi_I}{2} \left( \frac{I_t}{I_{t-1}} - 1 \right)^2 I_t$$

in the units of the home good, where $\psi_I$ is the investment adjustment cost. The representative capital producer solves:

$$\max_{\{I_t\}_{t=0}^{\infty}} \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \Lambda_{t,t+j} \left[ q_{t+j}I_{t+j} - \frac{P_{Ht+j}}{P_{t+j}} \phi_{It+j} \right] \right\}$$

where $q_t$ is the real price of capital goods i.e. Tobin’s q. $\Lambda_{t,t+j}$ is the domestic household’s real stochastic discount factor between $t$ and $t+j$ defined as $\Lambda_{t,t+j} \equiv \beta^j \left( \frac{C_{t+j}}{C_t} \right)^{-\sigma}$.

Similar to consumption, investment goods are composite goods of Home and Foreign goods:

$$I = \left[ \omega \frac{1}{\sigma} I_H^{\frac{\sigma-1}{\sigma}} + (1 - \omega) \frac{1}{\sigma} I_F^{\frac{\sigma-1}{\sigma}} \right]^\frac{1}{\sigma-1}$$

Optimizing with respect to the investment aggregate $I_t$ gives rise to an investment-Tobin’s q relation:

$$q_t = 1 + \frac{P_{Ht}}{P_t} \left[ \psi_I \left( \frac{I_t}{I_{t-1}} - 1 \right) + \frac{\psi_I}{2} \frac{\left( I_t \frac{I_{t-1}}{I_{t-1}} - 1 \right)^2}{I_{t-1}} \right] - \mathbb{E}_t \left\{ \Lambda_{t,t+1} \frac{P_{Ht+1}}{P_{t+1}} \psi_I \left( \frac{I_{t+1}}{I_t} - 1 \right) \left( \frac{I_{t+1}}{I_t} \right)^2 \right\}$$

3.4 Central Bank

The central bank engages in a Taylor rule and sets the nominal interest rate, $R^n_t$, with inflation targeting defined as follows:

$$R^n_{t+1} = \beta^{-1} \pi_t \gamma_{\pi}$$

where $\gamma_{\pi}$ is the response in Taylor rule to producer price inflation.

In each period alongside a Taylor rule, the Home central bank also uses sterilized intervention in order to control for exchange rate variation. That is, in response to the nominal exchange rate levels $E_t$, the central bank sells or buys dollar reserves $R^S_t$. In order to keep the money supply constant and policy interest rate unchanged, the central bank
buys/sells sterilized bonds for next period $S_{t+1}^b$ to offset any reserve changes, where only domestic banks have access to sterilized bonds.\footnote{There is a lag in the indexation to avoid interdependency between variables. In economic terms, at a given time central bank chooses next periods sterilized bond levels based on today’s reserve levels, similar to the indexation of the nominal interest rate.}

Consider the reserve accumulation as follows:

$$R_t^S = \left( R_{t-1}^S \right)^\eta \left( \frac{1}{E_t^\gamma_e} \right)^{1-\eta}, \eta \in (0, 1)$$

(15)

where $E_t$ is the nominal exchange rate, $\eta$ the sensitivity of reserve levels to previous levels, i.e. insensitivity to the nominal exchange rate, and $\gamma_e$ the response in reserve levels to nominal exchange rate.

Define the sterilization equation, in real terms, as follows:

$$Q_t(R_t^S - R_{t-1}^S) = S_{t+1}^b - R_{t-1}S_t^b$$

(16)

This equation implies a change in the stock of public debt held by private sector (i.e. Home banks) in response to a reserve change.\footnote{The level of government debt held in bank’s balance sheet can signal to the stability of the EM banking system.}

### 3.5 Banks

Home country financial markets are incomplete, meaning that bankers can only obtain funding via non-contingent deposits. An agency friction in financial markets potentially limits bankers’ ability to borrow. Each period, Home banks receive deposits ($D_t$, in units of Home good) from domestic households and from Foreign investors ($D_t^*$, in units of Foreign good) to finance purchases of claims on the capital good, denoted $S_t$, and hold central bank issued sterilized bonds, $S_t^b$, where Home banks alone can hold such bonds to ensure sterilization.

The banking side described below allows for the endogenous UIP deviation implemented by Akinci and Queralto (2018) with a novel component of the sterilized bonds.

The banks’ balance sheet (BS) identity is:

$$q_tS_t + S_t^b = D_t + Q_tD_t^* + N_t$$

(17)

where $N_t$ denotes the bank’s net worth.

The budget constraint (BC) in real domestic currency is:

$$q_tS_t + S_t^b + R_tD_{t-1} + R_t^*Q_tD_t^* \leq R_{Kt}q_{t-1}S_{t-1} + R_tS_{t-1}^b + D_t + Q_tD_t^*$$

(18)

where the left-hand side is banks’ use of funds: lending to non-financial firms, lending to public sector, and domestic and foreign deposit repayments. The right-hand side is the
banks’ source of funds, including return received on past loans and incoming deposits. $R_{Kt}$ denotes the return on capital assets.

There is a random turnover between bankers and workers: bankers alive at period $t$ survive into $t+1$ with probability $\sigma_b > 0$ and workers become bankers with probability $(1 - \sigma_b)$. New bankers receive an endowment $\xi_b$ of the value of the capital stock.

Combining the BS with the BC, the bank’s evolution of net worth (conditional upon surviving into $t+1$) is:

$$N_t = (R_{Kt} - R_t)q_{t-1}S_{t-1} + \left( R_t - R^*_t \frac{Q_t}{Q_{t-1}} \right) Q_{t-1}D^*_{t-1} + R_t N_{t-1}$$

(19)

Banker’s objective is:

$$V_t = \max_{S_t, D^*_t}(1 - \sigma_b)E_t(\Lambda_t, t+1)N_{t+1} + \sigma_b E_t(\Lambda_t, t+1) V_{t+1}$$

subject to 19 and

$$(1 - \sigma_b)E_t(\Lambda_t, t+1)N_{t+1} + \sigma_b E_t(\Lambda_t, t+1) V_{t+1} \geq \Theta(x_t)(q_t S_t + S^*_b)$$

(21)

