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Optimal Exchange Rate Policy with Oil Shocks

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Optimal Exchange Rate Policy with Oil Shocks*

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ABSTRACT: We study optimal monetary and exchange rate policy in a small open economy facing oil price shocks. In a model with segmented financial markets that generate endogenous UIP deviations, the first-best allocation is achieved through a combination of interest rate policy and foreign exchange intervention (FXI). Monetary policy stabilizes domestic inflation and the output gap, while FXI targets the UIP wedge to offset financial frictions. Oil price shocks endogenously move the net foreign asset position, giving rise to financial imbalances that make FXI essential—a mechanism distinct from exogenous financial shocks highlighted in the literature. Quantitatively, for a calibrated oil exporter, suboptimal regimes such as a free float or a simple peg entail sizable welfare losses of around 2% in consumption-equivalent terms, though peg, and especially peg with fuel subsidies, can outperform free floats. Overall, FXI is crucial to break the destabilizing link between real commodity shocks and financial risk premia.

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WORKING PAPERS

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Contents

1 Introduction

Oil and energy price volatility has long posed significant policy challenges for oil-exporting economies. Sharp price swings, such as the 2008 oil boom and collapse, the 2014–15 plunge, and the recent surges following geopolitical tensions, can trigger large fluctuations in trade balances, capital flows, and economic activity. Oil exporters in the Gulf Cooperation Council (GCC) have tended to maintain fixed exchange rate regimes and historically relied on extensive energy price subsidies to shield domestic prices from external shocks.[1] Other oil exporters rely more on flexible exchange rates or fiscal buffers to absorb volatility. Yet despite the prominence of these policies, it remains unclear whether pegged regimes, energy subsidies, or foreign exchange intervention (FXI) represent optimal responses to oil price shocks, particularly for small open economies with shallow financial markets.

Motivated by this gap, this paper examines how an oil-exporting country should manage its exchange rate in the face of oil price volatility. While a vast literature studies optimal exchange rate policy in response to financial shocks, the role of policy in managing the challenges of supply-side commodity shocks is less understood. We bridge this gap by developing an open-economy model with two key frictions: sticky prices in the domestic sector and segmented financial markets that generate an endogenous currency risk premium. Our central contribution is to show how real, supply-side oil shocks endogenously generate the very financial imbalances that necessitate FXI. An oil price shock shifts the natural real exchange rate and the economy's net foreign asset (NFA) position. For an oil exporter, a price rise improves the NFA; for an importer, it worsens it. These NFA fluctuations must be absorbed by risk-averse financial intermediaries, creating pressures on the currency market that, without intervention, lead to a costly and inefficient deviation from uncovered interest parity (UIP). This provides a new, fundamentals-based rationale for FXI, distinct from the exogenous currency demand shocks emphasized in the benchmark literature.

With oil as a production input, oil price shocks impact the marginal cost of production.[2] When prices are flexible, firms can modify their output prices in response to oil price shocks, allowing them to effectively adjust the overall demand level in the economy. However, in the presence of sticky prices, monetary policy must intervene to maintain de-

[1] Several GCC countries have implemented significant energy-price reforms in recent years, including Saudi Arabia.

[2] Under Calvo pricing, inflation is tied to expected future real marginal costs; oil price volatility therefore raises the welfare cost of price stickiness.

mand at its optimal level. While monetary policy can directly influence the consumption of domestic goods by altering the inter-temporal rate of substitution, its effect on the consumption of foreign goods is more limited. The consumption of foreign goods depends on aggregate wage levels, which are affected by monetary policy, as well as the exchange rate, which is determined by conditions in the financial market.

The nominal exchange rate serves two primary functions in the economy. First, in goods markets, it facilitates adjustments in the real exchange rate in response to fundamental shocks, enabling efficient allocation between domestic and foreign goods, especially when domestic prices are sticky. Second, it influences the production structure, summarized by the labor-to-oil ratio, because it affects the domestic oil prices faced by producers. For example, an overvalued exchange rate lowers domestic energy costs, encouraging firms to rely more on oil than labor, thus moving the economy away from an efficient input allocation. Consequently, maintaining an optimal exchange rate is essential for achieving both an efficient level of goods consumption and an efficient production structure.

However, in the financial market, this necessary volatility of the exchange rate becomes the source of the financial friction. International capital flows are managed by risk-averse financial intermediaries who demand compensation for bearing currency risk. The size of the currency exposure of arbitrageurs, which varies with a country's NFA, combined with oil-driven exchange rate volatility, gives rise to a currency risk premium for these intermediaries.[3] This UIP risk limits international risk-sharing and distorts the efficient level of labor-to-oil ratio, causing welfare losses that warrant government intervention. Effectively, an oil price shock is not just a domestic cost shock that affects the production structure; it is also a terms-of-trade shock that directly impacts the country's NFA position and will have implications for the financial markets.

These frictions prompt a two-fold optimal policy response: monetary policy adjusts to close the domestic output gap and inflation, while FXI mitigates financial frictions exacerbated by oil shocks to achieve the first-best allocation.[4] Under this optimal "managed float," FXI does not aim to eliminate exchange rate volatility entirely; rather, it neutralizes the associated financial friction, thereby freeing the exchange rate to adjust efficiently in line with the fundamentals-driven "natural" rate. The welfare losses associated with

[3]This friction, which generates deviations from Uncovered Interest Parity, is central to matching key empirical puzzles of exchange rate behavior and provides a robust microfoundation for the effectiveness of sterilized intervention (Gabaix and Maggiori 2015; Itskhoki and Mukhin 2021a).

[4]The oil price shock is not a pure cost-push shock. It is a terms-of-trade shock that can be offset with the adjustments in the exchange rate.

these frictions in the absence of an optimal policy depend on the economy's degree of openness and the share of energy in production. Although a pegged exchange rate regime is not optimal in our model, its welfare cost tends to fall as openness rises. Additionally, when oil is a factor in production, oil price shocks can shift the natural equilibrium exchange rate analogous to TFP shocks. Thus, a higher share of oil as a production input increases the welfare cost associated with oil price volatility in a pegged exchange rate regime.

Our analysis builds on the tractable policy framework developed by Itskhoki and Mukhin (2023), which accounts for key empirical puzzles of exchange rate behavior.[5] The model's capacity to capture nominal exchange rate movements makes it a valuable tool for central bank interventions aimed at mitigating financial market risks arising from oil price volatility. In this framework, where risk-averse arbitrageurs trade home and foreign currency bonds in segmented financial markets, there is significant scope for FXI. While they focus on the role of policy in response to exogenous financial shocks (i.e., ”noise traders”), our primary innovation is to integrate an oil-production structure and demonstrate that fundamental, real-sector shocks can themselves be a primary source of the financial frictions that make an integrated policy framework essential.

To assess the economic significance of this mechanism, we calibrate the model to a representative oil-exporting (GCC) economy. Quantitatively, we find that this endogenous channel is a more powerful justification for FXI than standard exogenous financial shocks. We also show that suboptimal policies, such as currency pegs or energy subsidies, generate substantial welfare losses. Relative to a float without FXI, a simple peg lowers losses by shutting down the financial wedge, but as oil intensity rises it becomes costly because adjustment is forced into the domestic gap and inflation. Pairing the peg with an energy-price stabilization rule further mitigates these domestic costs by damping marginal-cost pass-through and inflation, and can therefore outperform a plain peg in oil-intensive economies. Nevertheless, both the peg and peg-plus-subsidy remain dominated by the integrated policy that combines an optimal interest-rate rule with FXI.

Section 2 provides the literature review on exchange rate policies and the role of oil prices. Section 3 presents the model incorporating oil price shocks. Section 4 provides the solution to the Ramsey problem, while section 5 examines the effects of different policies

[5] To design an optimal exchange rate policy, we require a model that avoids exchange rate puzzles established in the literature. Itskhoki and Mukhin (2021a) demonstrates that models that incorporate endogenous deviations from uncovered interest parity (UIP) due to arbitrage limits can explain the general exchange rate disconnect and Mussa facts. The model incorporates international finance puzzles without relying on external shocks, unlike previous literature.

within the model framework. Section 6 extends the model by relaxing certain pricing assumptions and presents a full quantitative analysis of the welfare costs under suboptimal policies, including no FXI, currency pegs, and subsidies. Finally, Section 7 offers concluding remarks.