This is the banks’ Incentive Constraint (IC) to be willing to lend funds to capital producers and to the central bank instead of defaulting on deposits. Assume $\Theta(x_t)$ to be quadratic to induce interior solution for banks’ foreign debt portfolio choice, $x_t$:

$$\Theta(x_t) = \theta_r \left(1 + \frac{\gamma}{2} x_t^2 \right)$$

(22)

where $x_t \equiv \frac{Q_tD^*_t}{q_t S_t + S^*_b}$ and $\theta_r$ the exogenous default risk probability.\(^6\) Assume that the IC binds. Appendix A.1 contains the derivation of the solution for the bankers’ problem. The first order condition is

$$\mu^*_t = y_t \mu_t \left( \frac{\Theta(x_t)}{\Theta'(x_t)} - x_t \right)^{-1}$$

(23)

where the coefficient $\mu_t$ and $\mu^*_t$ are defined as:\(^7\):

$$\mu_t = E_t[\Lambda_{t,t+1} \Omega_{t+1} (R_{Kt+1} - R_{t+1})]$$

(24)

$$\mu^*_t = E_t[\Lambda_{t,t+1} \Omega_{t+1} (R_{t+1} - R^*_{t+1} \frac{Q_{t+1}}{Q_t})]$$

(25)

with

$$\nu_t = E_t[\Lambda_{t,t+1} \Omega_{t+1} R_{t+1}]$$

(26)

$$\Omega_t = 1 - \sigma_b + \sigma_b ((y_t \mu_t + x_t \mu^*_t) \phi_t + \nu_t)$$

(27)

\(^6\) $\gamma$ captures the idea that due to imperfect institutions of the EM it is harder for foreign creditors to recover assets from a default compared to domestic depositors.

\(^7\) Notice $\mu$ is the credit spread and $\mu^*$ the UIP spread. Also, $\mu^*$ is a function of $\mu$. 

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where the leverage ratio is \( \phi_t \equiv \frac{q_t S_t + S^b_t}{N_t} \) and the asset choice in capital \( y_t \equiv \frac{q_t S_t + S^b_t}{q_t S_t + S_t} \). Notice that \( \Lambda_{t,t+1} \Omega_{t+1} \) is an augmented discount factor that accounts for the marginal value of funds of the bank.

With this construction it is clear that the level of sterilized bonds \( S^b_t \) directly affects the bank’s asset choice in capital \( y_t \). High levels of sterilized bonds limits bank’s portfolio choice. Further \( S^b_t \) also adjusts \( \mu^*_t \), the UIP deviation and \( \mu_t \), the credit spread through the augmented discount factor.

### 3.6 Foreign Economy

The foreign economy is defined identical to the Home economy except that the financial markets are complete and the central bank only uses a Taylor rule to control for domestic inflation as follows:

\[
R^{n*}_{t+1} = \beta^{t+1} \pi^{n*}_t \gamma
\]

(28)

As described above, Foreign households deposit \( D^*_t \) to home banks. Thus define the Foreign households problem as follows: The representative household solves:

\[
\max_{\{C^*_t, D^*_t, W^*_t, L^*_t\}} \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \beta^j C^{1-\sigma}_{t+j} - \chi \right\}
\]

subject to

\[
P^*_t C^*_t + P^*_t D^*_t + B^*_t \leq W^*_t L^*_t + P^*_t R^*_t D^*_t - 1 + R^*_t B^*_t, \forall t
\]

(30)

where \( R^*_t \) is the real return received from deposits in Home country (in real dollars). Aside from the absence of financial frictions, the remainder of the model equations for Foreign country follows similarly to Home economy.

### 3.7 Market Clearing, Balance of Payments

The market clearing conditions for the final goods \( Y \), and \( Y^* \) are as follows:

\[
Y = (C_H + I_H) + \frac{1-n}{n}(C^*_H + I^*_H) + \frac{\psi_I}{2} \left( \frac{I_t}{I^*_t} - 1 \right)^2 I_t
\]

(31)

\[
Y^* = (C^*_F + I^*_F) + \frac{n}{1-n}(C^*_F + I^*_F) + \frac{\psi_I}{2} \left( \frac{I^*_t}{I^*_t} - 1 \right)^2 I^*_t
\]

(32)

The aggregate capital stock evolves according to

\[
K_{t+1} = (1-\delta)K_t + I_t
\]

(33)
Further, market clearing for Home physical capital, held by Home banks, implies

$$S_t = (1 - \delta)K_t + I_t$$

(34)

Since both foreign deposits $D^*$ and dollar reserves $R^8$ flow between the 2 countries, the balance of payment equation, in real terms, is aggregated from the budget constraint of agents in Home country:

$$Q_t(D^*_t - R^*_t D^*_{t-1} - R^8_t + R^*_t R^8_{t-1}) = C_t + I_t + p_H \psi_H \left( \frac{I_t}{I_{t-1}} - 1 \right)^2 I_t - p_H Y_t$$

(35)

Notice that without sterilization the BOP equation above is the only way dollar reserve changes affect the real exchange rate.

3.8 Discussion of Assumptions

There are a few key assumptions made in the model. Unlike the Foreign country where there are complete financial markets, Home country households cannot own capital directly, nor can they engage in international financial markets directly. Rather, the financial intermediaries, Home banks, borrow from Home households and Foreign investors (in foreign currency) to directly fund capital acquisition and sterilized bonds.

Thus there is market segmentation implying the underlying reason for the failure of UIP and a positive currency risk premium when the EM is more risky than the US. Additionally, financial contracts are less enforceable across borders than within, captured by $\gamma > 0$, contributing to the failure of UIP. Since the standard UIP condition fails, the effectiveness of intervention with a currency risk premium can be analyzed.

In order to achieve sterilized intervention, the central bank buys/sells sterilized bonds to Home banks, where the quantity of such bonds is solely determined by the central bank and the Home banks have to acquire all such bonds. This can be considered a requirement imposed by the government, such as a reserve requirement. Furthermore, sterilized bonds cannot be held by foreign investors by definition of a sterilized intervention.

For simplicity, dollar reserve levels are determined only by the level of sterilized bonds. Additional sources of incoming dollar reserves are not considered in the model.

4 Calibration and Results

4.1 Calibration

Table 4 describes the values and parameter descriptions. The Foreign economy is calibrated to the United States and Home economy to an EM, either one specific country, such as Mexico, or a bloc of EMs. The calibration is asymmetric: US is much larger than the EM and EM households are relatively impatient ($\beta < \beta^*$), thus introducing the incentives
for US investors to invest in the EM. The size of the home country relative to the United Satates \((n)\) is 1/3.

Following Akinci and Queralto (2018), the intertemporal elasticity of substitution \((\sigma)\), capital share \((\alpha)\) and capital depreciation rate \((\delta)\) are calibrated to the conventional values of 1, 0.33, and 0.025, respectively. Similarly, the steady-state price markup, \(\theta_p\) is calibrated to 20 percent, a conventional value. The remaining parameters on households and firms are based on estimates from Justiniano et al. (2010): the inverse Frisch elasticity of labor supply\((\chi)\), price rigidity \((\xi_p)\), and the investment adjustment cost \((\psi_I)\).

The Taylor rule in the US features inertia with coefficient \((\gamma_r) 0.82\), from Justiniano et al. (2010). The standard deviation and persistence of US monetary shocks are calibrated from Akinci and Queralto (2018)’s estimates to fit an AR(1) process of \(\varepsilon_t\), with \(\rho_r = 0.25\) and \(\sigma_r = 0.20/100\).

International trade parameters \(\omega\) and \(\omega^*\) are restricted to \((1 - \omega^*) = \omega n\) frequent in literature (e.g. Blanchard et al. (2016)). Following Akinci and Queralto (2018), set \(1 - \omega = 0.20\) meaning 20% of home economy’s output is exported in steady state.

Finally, financial markets strictly follow Akinci and Queralto (2018)’s calibration and estimate as follows: the survival rate \((\sigma_b)\) to 0.95, implying a 6 year expected horizon. Remaining parameters are calibrated as \(\theta_r = 0.41, \xi_b = 0.07,\) and \(\gamma = 2.58\).

Intervention specific parameter \(\gamma_e\), nominal exchange rate coefficient in reserve accumulation is key for the effectiveness of the policy. With a lack of information on intervention data, this parameter is set at 2.09 to match the response to inflation in Taylor rule, \(\gamma^\pi\).

### 4.2 IRF Plots and Analysis

Simulating the model described in the previous section, impulse response functions for a positive 1 percentage point in the Fed Funds Rate shock can be found in Section A.6. This shock depicts the US monetary tightening policy with each period representing a quarter. Figure 1 compares the essential variables of the model with and without an intervention policy.

The general mechanism of the model is as follows: due to a positive monetary shock, the US nominal interest rate goes up. This alters the US households consumption-saving decision to save more and consume less by \(-1\%\) upon impact. Due to international consumption risk sharing, Home consumption also goes down by \(-0.2\%\). By raising the nominal interest rate, the US money supply shrinks and due to a lowered demand for consumer goods the US economy incurs a deflation, leading to currency appreciation. Similarly, there is a lower demand for investment causing further US deflation. This leads to an increase in the terms of trade and thus the real exchange rate by approximately 1%, i.e. a currency depreciation in the Home economy. With the currency depreciation of the economy, Home exports are much cheaper than before and US imports are more expensive, thus leading to an increase in the trade balance of the Home economy by 0.5%. The increase in the trade surplus balances out the decrease in consumption and investment totalling to a small increase in
Home output. Combining these effects, the Home economy incurs an inflation smaller in absolute terms than the US. It is important to note the asymmetry of the model: the US is much larger than the Home economy. Due to this asymmetry, the changes in trade are more sizable for the Home economy. The US output sees a 1% downfall mostly due to consumption and investment rather than the trade patterns.

Comparing the model with and without intervention, notice that the real exchange rate initially remains unchanged by intervention while reaching a slightly lower level in the long run. This is due to the price stickiness of the model as well as the delay in sterilization. CPI-inflation remains unchanged by intervention, perhaps echoing results from Backus and Kehoe (1989). While intervention does not change CPI-inflation, \( \pi^c \), it does change producer price inflation, \( \pi \). Intervention results in a lower inflation volatility. In the first 6 quarters intervention results in a smaller deflation, afterwards the model without intervention converges faster to the steady state. This can be viewed as a transfer of deviation across time. The model suggests that upon impact firms benefit more than consumers when there is an aim to control prices. This is supported by the faster convergence of investment with intervention. Thus, an intervention policy could be effective for controlling domestic producer prices, at the level of the price stickiness. Since the Taylor rule uses \( \pi \) this result implies that sterilized intervention is an effective short run supplementary tool to the Taylor rule, especially at the presence of exchange rate hikes. As predicted, there is a much lower net export since there is a lower exchange rate achieved and slightly higher consumption, thus shrinking the demand for Home exports and the trade balance. Combining these results, output is slightly higher after 20 periods with intervention. Even though most implications are due to spillover effects from the US, there appears to be a surprising spill-back effect on US CPI-inflation with intervention. Under intervention policy the US incurs a larger CPI-deflation. The mechanism can be potentially explained by the additional fall in the demand for US investment under intervention. Though it is unlikely that one EM engaging in intervention can have a significant impact on the US, enough EMs simultaneously using intervention can have sizable spill-back effect for US prices.

Figure 2 shows the banking side of the model. With a fall in investment the price of capital, i.e. Tobin’s q falls. Both spreads \( \mu \) and \( \mu^* \) comove with the exchange rate, as suggested by Akinci and Queralto (2018), see equations 23 and 24. Due to an increased domestic credit spread, the effective cost of investment rises. The ratio of foreign debt, \( x \), rises upon impact due to an increased exchange rate, keeping the deposit amount constant. Without intervention the total foreign debt, \( D^* \), starts to rise after impact because the jump in the UIP spread creates an opportunity to invest overseas.

With the intervention policy the Home central bank responds to the currency deprecation by engaging in sterilized intervention thus selling dollar reserves and buying back an equivalent amount of sterilized bonds from the Home banks. From the balance of payments equation 35 a fall in dollar reserves also leads to a fall in dollar deposits, \( D^* \) coming in converging to a new dollar-dependency steady state. The credit and UIP spreads are
lowered faster by the sterilization since the central bank sells reserves and buys back bonds thus freeing up Home banks’ resources and changing private to public debt ratio by giving more loans to capital producers. Freeing up banks’ resources also leads to a slightly faster recovery of Tobin’s \( q \). Further the UIP spread, \( \mu^* \), achieves a much lower level after 20 periods suggesting a long term effect of narrowing the spread with intervention. It is interesting however that upon impact the spreads are more volatile with intervention. This is because banks were forced to invest a portion of their deposits in bonds thus limiting the banks balance sheet and thus the ability to freely lend to firms on top of the existing bank frictions.