2 Literature Review

This paper sits at the intersection of two strands of literature: the macroeconomic management of commodity price shocks and the theory of optimal exchange rate policy under financial frictions. We synthesize these strands by examining the interplay between oil shocks[6] and FXI within a small, open, oil-exporting economy. We extend the standard model to incorporate oil as a productive input, thereby allowing us to evaluate the potential role of FXI and assess its capacity to improve the monetary policy trade-offs identified in the existing literature.[7]

The first strand examines how commodity price shocks propagate through the economy and the role of policy in mitigating their effects. Several studies investigate optimal central bank targeting rules when oil is part of the production function, including Catao and Chang (2013), Bergholt et al. (2019), Bergholt (2014), Omotosho (2022), and Chan et al. (2024). Bjørnland et al. (2018) documents that oil shocks remained a recurrent source of macroeconomic fluctuations even during the Great Moderation, and Fernández et al. (2018) show that commodity price shocks explain roughly one-third of real economic fluctuations in emerging markets. Fiscal policies can also help mitigate oil shocks; Auclert et al. (2023) examine interventions in energy-importing economies, while Hevia and Nicolini (2013) and Mendes and Pennings (2025) focus on commodity-exporting economies. However, these studies typically abstract from the financial frictions that motivate FXI.

There are a few papers that have analyzed how foreign exchange rate policies respond to commodity shocks and contribute to macroeconomic stabilization. For instance, Al-Abri (2014) examines the optimal exchange rate regime for a small oil-exporting economy,

[6] Although our focus is on oil, the framework can be applied to other commodities. We focus on oil exporters, as FXI does not face binding constraints in our setting.

[7] The model proposed in Itskhoki and Mukhin (2023) has several advantages over other models. Itskhoki and Mukhin (2021b) demonstrate that while other papers in the literature can explain exchange rate disconnect, only their model with endogenous UIP deviations due to limits to arbitrage can successfully account for the Mussa facts, crucial for analyzing optimal exchange rate policy. Models with exogenous financial shocks, on the other hand, fail to capture the Mussa Puzzle, as they unrealistically shift floating exchange rate volatility into inflation and the output gap under a currency peg.

finding that the optimal regime depends on the import pricing scheme—whether based on producer or local currency pricing. Jin and Xiong (2021) studies a small oil-exporting economy within a regime-switching model, analyzing how transmission channels of oil price shocks differ across policy regimes. Faltermeier et al. (2022) focuses on exchange rate policies in commodity-exporting economies, concluding that the optimal response to a commodity boom involves increasing foreign exchange reserves to stabilize the real exchange rate and tradable production. Our paper deviates from these papers in three main ways. First, in contrast to these studies, our paper introduces oil into production within a model featuring nominal rigidities and financial frictions that generate endogenous deviations from both purchasing power parity (PPP) and uncovered interest parity (UIP). Second, this approach enables us to analyze optimal exchange rate policy without relying on exogenous financial shocks. Third, our framework is analytically tractable, allowing us to derive clear, intuitive optimal policy rules and welfare results without relying on complex numerical simulations.

The second strand focuses on financial-market frictions and the rationale for FXI. Models in this literature highlight how exogenous shocks to currency demand (noise-trader or portfolio flow shocks) create deviations from UIP, which can be corrected through FXI. Key contributions include Gabaix (2014), Gabaix and Maggiori (2015), Chang et al. (2015), Cavallino (2019), Maggiori (2022), and Camanho et al. (2022), who show that exchange rates are driven as much by the risk-bearing capacity of intermediaries as by macroeconomic fundamentals. Further studies (Benes et al. (2015), Bianchi et al. (2021), Fanelli and Straub (2021), Mukhin (2022), Iovino and Sergeyev (2023), Egorov and Mukhin (2023), Ottonello et al. (2024)) investigate the interactions of FXI with monetary policy, liquidity shocks, and capital flows. In these models, FXI can improve welfare by moderating financial-market distortions that are not fully absorbed by the exchange rate.[8]

In the Integrated Policy Framework (IPF), Basu et al. (2023, 2020) develop a small open-economy model to evaluate how different instruments—including the policy rate, FXI, capital controls, and macroprudential measures—jointly address trade, financial, and exchange-rate frictions. Their framework highlights how real shocks, balance-sheet exposures, shallow FX markets, and dominant-currency pricing can generate inefficient exchange-rate movements, thereby creating a motive for coordinated use of multiple policy tools. Although their model includes a commodity-exporting sector, commodity pro-

[8]Other notable works investigating exchange rate policies and capital controls include Blanchard et al. (2015), Liu and Spiegel (2015), Drechsel et al. (2019), Adler et al. (2019), Cavallino (2019), Davis et al. (2021), Adrian et al. (2022), Bianchi and Sosa-Padilla (2024), Davis et al. (2023) and Beltran and He (2024).

duction does not interact with domestic marginal costs or the structure of production; commodities are exported but not used as inputs. As a result, IPF analysis in their setting abstracts from the dual role of commodity shocks as both supply-side disturbances and sources of terms-of-trade–driven financial imbalances. Our paper extends this line of work by integrating oil directly into domestic production. Nevertheless, and consistent with our results, Basu et al. (2020) note that for economies with large commodity sectors, permanent commodity-price shocks can justify FXI in shallow markets to reduce inefficient risk premia while preserving the degree of exchange-rate flexibility observed in deep FX markets.[9]

Our key contribution is to integrate these two strands. We show that the financial pressures that justify FXI need not be exogenous; they can be endogenously generated by oil price shocks through the NFA channel. This mechanism creates a UIP risk wedge even without any financial shocks. In our framework, optimal policy uses the interest rate to stabilize domestic price dispersion and FXI to neutralize the UIP wedge, achieving the first-best allocation. Calibration to a representative oil exporter (GCC) demonstrates that the FXI motive generated by oil shocks is quantitatively larger than that from standard noise-trader shocks. Finally, we quantify the welfare costs of commonly used suboptimal policies—currency pegs, which block efficient expenditure switching, and energy subsidies, which distort the labor–oil ratio while failing to stabilize the output gap.

3 Model

We build on international macro models with financial frictions to examine a small open economy where oil (energy) serves as a factor of production. In our model, the country receives a periodic oil endowment and, depending on its domestic production needs, acts as either a net oil exporter or importer.

[9] In models emphasizing expenditure switching and price stickiness, floats help align relative prices with fundamentals, while pegs trade that margin for reduced exchange-rate variability and (potentially) lower risk premia. In the absence of oil shocks, pegs are relatively costly when the economy is closed—because they force adjustment into domestic gaps—but their welfare cost declines with openness, as the weight on home-goods distortions falls, consistent with work linking openness to a smaller output cost of pegs and a narrower volatility trade-off (Faia and Monacelli 2008). Yet, our findings can rationalize why highly open commodity exporters sometimes favor tighter exchange-rate management, while also clarifying the conditions—openness and oil intensity—under which greater flexibility can be welfare improving (see also the IPF perspective in Basu et al. 2020).

3.1 Households

Households consume two types of goods: domestically produced goods, denoted by C_{Ht}, and foreign-produced goods, denoted by C_{Ft}. They maximize the expected utility, which is derived from the consumption of both domestic and foreign goods, while also taking into account the disutility associated with labor:[10]

$$\max_{C_{Ht},C_{Ft},L_t,B_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[(1-\gamma)\log C_{Ht} + \gamma \log C_{Ft} - L_t\right],$$

subject to the following budget constraint:

$$P_{Ht}C_{Ht} + P_{Ft}C_{Ft} + \frac{B_t}{R_t} = B_{t-1} + W_t L_t + \Pi_t + T_t + P_{Ot}O_{wt}, \tag{1}$$

where Π_t represents firms' profits, T_t refers to transfers from financial markets and government operations in the currency market, and O_{wt} is the oil endowment received by the household in each period. We assume that the law of one price holds for oil and the foreign goods: $P_{Ft} = \varepsilon_t P^*_{Ft}$ and $P_{Ot} = \varepsilon_t P^*_{Ot}$. Both P_{Ht} and P^*_{Ft} are fully sticky and normalized to 1.[11] Therefore, foreign good price, P_{Ft}, tracks the nominal exchange rate, ε_t.

In this setting, first-order conditions can be written as:

$$C_{Ft} = \gamma \frac{W_t}{\varepsilon_t}, \tag{2}$$

$$C_{Ht} = (1-\gamma)W_t, \tag{3}$$

$$\frac{1}{R_t} = \beta \mathbb{E}_t \frac{W_t}{W_{t+1}}, \textbf{ or } \frac{1}{R_t} = \beta \mathbb{E}_t \frac{C_{Ht}}{C_{Ht+1}}. \tag{4}$$

Equation (4) illustrates how the central bank can influence wages and the consumption of domestically produced goods, due to the assumption of fully sticky prices for these goods, by altering the path of the interest rate R_t. Equations (2) and (3) give us the expenditure switching condition:

$$\frac{\gamma}{1-\gamma}\frac{C_{Ht}}{C_{Ft}} = \varepsilon_t, \tag{5}$$

[10] In the benchmark model, we assume a linear disutility of labor for analytical convenience. In Appendix E, we show that all qualitative results remain unchanged when we adopt a more general specification with a finite Frisch elasticity of labor supply. The appendix also demonstrates that our main results are robust to the inclusion of non-tradable goods in the model.