After 20 periods (i.e., 5 years), dollar reserves and sterilized bonds do not go back to the steady state levels. This echoes the concerns that foreign investors have about repeated intervention and the continued depletion of dollar reserves. If such shocks are persistent enough, there could be a constant fall in reserves, which raises concerns about the financial credibility of the government and the domestic currency. On the other hand, a lower real exchange rate and UIP spread in the long run is achieved, suggesting that intervention does have long term effects on the financial sector as well as on international variables. The spillovers from a lower exchange rate and UIP spread imply also a new steady state for foreign debt ratio since foreign investors are less encouraged to invest overseas.

Figure 3 compares high versus low levels of the parameter \( \gamma_e \) in the reserve accumulation equation. As predicted by the equation, higher \( \gamma_e \) leads to lower reserve levels. Lower nominal exchange levels are reached with no changes to the real exchange rate. In the long run there is a slightly lower UIP spread achieved. This comes at a cost of a lower trade balance. Additionally, there is no significant changes to either price levels. The appropriate value of \( \gamma_e \) would be an interesting empirical investigation.

The main results of the model imply that intervention policy is effective in controlling real exchange rate volatility as well as the long run levels. Intervention policy is also effective in controlling PPI-deflation in the short run as well as long term price stability. Intervention implies a lower trade balance as predicted. Finally, the model suggests that intervention can have a spill-back effect that further deflates US consumer prices.

### 4.3 Simulated Data Regressions

Comparing the same regression from the data from Section 1.1 to the simulated data, Table 2 is the regression table based on individual shocks. Notice that simulated data based on a Foreign monetary policy shock captures more of the data, especially the inflation coefficients. This supports the claim that there are strong foreign monetary spillover effects influencing domestic prices compared to other shocks in the model.

Consider a similar regression with producer price inflation rather than consumption price inflation, yielding the regression Table 3. Notice that EM producer prices in the model are much more exposed to exchange rate dynamics than consumption prices, likely due to foreign financing in capital production. This is consistent with the efficiency of an
5 Comparing the Simulations to the Data

In this section I compare correlations of key variables from the simulated model with the data from Turkey and the US for the purpose of benchmarking and to see how much of the data the model is able to capture. There are 2 data sources to compare correlations: OECD and FRED in Section A.5.

Panels A and B are correlation tables from the simulated model. Panels C and D are the correlation tables from the OECD and E and F are similarly from the FRED. Note that Panels D and F are made stationary using the hpfilter to accurately compare results of the model.

Panel A considers basic variables of both economies in the model, such as consumption, GDP etc. In both countries consumption and output are positively correlated as theory would suggest: 0.57 in Home and 0.92 in Foreign, whereas the data suggests a similar relationship. International risk sharing is supported in the model since consumption in two countries are positively correlated (0.24). Data suggests a similar relationship here as well. The outputs of the two countries are negatively correlated (-0.14) whereas the data shows a strong positive relationship. This divergence could be explained by the two country set up of the model. Theory would suggest a positive relationship between net exports and Home GDP yet the coefficient from the model is -0.78. This seems strange; however the two data sources agree with the model: OECD (-0.75) and FRED (-0.27).

Overall, the model is able to follow closely the data for aggregate variables.

Panel B focuses on exchange rates, CPI and PPI-inflation in the model. A key difference with the data is the correlation of the Fed funds rate and US inflation, where the model yields a negative correlation of $-0.16$ and both data sources suggest a positive correlation of 0.37. The model captures the mechanism that when the Fed raises rates, inflation goes down. Whereas the data captures the mechanism that when there is high inflation, the Fed raises rates to control for prices. On the topic of correlations between inflation and exchange rate the model underestimates the data. The addition of DCP paradigm would be useful to see whether the model is closer to the data considering that a lot of world trade is dollar or euro denominated.

6 Further Expansions

Currently, the model includes a simple foreign exchange intervention rule that pins down the optimal reserve accumulation for the central bank. The Home economy is only dollar dependent in its foreign financing for capital. Even though the positive correlation between CPI-inflation and the exchange rate is present in the simulated data from the model, it does not capture the strong correlation that the data displays suggesting that there is a
stronger linkage between prices and exchange rates than the model is currently able to capture.

6.1 Dominant Currency Pricing

Further extensions of the model are aimed to capture the exposure of the Home economy prices to the exchange rate and the value of the dollar. To reflect this, a Dominant Currency Pricing (DCP) scheme can be added to the Home economy equations following Gopinath et al. (2016), also implemented in Akinci and Queralto (2018). Previous works have used DCP to show the spillovers from the exchange rate can have on the performance of the Home economy. This has been a very common trade pattern since the dollar has been the dominant trading currency and thus the benefits from a currency depreciation to increased demand of export goods is diminished relative to the baseline model. With additional vulnerability to the dollar, intervention policy could be more effective in controlling domestic consumer prices.

7 Conclusion

In this paper I developed a two-country model with imperfect financial markets to study the effectiveness of a sterilized foreign exchange intervention policy by an EM central bank in response to a US monetary tightening policy. The model includes strong financial amplifications due to an endogenous UIP deviation and the presence of dollar-denominated debt. This model captures spillovers and some spill-back from a US monetary policy.

Under heightened dollar dependency of the banking sector, a sterilized intervention is effective in the long run to control exchange rate hikes and effective in the short run for controlling producer prices. Further intervention reduces both real exchange rate and producer price inflation volatility. The intervention leads the model to converge to a new steady state with a significantly lower dollar debt ratio, a lower real exchange rate, UIP spread and dollar reserve levels. It is an unexpected result that intervention can lead to a spill-back effect on US CPI-inflation further deflating the dollar. Though this effect is rather small, if enough EMs simultaneously implement such policies during US monetary tightening periods, the model implies that the US could have further deflation.

It can be speculated that the size of sterilized foreign exchange intervention should be included in the decision-making of the Fed on monetary policy. For EM central banks, such interventions can be theoretically effective for the economic and financial stability from a US spillover. Yet repeated intervention could lead to a depletion of foreign reserves of the EM central bank.

Looking ahead, it would be beneficial to adopt a dominant currency paradigm where EM exports are dollar-denominated. Under such circumstances the EM would be more exposed to exchange rate fluctuations and could amplify the effectiveness of an intervention policy for controlling domestic consumption prices as well.
References


A Appendix

A.1 Solving Banker's Problem

To solve the bankers' problem assume the value function is linear in New Worth ($N_t$) such that

\[ V_t = \alpha_t N_t. \]  

Define variables $\mu_t$, $\nu_t$, and $\mu^*_t$:

\[ \mu_t = E_t [\Lambda_{t,t+1}(1 - \sigma_b + \sigma_b \alpha_{t+1})(R_{Kt+1} - R_{t+1})] \]  

(A.1)

\[ \nu_t = E_t (\Lambda_{t,t+1}(1 - \sigma_b + \sigma_b \alpha_{t+1})) R_{t+1} \]  

(A.2)

\[ \mu^*_t = E_t \left[ \Lambda_{t,t+1}(1 - \sigma_b + \sigma_b \alpha_{t+1})(R_{t+1} - R^*_{t+1} \frac{Q_{t+1}}{Q_t}) \right] \]  

(A.3)

Redefining the bankers' objective as before:

\[ \alpha_t = \max_{\phi_t, x_t} (y_t \mu_t + x_t \mu^*_t) \phi_t + \nu_t \]  

(A.4)

subject to

\[ \alpha_t = \max_{\phi_t, x_t} (y_t \mu_t + x_t \mu^*_t) \phi_t + \nu_t \]  

(A.5)

where $y_t$ is defined as $y_t \equiv \frac{q_t S_t}{q_t S_t + S^b_t}$ and the bank’s leverage ratio $\phi_t \equiv \frac{q_t S_t + S^b_t}{N_t}$. Solving for the 2 Lagrangian F.O.C.s:

\[ y_t \mu_t + x_t \mu^*_t = \frac{\lambda_t}{1 + \lambda_t} \Theta(x_t) \]  

(A.6)

\[ \mu^*_t = \frac{\lambda_t}{1 + \lambda_t} \Theta'(x_t) \]  

(A.7)

Combining the above 2 equations we get:

\[ \mu^*_t = y_t \mu_t \left( \frac{\Theta(x_t)}{\Theta'(x_t)} - x_t \right)^{-1} \]  

(A.8)

Assuming the IC binds:

\[ \phi_t = \frac{\nu_t}{\Theta(x_t) - (y_t \mu_t + x_t \mu^*_t)} \]  

(A.9)

Therefore we can solve for the undefined coefficient using

\[ \alpha_t = (y_t \mu_t + x_t \mu^*_t) \phi_t + \nu_t \]  

(A.10)
Define $\Omega_t$ as:

$$\Omega_t = 1 - \sigma_b + \sigma_b \alpha_t = 1 - \sigma_b + \sigma_b ((\mu_t^{\prime} \mu_t + x_t \mu_t^{\prime}) \phi_t + \nu_t)$$  \hspace{1cm} (A.11)$$

Banks' net worth evolution becomes:

$$N_t = \sigma_b \left[ R_{Kt} - R_t \right] q_{t-1} S_{t-1} + \left( R_t - R^{*}_{t} \frac{Q_t}{Q_{t-1}} \right) Q_{t-1} D_{t-1}^{*} + R_t N_{t-1} + (1 - \sigma_b) \xi_b (q_{t-1} S_{t-1} + S_b^{\prime})$$  \hspace{1cm} (A.12)$$