[11] The assumption that $P^*_{Ft} = 1$ for all t is justified by the fact that a substantial portion of global trade is priced in U.S. dollars. These international prices tend to exhibit stickiness in dollar terms for periods up to two years (Goldberg and Tille 2008; Gopinath and Rigobon 2008; Gopinath 2015). In subsequent sections, we will relax the assumption of fully sticky prices for domestically produced goods.

showing when the domestic currency depreciates (higher ε_t), foreign goods become more expensive, encouraging consumers to buy more domestically produced goods instead. Conversely, if the domestic currency appreciates (lower ε_t), foreign goods become cheaper, prompting a shift towards increased imports.

3.2 Firms

Firms use oil, O_t, and labor, L_t, as inputs in a Cobb-Douglas production function to produce goods.[12] The output is consumed domestically by households and is also exported. For simplicity, we assume that export demand, C^*_{Ht}, is exogenously given. Firms operate in perfectly competitive markets, acting as price takers with no influence over market prices. They make production decisions by optimizing their input mix of oil and labor to maximize profits, ensuring that their production satisfies both domestic consumption and the exogenous export demand.

$$\max_{C_{Ht},L_t,O_t} \quad P_{Ht}C_{Ht} + \varepsilon_t P^*_{Ht}C^*_{Ht} - W_tL_t - P_{Ot}O_t,$$

subject to

$$C_{Ht} + C^*_{Ht} = A_t L_t^{\alpha} O_t^{1-\alpha}, \tag{6}$$

where A_t represents total factor productivity (TFP).[13] For the pricing of their output, we make two simplifying assumptions in this baseline model. First, the domestic price, P_{Ht}, is fully sticky, which we relax later in the quantitative exercise. Second, for exports, we assume dominant currency pricing (DCP), where the prices are invoiced in dollar and remain fully rigid. We normalize this export price to one ($P^*_{Ht} = 1$). This implies that the quantity of exports demanded by the rest of the world, C^*_{Ht}, is treated as an exogenous shock. These assumptions are relaxed in Section 6, where we show our results hold under more general price-setting protocols. The firm's problem is to choose inputs to maximize profit:

The optimality condition is derived as:

$$\frac{L_t}{O_t} = \frac{\alpha}{1-\alpha}\frac{\varepsilon_t P^*_{Ot}}{W_t}, \tag{7}$$

[12] We use a two-input Cobb-Douglas block as a parsimonious device to map oil/energy cost shocks into marginal costs, in line with the standard open-economy oil-shock literature. We can interpret $1-\alpha$ as an effective energy intensity parameter—capturing not only crude oil per se but more broadly energy-related intermediate inputs that co-move with oil prices. Our quantitative results should be read through this lens.

[13] As shown in Appendix F, the theoretical implications are robust to using a CES production function instead of the Cobb-Douglas specification.

which shows that the firm's decision regarding the labor-energy ratio depends on the exchange rate, global price of oil, and wages.

3.3 Financial Markets

Financial markets are segmented, which implies that domestic households can only trade bonds denominated in local currency. In contrast, the government, arbitrageurs, and noise traders actively participate in trading both domestic and foreign bonds. The foreign bond offers an exogenous interest rate, denoted as R_t^*, and is available to investors with perfect elasticity, allowing them to buy or sell unlimited quantities at the prevailing market rate.

Arbitrageurs: In each period, arbitrageurs engage in a carry trade with a zero-capital portfolio, taking a short position on one bond while simultaneously taking a long position on another. This relationship is represented as:

$$\frac{D_t}{R_t} + \frac{\varepsilon_t D_t^*}{R_t^*} = 0.$$

The income generated from this carry trade is transferred to households in a lump-sum manner. The profit from the carry trade in dollar terms is given by:

$$\pi_{t+1}^* = D_t^* + \frac{D_t}{\varepsilon_{t+1}} = \tilde{R}_{t+1}^* \frac{D_t^*}{R_t^*},$$

where $\tilde{R}_{t+1}^* = R_t^* - R_t \frac{\varepsilon_t}{\varepsilon_{t+1}}$. Arbitrageurs choose D_t^* to maximize their mean-variance preferences:

$$\max_{D_t^*} \mathbb{E}_t \left[\Theta_{t+1} \pi_{t+1}^{D^*} \right] - \frac{\omega}{2} \text{var}_t \left(\pi_{t+1}^{D^*} \right),$$

where $\Theta_{t+1} = \beta \frac{C_{Ft}}{C_{Ft+1}}$, and ω is a parameter that determines how risk averse arbitrageurs are in the economy. The solution to the arbitrageurs' maximization problem is expressed as:

$$\mathbb{E}_t \left[\Theta_{t+1} \left(R_t^* - R_t \frac{\varepsilon_t}{\varepsilon_{t+1}} \right) \right] = \omega \frac{D_t^*}{R_t^*} \text{var}_t \left(R_t \frac{\varepsilon_t}{\varepsilon_{t+1}} \right), \tag{8}$$

where the right-hand side represents the deviation from the uncovered interest parity (UIP) condition.

Noise Traders: Noise traders also maintain a zero-capital portfolio consisting of domestic and foreign bonds, represented by the following relationship:

$$\frac{N_t}{R_t} = -\frac{\varepsilon_t N_t^*}{R_t^*},$$

where N_t^* denotes an exogenous liquidity demand shock. The net income generated by the noise traders is also transferred to households at the end of each period.

Government: The government also holds both foreign and domestic bonds, adjusting its positions in these markets through open market operations. The value of the government's portfolio is given by:

$$\frac{F_t}{R_t} + \varepsilon_t \frac{F_t^*}{R_t^*}.$$

The net profit or loss from government operations is transferred to households. By aggregating all transfers to households, we obtain:

$$T_t = \left(F_{t-1} + \varepsilon_t F_{t-1}^*\right) - \left(\frac{F_t}{R_t} + \varepsilon_t \frac{F_t^*}{R_t^*}\right) + \varepsilon_t \tilde{R}_t^* \frac{N_{t-1}^* + D_{t-1}^*}{R_{t-1}^*}.$$

Market clearing in the domestic bond market implies

$$B_t + F_t + N_t + D_t = 0.$$

Let us define B_t^* as the NFA position of the country, which encompasses the combined positions of households, the government, noise traders, and arbitrageurs.[14] Financial market clearing requires that the combined foreign currency bond holdings of the government (F_t^*), arbitrageurs (D_t^*), and noise traders (N_t^*) equal the country's total net claims on the rest of the world.

$$\frac{B_t^*}{R_t^*} = \frac{1}{\varepsilon_t} \frac{B_t + F_t}{R_t} + \frac{F_t^*}{R_t^*}.$$

By performing some algebraic manipulation, we arrive at the following result:

$$B_t^* = F_t^* + N_t^* + D_t^*. \tag{9}$$

This equation indicates that the NFA position equals to the holdings of foreign bonds by the government, arbitrageurs, and noise traders.

[14] The latter two hold zero-capital portfolios. So, combining domestic bond-market clearing with the zero-capital constraints for noise traders and arbitrageurs, this expression reduces to the identity that NFA equals the sum of dollar portfolios held by government, noise traders and arbitrageurs.

3.4 Home Country Equations

Budget Constraint: Total profit in the economy from firms is:

$$\Pi_t = P_{Ht}C_{Ht} + \varepsilon_t P^*_{Ht}C^*_{Ht} - W_t L_t - P_{Ot}O_t.$$

By substituting this profit function into the household's budget constraint and accounting for the net profit from the financial market, we derive the following budget constraint for the home country:

$$\frac{B^*_t}{R^*_t} - B^*_{t-1} = P^*_{Ht}C^*_{Ht} - P^*_{Ft}C_{Ft} + P^*_{Ot}(O_{wt} - O_t). \tag{10}$$

This equation indicates that changes in the net foreign assets, expressed in dollars, are equal to the net exports of the country.

International Risk Sharing: Using equations (4), (8), and (9), we can derive the international risk-sharing condition:

$$\mathbb{E}_t\left[\Theta_{t+1}R^*_t\right] = 1 + \underbrace{\frac{B^*_t - N^*_t - F^*_t}{R^*_t}\omega\sigma^2_t}_{\text{Risk-sharing wedge}}, \tag{11}$$

where $\sigma^2_t = \text{var}_t\left(R_t\frac{\varepsilon_t}{\varepsilon_{t+1}}\right)$. The second term represents the risk-sharing wedge resulting from the risk premium charged by arbitrageurs. The risk-sharing wedge depends on the level of risk aversion, the volatility of the exchange rate, and the size of the position held by arbitrageurs.

4 Policy Problem

Government's problem is a Ramsey problem of choosing a sequence of government policies F^*_t and R_t that maximize household's welfare under commitment.

$$\max_{R_t, F^*_t, C_{Ht}, C_{Ft}, B^*_t, \varepsilon_t, \sigma^2_t, O_t, L_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[(1-\gamma)\log C_{Ht} + \gamma \log C_{Ft} - L_t\right],$$

subject to (3), (4), (5), (6), (7), (10), and (11). To solve this problem, we define an approximate version of the Ramsey problem in terms of deviations from the first-best allocation. Therefore, it is essential to first define the first-best allocation.

4.1 First-Best Allocation

The first-best allocation problem abstracts from both price stickiness in the goods market and intermediation frictions in the financial market. Additionally, the local planner treats the structure of the international financial market as exogenous, granting access to a perfectly elastic supply of dollar-denominated risk-free bonds at the given interest rate R_t^*. The social planner's optimization problem is:

$$\max_{C_{Ht}, C_{Ft}, B_t^*, O_t, L_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[(1-\gamma) \log C_{Ht} + \gamma \log C_{Ft} - L_t \right],$$

subject to (6), (10), and taking as given the path of shocks $\{P_{Ot}^*, O_{wt}, C_{Ht}^*, A_t, R_t^*\}$ and the initial net foreign assets B_{-1}^*, as well as the No-Ponzi-Game Condition (NPGC) for B_∞^*. The optimality conditions for the social planner are

$$\beta R_t^* \mathbb{E}_t \frac{\tilde{C}_{Ft}}{\tilde{C}_{Ft+1}} = 1, \tag{12}$$

$$\tilde{C}_{Ht} = (1-\gamma)\alpha A_t (\frac{\tilde{L}_t}{\tilde{O}_t})^{\alpha-1}, \tag{13}$$

$$\tilde{C}_{Ft} = \gamma \frac{\alpha}{1-\alpha} \frac{P_{Ot}^* \tilde{O}_t}{\tilde{L}_t}. \tag{14}$$

Let us also define the natural real exchange rate $\tilde{Q}_t$ as follows:

$$\tilde{Q}_t = \frac{\gamma}{1-\gamma} \frac{\tilde{C}_{Ht}}{\tilde{C}_{Ft}}. \tag{15}$$

The natural rate is the first-best real exchange rate that ensures an efficient expenditure allocation between home and foreign goods.

4.2 The Approximate Ramsey Problem

Now, we derive the second-order approximation of the loss function. First, let the wedges in the consumption of home and foreign goods be defined as $v_t \equiv \log\left(C_{Ht}/\tilde{C}_{Ht}\right)$ and $u_t \equiv \log\left(C_{Ft}/\tilde{C}_{Ft}\right)$, respectively. Additionally, let the wedge in the labor-to-oil ratio be expressed as $w_t = \log(L_t/O_t) - \log(\tilde{L}_t/\tilde{O}_t)$. Given these definitions, the objective function of the Ramsey problem, in terms of the deviation from the first-best allocation, becomes:

$$\frac{1}{2}\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ (1-\gamma)v_t^2 + \gamma u_t^2 + (1-\alpha)\alpha(1-\gamma)\frac{\bar{Y}_H}{\bar{C}_H} w_t^2 \right\}.$$

Thus, the loss function depends on the wedges in the consumption of both home and foreign goods, as well as the deviation of the labor-to-oil ratio from its efficient level. In Appendix A, we show that the wedge in the labor-to-oil ratio and the wedge in consumption of foreign good are directly related. The consumption of foreign goods is affected by the exchange rate and the extent to which households are compensated for the disutility of labor, as reflected in the wage rate (equation 2). At the same time, the labor-to-oil ratio is determined by the relative costs of labor and oil as production inputs, which are governed by the oil price-to-wage ratio (equation 7). Consequently, fluctuations in foreign goods consumption, caused by shifts in the exchange rate or wages, are mirrored by opposite changes in the labor-to-oil ratio. In other words, $u_t = -w_t$. Thus, we can rewrite the approximate Ramsey problem as follows:[15]

$$\min_{u_t, v_t, f_t^*, b_t^*, e_t, o_t} \frac{1}{2}\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ (1-\gamma)v_t^2 + \chi u_t^2 \right\} \tag{16}$$

$$\begin{aligned} s.t. \quad & e_t = \tilde{q}_t + v_t - u_t, \\ & \frac{\bar{C}_H}{\bar{Y}_H} v_t = -\alpha u_t + o_t - \tilde{o}_t, \\ & \beta b_t^* - b_{t-1}^* = \frac{-1}{\bar{Y}_H}\left(\bar{C}_F u_t + \bar{P}_O^* \bar{O}(o_t - \tilde{o}_t)\right), \\ & \mathbb{E}_t \Delta u_{t+1} = \bar{\omega} \text{var}_t(\Delta e_{t+1})(n_t^* + f_t^* - b_t^*), \end{aligned}$$

where $\bar{Y}_H = \bar{C}_H + \bar{C}_H^*$, $\chi = \gamma + (1-\alpha)\alpha(1-\gamma)\frac{\bar{Y}_H}{\bar{C}_H}$, $e_t = \log \varepsilon_t$, $\tilde{q}_t = \log \tilde{Q}_t$, $\tilde{o}_t = \log \tilde{O}_t$, $o_t = \log O_t$, $b_t^* = \frac{B_t^* - \tilde{B}_t^*}{\bar{Y}_H}$, $n_t^* = \frac{N_t^* - \tilde{B}_t^*}{\bar{Y}_H}$, $f_t^* = \frac{F_t^*}{\bar{Y}_H}$, and $\bar{\omega} = \frac{\omega}{\beta}\bar{Y}_H$.

As this optimization problem suggests, the cost of deviating from the first-best allocation depends on two wedges: one in the consumption of home goods and the other in the consumption of foreign goods. The weight assigned to foreign good consumption wedge χ depends on the openness of the economy, the share of oil in production, and the share of export goods in output.[16]

[15] See Appendix A for further details.

[16] The share of export goods matters because it increases aggregate demand in this model. Consequently, firms will use more inputs to meet this demand. As a result, deviations from the first-best allocation of resources become more costly for households, given decreasing return of labor in production function.

What is the optimal policy, and can the government achieve the first-best outcome? The following proposition addresses this question.

Proposition 1. *Optimal policy eliminates the wedge in consumption of home goods v_t and foreign goods u_t. Monetary policy targets v_t and FXI closes the UIP gap by setting $f_t^* = -n_t^*$. The nominal exchange rate e_t adjusts one to one with the movement in natural equilibrium exchange rate $\tilde{q}_t$.*

Proof. Appendix B.1. □

When both the u_t and v_t gaps are closed, oil consumption also follows the first-best path. It is important to note that productivity shocks will influence the amount of oil required for production, thereby affecting the first-best path of NFA. This can exacerbate the UIP gap due to market segmentation and arbitrageurs' risk aversion. However, optimal FXI can effectively eliminate these inefficiencies. In this framework, even in the absence of noise trader shocks, the government must still respond to changes in the NFA that arise from oil price shocks.

Intuitively, the logic of the optimal policy assignment is as follows: (i) Monetary policy is the ideal tool to manage the domestic wedge. By controlling the domestic interest rate, the central bank directly influences the intertemporal trade-off for households, allowing it to stabilize domestic consumption and close the gap caused by sticky prices. (ii) FXI is the ideal tool to manage the external wedge. The external wedge is driven by the UIP risk premium, which arises because risk-averse arbitrageurs must be compensated for holding the country's net foreign assets. By using FXI, the government can adjust its own foreign asset holdings to perfectly offset the NFA pressures coming from households, firms, and noise traders. This neutralizes the position that arbitrageurs must hold, eliminating the risk premium and closing the external wedge. This clear division of labor, formalized in the proposition above, allows both wedges to be closed completely, achieving the first-best allocation.

5 Some Applications

In this section, we analytically explore the implications of several alternative policies and economic structures before quantifying their welfare costs. Specifically, we examine the effects of fixed exchange rate regimes and energy subsidies. We also analyze the model's sensitivity to key parameters, including trade openness and the share of oil in production.