### A.2 List of Model Equations

#### Home Country:

- $C_t^{-\sigma} = \beta \mathbb{E}_t \left[ \frac{C_{t+1}^{-\sigma} R_{t+1}^{n}}{\pi_{t+1}^{\alpha}} \right]$  \hspace{1cm} (1)
- $N_{t+1} = \beta \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma}$  \hspace{1cm} (2)
- $C_H = \omega (p_H)^{-\theta} C$  \hspace{1cm} (3)
- $C_F = (1 - \omega) (T p_H)^{-\theta} C$  \hspace{1cm} (4)
- $C^\sigma L^\chi = w$  \hspace{1cm} (5)
- $p_H = \left[ \omega + (1 - \omega) (T)^{1-\theta} \right]^{\frac{1}{1-\theta}}$  \hspace{1cm} (6)
- $Y = K^\alpha L^{1-\alpha}$  \hspace{1cm} (7)
- $mc = \left( \frac{w}{1-\alpha} \right)^{1-\alpha} (\frac{r_K}{\alpha})^\alpha$  \hspace{1cm} (8)
- $w = \frac{(1 - \alpha) K}{\alpha L^{r_K}}$  \hspace{1cm} (9)
- $x_{1t} = C_t^{-\sigma} mc_t Y_t + \beta \xi_p \pi_t \frac{1+\theta_p}{\theta_p} \mathbb{E}_t \left\{ x_{1t+1} \frac{1+\theta_p}{\theta_p} \right\}$  \hspace{1cm} (10)
- $x_{2t} = C_t^{-\sigma} p H_t Y_t + \beta \xi_p \pi_t \frac{1+\theta_p}{\theta_p} \mathbb{E}_t \left\{ x_{2t+1} \frac{1+\theta_p}{\theta_p} \right\}$  \hspace{1cm} (11)
- $\pi_t^o = (1 + \theta_p) \frac{x_{1t}}{x_{2t}} \pi_t$  \hspace{1cm} (12)
- $\pi_t = \left( (1 - \xi_p) (\pi_t^o)^{-\frac{1}{\theta_p}} + \xi_p (\pi_{t-1})^{-\frac{1}{\theta_p}} \right)^{-\theta_p}$  \hspace{1cm} (13)
- $I_H = \omega (p_H)^{-\theta} I$  \hspace{1cm} (14)
\[ I_F = (1 - \omega) (T_{PH})^{-\theta} I \]  
\[ K_{t+1} = (1 - \delta) K_t + I_t \]  
\[ q_t = 1 + pH_t \left[ \psi_I \left( \frac{I_t}{I_{t-1}} - 1 \right) \frac{I_t}{I_{t-1}} + \frac{\psi_I}{2} \left( \frac{I_t}{I_{t-1}} - 1 \right)^2 \right] \]  
\[ R_t = \frac{R_t}{R_{t-1}} \eta \left( \frac{1}{E_t^{\gamma_c}} \right)^{1-\eta} \]  
\[ Q_t(R_t - R_{t-1}) = S_{t+1}^b - R_{t-1}S_t^b \]  
\[ R_{Kt} = \frac{r_{Kt} + (1 - \delta) q_t}{q_t} \]  
\[ N_t = \sigma_b \left[ R_{Kt} - R_t \right] q_{t-1} S_{t-1} + \left( R_t - R_{t-1} \frac{Q_t}{Q_{t-1}} \right) Q_{t-1}^* D_{t-1}^* + R_t N_{t-1} \]  
\[ \phi_t N_t \]  
\[ Q_t D_t^* = x_t \phi_t N_t \]  
\[ q_t S_t = y_t \phi_t N_t \]  
\[ x_t = \left( \frac{\mu_t^*}{yt \mu_t} \right)^{-1} \left( -1 + \sqrt{1 + \frac{2}{\gamma} \left( \frac{\mu_t^*}{yt \mu_t} \right)^2} \right) \]  
\[ \mu_t = E_t \left[ \Lambda_{t,t+1} \Omega_{t+1} (R_{Kt+1} - R_{t+1}) \right] \]  
\[ \mu_t^* = E_t \left[ \Lambda_{t,t+1} \Omega_{t+1} (R_{t+1} - R_{t+1}^* \frac{Q_{t+1}}{Q_t}) \right] \]  
\[ \nu_t = E_t \left[ \Lambda_{t,t+1} \Omega_{t+1} R_{t+1} \right] \]  
\[ \Omega_t = 1 - \sigma_b + \sigma_b ((yt \mu_t + x_t \mu_t^*) \phi_t + \nu_t) \]  
\[ S_t = (1 - \delta) K_t + I_t \]  
\[ Y = C_H + I_H \frac{1 - n}{n} (C_H + I_H^*) + \frac{\psi_I}{2} \left( \frac{I_t}{I_{t-1}} - 1 \right)^2 I_t \]  
\[ R_{t+1}^n = \beta^{-1} \pi_t^\delta \]  
\[ \pi_t = \frac{\pi_t^\gamma_{PH,t}}{\pi_t^\gamma_{PH,t-1}} \]  
\[ R_t = \frac{R_t}{\pi_t^\gamma_{PH,t+1}} \]
Equations (19) and (20) reflect the reserve accumulation and sterilized intervention respectively. Dollar reserves also appear in the balance of payments equation (59).

Foreign Country:

\[ C_i^{\alpha-\sigma} = \beta \mathbb{E}_t \left[ \frac{C_{i+1}^{\alpha-\sigma}}{\pi_i^{\alpha-\sigma}} \right] \]  \hspace{1cm} (36)

\[ \Lambda_{t+1}^* = \beta \left( \frac{C_{t+1}^*}{C_t^*} \right)^{-\sigma} \]  \hspace{1cm} (37)

\[ C_H^* = \omega^* \left( \frac{p_F}{\bar{T}} \right)^{-\theta} C^* \]  \hspace{1cm} (38)

\[ C_F^* = (1 - \omega^*) (p_F)^{-\theta} C^* \]  \hspace{1cm} (39)

\[ \pi_t^* = \left( 1 + \theta_p \right) \frac{x_1^*}{x_2^*} \pi_t^* \]  \hspace{1cm} (47)

\[ \pi_t^* = \left( 1 - \xi_p \right) (\pi_{t-1}^*)^\frac{1}{\theta_p} + \xi_p (\pi_{t-1}^*)^\frac{1}{\theta_p} \]  \hspace{1cm} (48)

\[ I_H^* = \omega^* \left( \frac{p_F}{\bar{T}} \right)^{-\theta} \]  \hspace{1cm} (49)

\[ I_F^* = (1 - \omega^*) (p_F)^{-\theta} \]  \hspace{1cm} (50)

\[ K_{t+1}^* = (1 - \delta) K_t^* + I_t^* \]  \hspace{1cm} (51)

\[ q_t^* = 1 + pF_t \left[ \psi_I \left( \frac{I_t^*}{I_{t-1}^*} - 1 \right) \frac{I_t^*}{I_{t-1}^*} + \frac{\psi_I}{2} \left( \frac{I_t^*}{I_{t-1}^*} - 1 \right)^2 \right] \]  \hspace{1cm} (52)

\[ q_t^* = \mathbb{E}_t \Lambda_{t+1}^* + (1 - \delta) q_{t+1}^* \]  \hspace{1cm} (53)
\[ Y^* = \left( C_F + I_F \right) + \frac{n}{1-n} \left( C_F + I_F \right) + \psi I \left( \frac{I_t^*}{I_{t-1}} - 1 \right)^2 I_t^* \] (54)

\[ R^*_{t+1} = \left( R^*_t \right)^{\gamma_r} \left( \beta - 1 \right) \pi^{*}_{t+1} \epsilon^*_t \] (55)

\[ \pi^{*}_{c_t} = \frac{\pi^{*}_{pF_{t-1}}}{p_{F,t}} \] (56)

\[ R^*_t = \frac{R^*_t}{\pi^{*}_{t+1}} \] (57)

**Common to Two Countries:**

\[ Q = \left[ \frac{\omega^* + (1 - \omega^*) T^{1-\theta}}{\omega + (1 - \omega) T^{1-\theta}} \right]^{\frac{1}{1-\theta}} \] (58)

\[ Q_t (D^*_t - R^*_t D^*_{t-1} - R^*_t R^*_{t-1} + R^*_t R^*_{t-1}) = C_t + I_t + p_H \frac{\psi I}{2} \left( \frac{I_t}{I_{t-1}} - 1 \right)^2 I_t - p_H Y_t \] (59)