5.1 Peg Regimes

Under a fixed exchange rate regime, the well-known trilemma constraint becomes binding: the central bank loses its ability to independently set interest rates and stabilize domestic consumption wedges. This limitation arises because fixing the exchange rate eliminates currency risk for arbitrageurs, making the supply of foreign exchange perfectly elastic and effectively ensuring perfect capital mobility. Consequently, arbitrage forces the domestic interest rate to converge with the global rate, rendering the central bank's open market operations ineffective. What, then, is the economic cost of maintaining a fixed exchange rate? The following proposition explores this question in greater detail.

Proposition 2. *The welfare loss from the peg is decreasing in the economy's openness (γ) and increasing in the share of oil in the production function ($1-\alpha$), and the volatility of oil price and productivity level.*

Proof. Appendix B.2 □

When the exchange rate is fixed, the UIP risk wedge is eliminated and the wedge in the consumption of foreign goods will disappear. However, monetary policy is no longer free to close the domestic consumption wedge, which is now forced to move one-to-one with the natural real exchange rate:

$$v_t = -\tilde{q}_t.$$

What causes the natural real exchange rate to fluctuate? The natural real exchange rate fluctuates in response to real fundamentals, such as productivity, oil prices, and world interest rates. More formally, its log-linear approximation is:

$$\tilde{q}_t = a_t - (1-\alpha)p^*_{Ot} + \alpha \sum_{i=0}^{\infty} \mathbb{E}_t r^*_{t+i}. \tag{17}$$

The welfare cost of a currency peg arises from its inability to accommodate shifts in the natural real exchange rate (q_t). The natural real exchange rate is the relative price of domestic to foreign goods that would prevail in a frictionless economy, ensuring an efficient allocation of resources. Real shocks—such as changes in domestic productivity (a_t) or fluctuations in world oil prices (p^*_{Ot})—affect the country's terms of trade and productive capacity, causing the natural real exchange rate to move. To preserve efficiency, these movements require corresponding adjustments in households' consumption behavior. Under an optimally managed float, the nominal exchange rate (e_t) adjusts so that the actual real exchange rate tracks this moving benchmark, allowing the economy to adapt smoothly. Under a peg, however, the nominal exchange rate is fixed. With sticky domestic prices (P_H), the actual real exchange rate also becomes rigid and cannot adjust to underlying shocks, leading to welfare-reducing inefficiencies.

The proposition's comparative statics follow directly from this mechanism, reflecting the relative weights of home and foreign goods in households' consumption baskets. In our framework, the distortion created by a rigid real exchange rate manifests as an output gap in the domestic goods sector. A higher γ—indicating greater trade openness—reduces the size of this sector relative to the overall economy. As a result, the inefficiency confined to this sector carries less weight in aggregate welfare, lowering the total cost of the peg.

Also, the cost of a peg is higher in economies with a greater dependence on oil in production (higher $1 - \alpha$). The share of oil in production determines how sensitive the country's marginal costs and, consequently, its natural real exchange rate are to oil price shocks. As the expression for q_t shows a larger oil share means that a given oil price shock causes a larger fluctuation in the natural rate. Since the welfare cost is proportional to the variance of q_t, a higher oil share directly amplifies the volatility that the peg is unable to accommodate, leading to larger output gaps and a greater welfare loss. In essence, a greater reliance on oil as a production input makes the economy's efficient equilibrium more volatile, which makes the rigidity of a peg more damaging.

5.2 Price Fixing as Energy Subsidy

While access to monetary policy and FXI as policy tools is adequate for achieving first-best allocation, the effectiveness of other tools may be in question. For example, governments sometimes resort to fixing energy prices to address price increases stemming from energy price hikes.[17] The key question, however, is whether such measures reduce inefficiencies or instead exacerbate them, particularly under a pegged exchange rate regime.

Let us assume that the government fixes the price of oil by applying a varying tax (or subsidy) τ_t, such that

[17] Erceg et al. (2024) show while subsidies can dampen headline inflation on impact, they raise the effective energy cost faced by firms, increasing price-setting persistence. In our model, we abstract from household energy consumption, so the subsidy directly reduces firms' input costs.

$$\bar{P}_O = (1-\tau_t)\varepsilon_t P^*_{Ot}.$$

This policy intervention, by design, severs the pass-through of global energy price and exchange rate fluctuations to the domestic economy. The state-contingent subsidy, τ_t, insulates domestic firms from terms-of-trade shocks by ensuring the domestic price of oil, $\bar{P}_O$, remains constant. However, in doing so, the policy obstructs the transmission of a critical price signal. The oil price, P_{Ot}, reflects the true opportunity cost of the resource to the economy. By neutralizing this signal, the government prevents firms from undertaking efficient adjustments in their production decisions in response to changes in global scarcity. The primary economic distortion arises from the divergence between the private marginal cost of the input, as perceived by firms, and its social marginal cost, as determined by the world price and the exchange rate. Firms optimize their factor mix based on the fixed domestic price, leading to a misallocation of resources. For example, when the world price P^*_{Ot} is high, the subsidy encourages an inefficiently high intensity of oil use relative to other factors of production, such as labor.

Comparing the equilibrium conditions with the first-best allocations reveals that fixing the price of oil introduces an additional wedge. In this case, the wedge in labor-to-oil ratio depends on the output gap v_t, the natural real exchange rate $\tilde{q}_t$ and, the global oil price p^*_{ot}:

$$l_{ot} - \tilde{l}_{ot} = -p^*_{ot} - \tilde{q}_t - v_t.$$ [18]

Consequently, the loss function can be expressed as:

$$\frac{1}{2}\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ (1-\gamma)v_t^2 + \gamma u_t^2 + (1-\alpha)\alpha(1-\gamma)\frac{\bar{Y}_H}{\bar{C}_H}\left(p^*_{ot} + \tilde{q}_t + v_t\right)^2 \right\}.$$

The first two terms capture the standard stabilization trade-offs faced by policymakers between domestic and external objectives. The third term reflects the additional welfare cost arising from having energy subsidies in an environment with oil price volatility. It highlights that fluctuations in international oil prices (p^*_{ot}), together with movements in the real exchange rate ($\tilde{q}_t$) and domestic distortions (v_t), generate another source of welfare loss. This term can be interpreted as the cost of imperfect transmission of global energy price shocks to domestic relative prices. Even if policy succeeds in eliminating consumption wedges between home and foreign goods—i.e., even if the first two terms

[18] Given that the household receives a lump sum transfer due to this tax, the home budget constraint will still be the same. Introducing distortionary taxation to finance fuel subsidies could materially affect the welfare analysis presented in this paper.

are minimized—the distortion created by administered domestic energy prices remains. As a result, the economy cannot reach the first-best allocation.

An important implication of this setup is that, under certain conditions, a fixed exchange rate regime combined with energy price subsidies may yield smaller overall welfare losses than a floating regime with the same subsidies. Under a peg, the real exchange rate and domestic price deviations move one-for-one ($v_t = -\tilde{q}_t$), implying that the third term in the loss function depends only on the volatility of the international oil price. In contrast, under a floating regime, the exchange rate fluctuations amplifies the welfare cost of oil price shocks. Moreover, fixing domestic energy prices can reduce inflation volatility—another source of welfare loss—which can make the combination of a peg and energy subsidy more desirable than a peg alone. This mechanism is explored more formally in the extended version of the model, where final-good prices are sticky but not fixed as in this simple setup.

6 Extended Model and Quantitative Results

Now, we aim to relax some of our assumptions, particularly the assumption of full price rigidity, which removes inflation as a policy concern. Since oil price shocks directly impact inflation rates, it becomes crucial to address this issue by allowing for price movements. Additionally, we will assume that export prices are determined by the exporter and that the price of imported goods is subject to fluctuations. The structure of households and the financial sector will remain identical to the baseline model, ensuring that our focus stays on the new dynamics introduced by relaxing full price rigidity.

6.1 Model Setup

Intermediate Good Producers: There is a representative intermediate good producer who hires labor and buys energy to produce goods and sell them at the competitive price of P_{IT} to home and export retailers.

$$\max_{L_t, O_t, Y_t} P_{It} Y_t - W_t L_t - P_{Ot} O_t$$

subject to

$$Y_t = A_t L_t^{\alpha} O_t^{1-\alpha}.$$

FOC results:

$$W_t = \alpha P_{It} A_t (\frac{L_t}{O_t})^{\alpha-1},$$

$$P_{Ot} = (1-\alpha) P_{It} A_t (\frac{L_t}{O_t})^{\alpha}.$$

The total output Y_t will be used by home retailers and the exporters: $Y_t = Y_{HT} + Y^*_{HT}$.