**List of Variables (59):**

\( C, C^*, C_H, C_F, C^*_F, I, I^*, I_H, I^*_H, I_F, I^*_F, \Lambda_{t,t+1}, \Lambda^*_{t,t+1}, Y, Y^*, K, K^*, L, L^*, mc, mc^*, w, w^*, r_K, q^*, q^d, R_K, R^m, R, R^8, R^*, x_1, x_2, \pi^o, \pi, x^*_1, x^*_2, \pi^{o*}, \pi^{c*}, \pi^{c*}, p_H, p_F, N, D^*, S, S^b, \phi, \Omega, \nu, \mu, \mu^*, x, y, Q, T \)

where \( p_H \equiv \frac{P_H}{P_F}, p_F \equiv \frac{P_F}{P_F}, mc \equiv \frac{MC}{P_F}, mc^* \equiv \frac{MC^*}{P_F}, w \equiv \frac{W}{P_F}, w^* \equiv \frac{W^*}{P_F}, r_K \equiv \frac{R_K}{P_F}, r^*_K \equiv \frac{R^*_K}{P_F}. \)

**A.3 Regression Tables**

FRED variable codes for Table 1 are in order: CPIAU, CCUS, CLM650N, CHLCPIALLMIN, CCUSMA02TRM618N, TURCPIALLMIN.
### Table 1: Dependent Variable: Change in NER with the $\pi_c$

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<th>Variable</th>
<th>Chile</th>
<th>Turkey</th>
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<tr>
<td>$\pi_{US}$</td>
<td>-2.31</td>
<td>-2.44**</td>
</tr>
<tr>
<td></td>
<td>(1.45)</td>
<td>(1.03)</td>
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<tr>
<td>$\pi_{CHL}$</td>
<td>2.31***</td>
<td>–</td>
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<tr>
<td></td>
<td>(0.85)</td>
<td></td>
</tr>
<tr>
<td>$\pi_{TUR}$</td>
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<td>1.29***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.39)</td>
</tr>
<tr>
<td>Constant</td>
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<td>1.00***</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.003)</td>
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<table>
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<td></td>
<td>201</td>
<td>0.18</td>
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</table>

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

### Table 2: Dependent Variable: Change in NER with the $\pi_c$

<table>
<thead>
<tr>
<th>Variable</th>
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<th>Home Tech Shock</th>
<th>Home Monetary Shock</th>
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<td>(X)</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>R²</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>200</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>X</td>
</tr>
</tbody>
</table>

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

### A.4 Calibration Tables
Table 3: Dependent Variable: Change in NER with the $\mathbf{π_{US}}$

<table>
<thead>
<tr>
<th>Variable</th>
<th>Foreign Monetary Shock</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi_{US}$</td>
<td>-1.26 (X)</td>
</tr>
<tr>
<td>$\pi_{EM}$</td>
<td>14.37 (x)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.00 (X)</td>
</tr>
</tbody>
</table>

| N | 200 |
| R² | X |

***p < 0.01, **p < 0.05, *p < 0.1

Table 4: Parameter Descriptions and Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>output elasticity of capital</td>
<td>0.33</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Home consumer’s discount rate</td>
<td>0.99688</td>
</tr>
<tr>
<td>$\beta^*$</td>
<td>Foreign consumer’s discount rate</td>
<td>0.997503</td>
</tr>
<tr>
<td>$\chi$</td>
<td>inverse labor supply elasticity</td>
<td>3.79</td>
</tr>
<tr>
<td>$\delta$</td>
<td>capital depreciation rate</td>
<td>0.025</td>
</tr>
<tr>
<td>$\eta$</td>
<td>$\mathbf{$}$ reserve inflexibility to nominal exchange rate</td>
<td>0.82</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Home bias in bank funding</td>
<td>2.58</td>
</tr>
<tr>
<td>$\gamma_e$</td>
<td>response in reserve accumulation to nominal exchange rate</td>
<td>2.09</td>
</tr>
<tr>
<td>$\gamma_\pi$</td>
<td>response in taylor rule to inflation</td>
<td>2.09</td>
</tr>
<tr>
<td>$\gamma_r$</td>
<td>Foreign Taylor rule inertia coefficient</td>
<td>0.82</td>
</tr>
<tr>
<td>$n$</td>
<td>Home country size ratio</td>
<td>1/3</td>
</tr>
<tr>
<td>$\omega$</td>
<td>weight given to Home good in Home consumption</td>
<td>0.80</td>
</tr>
<tr>
<td>$\omega^*$</td>
<td>weight given to Home good in Foreign consumption</td>
<td>0.20/3</td>
</tr>
<tr>
<td>$\psi_I$</td>
<td>investment adjustment cost</td>
<td>2.85</td>
</tr>
<tr>
<td>$\rho_r$</td>
<td>persistence of Foreign monetary shock</td>
<td>0.25</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>inverse elasticity of substitution</td>
<td>1.00</td>
</tr>
<tr>
<td>$\sigma_b$</td>
<td>banks’ survival rate</td>
<td>0.95</td>
</tr>
<tr>
<td>$\sigma_r$</td>
<td>standard deviation of Foreign monetary shock</td>
<td>0.20/100</td>
</tr>
<tr>
<td>$\theta$</td>
<td>trade price elasticity</td>
<td>0.90</td>
</tr>
<tr>
<td>$\theta_p$</td>
<td>net price markup</td>
<td>0.20</td>
</tr>
<tr>
<td>$\theta_r$</td>
<td>banks’ default probability</td>
<td>0.41</td>
</tr>
<tr>
<td>$\xi_b$</td>
<td>transfer rate to entering banks</td>
<td>0.07</td>
</tr>
<tr>
<td>$\xi_p$</td>
<td>price stickiness</td>
<td>0.84</td>
</tr>
</tbody>
</table>
A.5 Correlation Tables

### A.5.1 Simulated Correlations

#### Panel A: Correlations

<table>
<thead>
<tr>
<th></th>
<th>$C$</th>
<th>$GDP$</th>
<th>$NX$</th>
<th>$C^*$</th>
<th>$GDP^*$</th>
<th>Fed F.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C$</td>
<td>1.00</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$GDP$</td>
<td>0.57</td>
<td>1.00</td>
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</tr>
<tr>
<td>$NX$</td>
<td>-0.25</td>
<td>-0.78</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$C^*$</td>
<td>0.24</td>
<td>-0.09</td>
<td>0.01</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$GDP^*$</td>
<td>0.23</td>
<td>-0.14</td>
<td>0.06</td>
<td>0.92</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Fed Funds</td>
<td>-0.28</td>
<td>0.10</td>
<td>0.05</td>
<td>-0.83</td>
<td>-0.78</td>
<td>1.00</td>
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</tbody>
</table>