Home Retailers: There is a continuum of retailers indexed by i who buy intermediate goods and sell them to final good producers in a monopolistic competitive market by setting price P_{iHT} . The retailers are allowed to set the price in each period with probability $1-\theta$, and the demand for their product is given by $C_{iHT} = (\frac{P_{iHt}}{P_{Ht}})^{-\epsilon_H} C_{Ht}$. Retailers' optimization problem is

$$\max_{P_{iHT}} \mathbb{E}_t \sum_{k=0}^{\infty} (\beta\theta)^k \Lambda_{t+k} \left(\frac{P_{iHt}}{P_{Ht+k}} - \eta \frac{P_{It+k}}{P_{Ht+k}} \right) (\frac{P_{iHt}}{P_{Ht+k}})^{-\epsilon_H} C_{Ht+k},$$

where $\Lambda_{t+k} = \frac{C_{Ht}}{C_{Ht+k}}$ and η is a subsidy to eliminate the inefficiency of monopolistic competition. The FOC results:

$$P^{\#}_{Ht} = \eta \frac{\epsilon_H}{\epsilon_H - 1} \frac{X_{1t}}{X_{2t}},$$

where

$$X_{1t} = \mathbb{E}_t \sum_{k=0}^{\infty} (\beta\theta)^k P_{It+k} P^{\epsilon_H - 1}_{Ht+k},$$

and

$$X_{2t} = \mathbb{E}_t \sum_{k=0}^{\infty} (\beta\theta)^k P^{\epsilon_H - 1}_{Ht+k}.$$

The profit of retail sector at time t is

$$\Pi^R_t = \int_0^1 (P_{iHt} - \eta P_{It}) C_{iHt} di.$$

Home Final Good Producers: They purchase intermediate goods, aggregate them using a CES function, and sell them to households at the competitive price P_{Ht} by optimizing the following problem:

$$\max_{C_{Ht}, C_{iHt}} P_{Ht} C_{Ht} - \int_0^1 P_{iHt} C_{iHt} \, di,$$

subject to

$$C_{Ht} = \left(\int_0^1 C_{iHt}^{\frac{\epsilon_H - 1}{\epsilon_H}} di \right)^{\frac{\epsilon_H}{\epsilon_H - 1}}.$$

The first-order condition yields the demand function for each intermediate good producer. Substituting this into the constraint results in:

$$P_{Ht}^{1-\epsilon_H} = (1-\theta) P_{Ht}^{\#\,1-\epsilon_H} + \theta P_{Ht-1}^{1-\epsilon_H}.$$

By performing some algebra, we can derive the New Keynesian Phillips Curve (NKPC):

$$\pi_t = \frac{(1-\theta)(1-\beta\theta)}{\theta} (p_{It} - p_{Ht}) + \beta \mathbb{E}_t \pi_{t+1}, \tag{18}$$

where $\pi_t = \log(P_{Ht}/P_{Ht-1})$, $p_{It} = \log(P_{It}/\bar{P}_I)$, and $p_{Ht} = \log(P_{Ht}/\bar{P}_H)$.

Exporters: We assume that the demand for exports is given by $C_{Ht}^* = P_{Ht}^{*\;-\epsilon_X} C_t^*$. We consider the case that exporters are able to set their demand by setting prices in the currency of destination P_{Ht}^*.[19] Exporter's optimization problem is:

$$\max_{P_{Ht}^*} \left(\varepsilon_t P_{Ht}^* - P_{It} \right) P_{Ht}^{*\;-\epsilon_X} C_t^*,$$

where the optimality condition results $P_{Ht}^* = \frac{\epsilon_X}{\epsilon_X - 1} \frac{P_{It}}{\varepsilon_t}$.

Home Budget Constraint: The home country budget constraint is similar to the baseline model, with some modifications to the transfers to the household.

$$P_{Ht} C_{Ht} + P_{Ft} C_{Ft} + \frac{B_t}{R_t} = B_{t-1} + W_t L_t + \Pi_t^T + T_t + P_{Ot} O_{wt}.$$

The sum of profits of all non-financial firms is[20]

$$\Pi_t^T = \varepsilon_t P_{Ht}^{*\;1-\epsilon_X} C_t^* + P_{Ht} C_{Ht} - W_t L_t - P_{Ot} O_t.$$

Home budget constraint then becomes

$$\frac{B_t^*}{R_t^*} - B_{t-1}^* = P_{Ht}^{*\;1-\epsilon_X} C_t^* - P_{Ft}^* C_{Ft} + P_{Ot}^* (O_{wt} - O_t).$$

[19] In the current setting, export prices are flexible and adjust in response to input costs and exchange rate fluctuations. Alternatively, we could assume that exporters use the output of final-good producers as their input. In that case, the framework would correspond to a standard producer currency pricing (PCP) setup. This modification would not alter the outcome of the first-best policy. However, if export prices instead follow dominant currency pricing (DCP), then P_{Ht}^* would be fixed, introducing an additional wedge and rendering the first-best allocation unattainable.

[20] It also includes the tax required to finance the subsidy to make the monopolistic competition efficient.

6.2 Policy Problem

Government's problem is a Ramsey problem of choosing a sequence of government policies F_t, F_t^*, R_t that maximize household's welfare under commitment.

$$\max_{R_t, F_t^*, C_{Ht}, C_{Ft}, B_t^*, P_{Ht}^*, \varepsilon_t, \sigma_t^2, O_t, L_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[(1-\gamma) \log C_{Ht} + \gamma \log C_{Ft} - L_t) \right],$$

subject to

$$A_t L_t^{\alpha} O_t^{1-\alpha} = {P_{Ht}^*}^{-\epsilon_X} C_t^* + \Phi_t C_{Ht},$$

and the optimality conditions of households, financiers, and firms in the economy. Φ_t is a measure of price dispersion in the economy given by

$$\Phi_t = \int_0^1 (\frac{P_{iHt}}{P_{Ht}})^{-\epsilon_H} di = (1-\theta)(\frac{P_{Ht}^{\#}}{P_{Ht}})^{-\epsilon_H} + \theta \Phi_{t-1}.$$

Following the steps explained in Appendix D, we can derive the approximate Ramsey problem in terms of deviation from the first-best allocation as follows:

$$\min \frac{1}{2} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ (1-\gamma)(v_t^2 + \chi_1 \pi_t^2) + \chi_2 u_t^2 \right\} \tag{19}$$

$$\begin{aligned} s.t. \quad & \Delta e_t = \Delta \tilde{q}_t + \Delta v_t - \Delta u_t + \pi_t - \Delta p_{Ft}^*, \\ & \mathbb{E}_t(\Delta u_{t+1}) = \bar{\omega} \text{var}_t(\Delta e_{t+1})(n_t^* + f_t^* - b_t^*), \\ & \frac{\bar{C}_H}{\bar{Y}} v_t = \alpha(\epsilon_x \frac{\bar{C}_H^*}{\bar{Y}} - 1) u_t + o_t - \tilde{o}_t, \\ & \beta b_t^* - b_{t-1}^* = \frac{-1}{\bar{Y}} \left((\bar{C}_H^* (\epsilon_X - 1) \alpha + \bar{C}_F) \, u_t + \bar{P}_O^* \bar{O} \, (o_t - \tilde{o}_t) \right), \\ & \pi_t = \frac{(1-\theta)(1-\beta\theta)}{\theta} \left(v_t - (1-\alpha) u_t \right)) + \beta \mathbb{E}_t \pi_{t+1}, \end{aligned}$$

where $\chi_1 = \frac{\theta}{(1-\beta\theta)(1-\theta)} \epsilon_H(\epsilon_H + 1)$, $\chi_2 = \gamma + (1-\gamma)(1-\alpha)\alpha \frac{\bar{Y}}{\bar{C}_H} + (1-\gamma)\alpha^2 \epsilon_X \frac{\bar{C}_H^*}{\bar{C}_H}$.

When comparing the loss function of the extended model to that of the baseline model, several key differences emerge. Most notably, inflation now appears in the objective function. The weight assigned to inflation in the loss function depends on two primary factors: the degree of openness of the economy, γ, and χ_1, where χ_1 incorporates θ, the measure of price stickiness. In this extended model, inflation reflects the discounted sum of current and future real marginal costs of production. These marginal costs are influenced by two

Table 1: Calibration of Model Parameters

Parameter	Value	Description
A. Preferences and Trade Structure		
β	0.99	Discount factor
γ	0.3	Trade openness (share of imports)
ω	345	Arbitrageur risk aversion (financial friction)
$\bar{C}^*$	0.5	Foreign demand
$\bar{O}_w$	0.5	Oil endowment
B. Technology and Pricing		
$1-\alpha$	0.17	Share of oil in production
ϵ_H	6	Elasticity of substitution (domestic goods)
ϵ_X	1.5	Elasticity of export demand
θ	0.75	Calvo price stickiness parameter
C. Policy Rules and Shocks		
γ_π	2.0	Taylor rule response to inflation
ρ_r	0.9	Taylor rule interest rate smoothing
$\rho_a, \rho_{p_o}, \rho_n$	0.9	Shock persistence (productivity, oil price, noise trader)
σ_a	0.0063	Std. dev. of productivity shock
σ_{p_o}	0.158	Std. dev. of oil price shock
σ_n	0.100	Std. dev. of noise trader shock

key variables: wages, which are closely linked to the wedge in home goods consumption, and energy prices, which are associated with the wedge in foreign goods consumption.

It is straightforward to verify that the optimal policy can achieve the first-best outcome by closing the u_t and v_t gaps through a combination of monetary policy and FXI. Therefore, the model's implications remain unchanged even when the full price rigidity assumption is relaxed.

6.3 Calibration

The model is calibrated at a quarterly frequency to reflect the key structural features of GCC economies.[21] The parameters are summarized in Table 1.

We set the discount factor to $\beta = 0.99$, a standard value in the literature that implies an annual real interest rate of approximately 4 percent. The trade openness parameter is calibrated to $\gamma = 0.3$, corresponding to the share of imported consumption goods in total consumption expenditure, using data from the World Integrated Trade Solution (WITS) database. The share of oil in production, $1-\alpha$, is set to 0.17, based on the average ratio of energy expenditure to non-oil GDP for GCC economies. This measure is computed using

[21] We use simple averages across GCC member countries based on the most recent data available from the respective sources.

data on GDP per unit of energy use from the World Development Indicators (WDI).[22] The steady-state foreign aggregate demand and oil endowment parameters, $\bar{C}^* = 0.5$ and $\bar{O}_w = 0.5$, are calibrated jointly to match two key ratios in the data: an oil export share in total exports of 0.6 (GCCSTAT) and a non-oil GDP share in total GDP of 0.7 (Haver Analytics).

The parameter governing financial frictions, ω, is set to 345. This value ensures that $\omega \text{Var}_t(\Delta \ln e_{t+1})\bar{Y} = 0.06$, consistent with the market shallowness parameter Γ for emerging market economies in Adrian et al. (2021). The elasticity of substitution between domestic goods, ϵ_H, is set to 6, following standard values in the literature. The elasticity of export demand, ϵ_X, is set to 1.5, in line with Itskhoki and Mukhin (2021a).

Nominal rigidities are captured by the Calvo parameter, $\theta = 0.75$, implying an average price duration of four quarters. The parameters of the monetary policy rule follow standard Taylor-type specifications. The response to inflation, γ_π, is set to 2, and the interest rate smoothing coefficient, ρ_r, is set to 0.9. The persistence parameters for productivity, oil price, and noise trader shocks, ρ_a, ρ_{p_o} and ρ_n, are all set to 0.9. The standard deviation of the productivity shock, $\sigma_a = 0.0063$, is based on the average standard deviation of TFP growth across GCC economies reported in Bannaga and Lezar (2024), assuming TFP follows a trend-stationary AR(1) process. The standard deviation of oil price shocks, $\sigma_{p_o} = 0.158$, is obtained by fitting an AR(1) process to the quarterly real oil prices and using the standard deviation of the residuals. Lastly, the noise-trader shock, $\sigma_n = 0.10$, represents an exogenous demand shock for foreign currency equivalent to 10 percent of quarterly GDP. Although the magnitude of such shocks is difficult to identify empirically for GCC economies, this calibration can be interpreted as an upper bound. Even under this large value, the results indicate that noise-trader shocks have negligible welfare implications, consistent with the exchange-rate disconnect emphasized in the literature.

6.4 Quantitative Results and Welfare Costs

We begin the quantitative analysis by considering a benchmark case in which the economy is subject to both productivity (A_t) and oil price shocks (O_t). This setup captures the main real sources of macroeconomic fluctuations and allows us to evaluate the welfare implications of alternative policy regimes under fundamental shocks. We then introduce

[22]While this proxy is imperfect, the calibrated value is higher than estimates for advanced economies (typically around 8-10 percent), consistent with the view that energy plays a more prominent role in production in energy-exporting economies, particularly given relatively lower energy prices.

currency demand shocks (N_t) to assess the quantitative importance of financial noise, specifically, whether noise-trader shocks materially amplify welfare losses or alter the relative ranking of policy regimes. The optimal policy serves as the benchmark, and deviations from it are expressed in consumption-equivalent terms. The welfare losses in the economy can be traced to several key distortions ("wedges") that emerge from nominal and real rigidities. The first source of inefficiency arises from price stickiness in domestic goods markets, which generates welfare losses through fluctuations in domestic inflation and output. Additional wedges emerge in the input mix, in foreign goods consumption, and in export pricing—each stemming from financial frictions and the absence of efficient international risk sharing. When there are no energy subsidies or when export prices are not subject to dominant currency pricing (DCP), these three external wedges move proportionally with the wedge in foreign goods consumption. Hence, closing that wedge effectively eliminates the others.

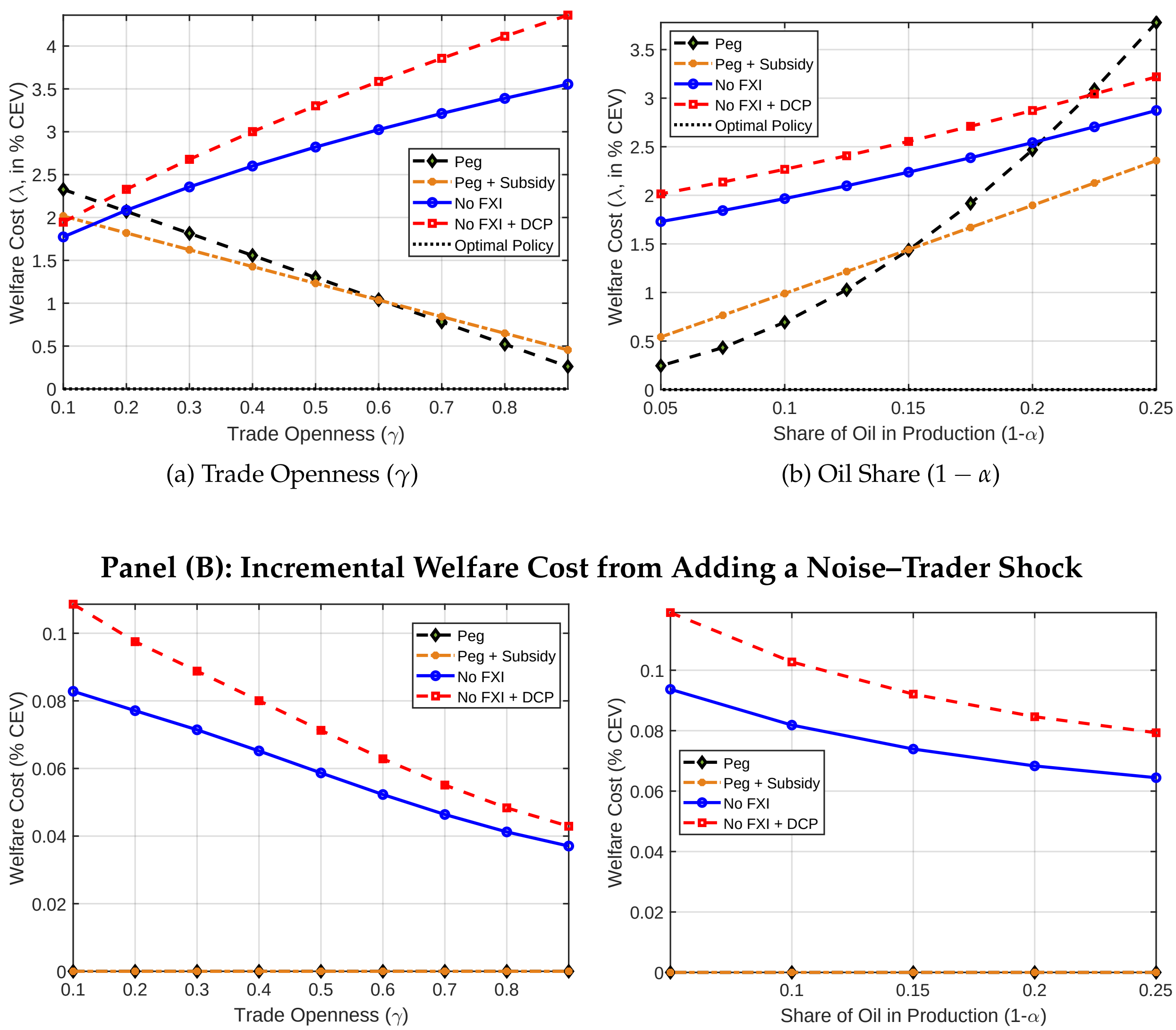
To interpret Figure 1, it is useful to recall that the per-period welfare loss from deviations relative to the first-best allocation is given by