#### Panel B: Correlations

<table>
<thead>
<tr>
<th></th>
<th>$NER$</th>
<th>$\Delta NER$</th>
<th>$\pi$</th>
<th>$\pi^c$</th>
<th>$\pi^*$</th>
<th>$\pi^{c*}$</th>
<th>Fed F.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$NER$</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta NER$</td>
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<td>1.00</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\pi$</td>
<td>-0.32</td>
<td>0.13</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\pi^c$</td>
<td>-0.08</td>
<td>0.83</td>
<td>0.58</td>
<td>1.00</td>
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</tr>
<tr>
<td>$\pi^*$</td>
<td>0.18</td>
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<td>0.001</td>
<td>0.10</td>
<td>1.00</td>
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<tr>
<td>$\pi^{c*}$</td>
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<td>-0.004</td>
<td>-0.05</td>
<td>0.98</td>
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<tr>
<td>Fed Funds</td>
<td>0.37</td>
<td>0.28</td>
<td>0.04</td>
<td>0.23</td>
<td>-0.11</td>
<td>-0.16</td>
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### A.5.2 Data Correlations

#### OECD Data: Panel C^8^: Correlations

<table>
<thead>
<tr>
<th></th>
<th>$NER_{TUR}$</th>
<th>$\Delta NER_{TUR}$</th>
<th>$\pi_{TUR}^c$</th>
<th>$\pi_{US}^c$</th>
<th>Fed F.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$NER_{TUR}$</td>
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<tr>
<td>$\Delta NER_{TUR}$</td>
<td>-0.42</td>
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<td></td>
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<tr>
<td>$\pi_{TUR}^c$</td>
<td>0.91</td>
<td>-0.34</td>
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<td></td>
</tr>
<tr>
<td>$\pi_{US}^c$</td>
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</tr>
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<td>Fed Funds</td>
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<td>0.10</td>
<td>-0.01</td>
<td>0.37</td>
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^8^FRED variable codes in order: CCUSMA02TRM618N, TURCPIALLMINMEI, CPALTT01USM657N, EFFR.
### Panel D: Correlations

<table>
<thead>
<tr>
<th></th>
<th>$C_{TUR}$</th>
<th>$GDP_{TUR}$</th>
<th>$NX_{TUR}$</th>
<th>$C_{US}$</th>
<th>$GDP_{US}$</th>
<th>Fed F.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_{TUR}$</td>
<td>1.00</td>
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<tr>
<td>$GDP_{TUR}$</td>
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<td>$NX_{TUR}$</td>
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<td>$C_{US}$</td>
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<tr>
<td>$GDP_{US}$</td>
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<td>0.89</td>
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<td>Fed Funds</td>
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<td>0.72</td>
<td>0.66</td>
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</table>

**FRED Data:**

### Panel E: Correlations

<table>
<thead>
<tr>
<th></th>
<th>$NER_{TUR}$</th>
<th>$\Delta NER_{TUR}$</th>
<th>$\pi^c_{TUR}$</th>
<th>$\pi^c_{US}$</th>
<th>Fed F.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$NER_{TUR}$</td>
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<td></td>
<td></td>
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<td>$\Delta NER_{TUR}$</td>
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<td>0.29</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\pi^c_{US}$</td>
<td>-0.08</td>
<td>-0.18</td>
<td>-0.10</td>
<td>1.00</td>
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</tr>
<tr>
<td>Fed Funds</td>
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<td>-0.12</td>
<td>0.06</td>
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</table>

### Panel F: Correlations

<table>
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<tr>
<th></th>
<th>$C_{TUR}$</th>
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<th>$NX_{TUR}$</th>
<th>$C_{US}$</th>
<th>$GDP_{US}$</th>
<th>Fed F.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_{TUR}$</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$GDP_{TUR}$</td>
<td>0.89</td>
<td>1.00</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$NX_{TUR}$</td>
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<td>-0.18</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$C_{US}$</td>
<td>0.25</td>
<td>0.19</td>
<td>-0.14</td>
<td>1.00</td>
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</tr>
<tr>
<td>$GDP_{US}$</td>
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<td>0.34</td>
<td>-0.18</td>
<td>0.89</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Fed Funds</td>
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<td>-0.07</td>
<td>0.72</td>
<td>0.66</td>
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</tr>
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</table>

### A.6 IRF Plots

---

9Variables are stationary using the hpfilter. FRED variable codes in order: NAEXKP02TRQ189S, NAEXKP01TRQ652S, NAEXKP06TRQ652S - NAEXKP07TRQ652S, PCEC96, GDPC1, EFFR.

10FRED variable codes in order: CCUSMA02TRM618N, TURCPIALLMINMEI, CPIAUCSL, EFFR.

11Variables are stationary using the hpfilter. FRED variable codes in order: TURPFCEQDSMEI, TURGDPNQDSMEI, XTNTVA01TRM664S, PCEC96, GDPC1, EFFR.
Figure 1: US Monetary Tightening with Imperfect Financial Markets - Macro Variables

Note: The dark blue line shows the effects, in the units of deviations from steady state, of a 1 percentage point increase in the US policy rate in the model with sterilized foreign exchange intervention policy. The light blue line shows the effects of the same model without intervention.
Figure 2: US Monetary Tightening with Imperfect Financial Markets - Banking Side

Note: The dark blue line shows the effects, in the units of deviations from steady state, of a 1 percentage point increase in the US policy rate in the model with sterilized foreign exchange intervention policy. The light blue line shows the effects of the same model without intervention.
Figure 3: Weight of Exchange Rates in Reserve Accumulation (High v. Low $\gamma_e$)

Note: The dark blue line shows the effects, in the units of deviations from steady state, of a 1 percentage point increase in the US policy rate in the model with intervention with a high weight ($\gamma_e = 5$) given to exchange rate fluctuations in determining reserve levels and light blue is with a low weight ($\gamma_e = 2.09$).