$$L_t = (1-\gamma)\big(v_t^2 + \chi_1 \pi_t^2\big) + \chi_2\, u_t^2,$$

where v_t represents the sticky-price (output-gap) wedge, u_t captures the UIP or financial wedge. The weight on UIP wedge, χ_2, increases with trade openness, γ. Mechanically, a higher γ reduces the relative weight on domestic distortions—output misallocation and inflation, while increasing the weight on external distortions, represented by the u_t block. Intuitively, as the economy becomes more open, it relies more heavily on foreign goods and international risk sharing. Consequently, domestic misallocation becomes less central to welfare, whereas external financing frictions and risk-sharing failures become more important.

We consider four policy regimes: (i) a no FXI regime, where the exchange rate freely floats and the central bank follows a Taylor rule that responds to inflation; (ii) a no FXI + DCP regime, which is identical except that export prices are invoiced in a dominant currency and thus do not adjust to exchange rate changes; (iii) a peg regime, where the exchange rate is fixed; and (iv) a peg + subsidy regime, where the government both pegs the exchange rate and fixes the domestic fuel price. From a policy perspective, the interest rate rule primarily stabilizes v_t and π_t, while FXI directly addresses u_t.

Panel (A) of Figure 1 compares welfare losses across policy regimes when the economy



Panel (A): Welfare Costs with Productivity and Oil Price Shocks

(a) Trade Openness (γ) (b) Oil Share ($1-\alpha$)

Panel (B): Incremental Welfare Cost from Adding a Noise–Trader Shock

(c) Trade Openness (γ) (d) Oil Share ($1-\alpha$)

Figure 1: Welfare Costs under Various Policies

Note: Each panel reports welfare costs across four policy regimes, measured as the percentage consumption-equivalent loss relative to the first-best allocation. Panel (A) considers an economy with productivity and oil price shocks only. The left subfigure varies the import share γ; the right varies the oil share $1-\alpha$. The benchmark calibration sets $\gamma = 0.3$ and $1-\alpha = 0.17$. Panel (B) plots the *incremental* welfare loss when a noise–trader shock is added to the baseline in Panel (A). We report the two float regimes—*No FXI* (blue) and *No FXI + DCP* (red). Under a peg, the UIP wedge u_t is effectively closed, so the noise–trader shock generates near zero incremental welfare loss.

is hit by both productivity and oil price shocks.[23] Oil shocks affect both key margins: they raise marginal costs of production and induce large trade-balance and exchange rate volatility. As a result, welfare losses are economically significant—ranging from about 1 to 4 percent. An oil-price shock constitutes a first-order terms-of-trade and wealth shock. For an oil exporter, periods of rising and falling oil prices lead to sharp swings in the net foreign asset position. In the absence of FXI, risk-averse arbitrageurs must absorb these fluctuations in currency exposure, giving rise to a time-varying UIP wedge.

The left subplot illustrates how welfare losses vary with the degree of trade openness, γ. As the economy becomes more open, the welfare weight on the foreign goods wedge increases relative to domestic distortions. Consequently, peg regimes tend to outperform free-floating regimes at higher levels of openness, since fixing the exchange rate eliminates the financial wedge and thereby reduces overall welfare losses.[24] In contrast, under a no FXI regime, welfare losses rise with openness. Although a higher γ lowers the share of oil exports in the trade balance, reducing the relevance of oil price shocks and stabilizing the wedge u_t, this effect is outweighed by the higher welfare weight attached to that wedge, making the overall welfare cost increase with openness. The ”no FXI + DCP” regime uniformly underperforms the baseline ”no FXI” regime because preset dollar prices erode the natural hedge provided by non-oil exports, thereby amplifying fluctuations in the UIP wedge, u_t.[25] Furthermore, the inability of exporters to adjust their pricing in response to changes in production costs introduces an additional misalignment between marginal costs and revenues, constituting a further source of welfare loss.

At low levels of openness, however, the no-FXI regime delivers higher welfare. Exchange rate flexibility allows partial adjustment through expenditure switching and relative price movements, thereby mitigating the impact of shocks on domestic inflation. For an oil exporter, a floating regime enables the currency to appreciate in response to higher global energy prices, effectively offsetting part of the shock. This appreciation allows

[23] With only productivity shocks, welfare costs remain small—below 0.10 percent of permanent consumption—consistent with Lucas (1987), who showed that the welfare costs of standard productivity fluctuations are modest.

[24] Under a peg, oil price shocks translate one-for-one into domestic marginal costs because the exchange rate is fixed and $u_t = 0$:

$$\pi_t \;=\; \kappa v_t + \beta\, E_t \pi_{t+1}.$$

The resulting welfare loss is thus driven primarily by domestic wedges, not financial ones.

[25] Our analysis does not model export diversification or the detailed sectoral composition of non-oil exports. Our contribution is about macroeconomic stabilization—closing domestic and external wedges—rather than export promotion or diversification policy. Here, when non-oil exports are invoiced in USD, a float without FXI can perform worse: import costs rise while export revenues are sticky in USD, limiting expenditure-switching benefits.

firms to substitute cheaper energy inputs for more expensive labor when needed, cooling domestic activity and helping to stabilize inflation.

A peg with an energy-price subsidy (Peg + Subsidy) also neutralizes u_t while further reducing inflation volatility by dampening the pass-through of oil shocks into marginal costs and therefore price dispersion. Consequently, this regime delivers the lowest welfare loss among peg-type policies for the baseline calibration, though it remains inferior to the integrated optimum that jointly targets both wedges through interest rate policy and FXI.

On the right subplot (varying $1-\alpha$), all curves slope upward because a higher oil share amplifies the transmission of oil price shocks to marginal costs. Since the oil input enters marginal costs with weight $(1-\alpha)$, a larger oil share implies stronger movements in marginal costs when oil prices fluctuate. Under Calvo pricing, these fluctuations translate into greater volatility in the output-gap and inflation through the NKPC, thereby increasing welfare losses associated with price dispersion. Higher oil intensity also makes the natural exchange rate more responsive to shocks, requiring adjustment through inflation, the nominal exchange rate, or wedges in goods consumption. The peg deteriorates most sharply as it rules out any adjustment through nominal exchange rate and transmits oil shocks directly into domestic marginal costs, amplifying v_t and inflation. By contrast, the Peg+Subsidy regime deteriorates more gradually, as it cushions this pass-through.

As shown in Panel (B) of Figure 1, introducing a noise–trader shock increases welfare losses only modestly under the floating regimes. The mechanism operates primarily through the financial wedge: a noise–trader disturbance raises exchange-rate volatility, which in turn increases the perceived risk faced by arbitrageurs. Risk-averse intermediaries demand a higher premium for bearing this volatility, thereby amplifying u_t. However, the wedge in foreign-goods consumption depends not only on the volatility of the exchange rate but also on the size of the underlying currency position, which reflects both the noise-trader shock N_t and the endogenous NFA position.[26] For instance, a surge in local currency demand appreciates the exchange rate and stimulates imports, partially offsetting the position that arbitrageurs must absorb. This offset is smaller in relatively closed economies, where imports constitute a limited share of expenditure; consequently, welfare losses from noise-trader shocks are larger when openness is low. Likewise, when labor has a higher share in production, an appreciation reduces demand for domestic

[26] Oil price shocks are one driver of external financial imbalances. Other determinants (e.g., market depth/liquidity, capital-flow composition, institutional features, and currency mismatch) can also move risk premia. We isolate the oil–NFA–FXI channel rather than claim exclusivity.

goods, lowers production costs, and boosts exports. This greater export response raises arbitrageurs' currency exposure, amplifying the effect of noise–trader shocks and the associated welfare loss.

Overall, this exercise solidifies our paper's central contribution. While the literature has correctly identified exogenous financial shocks as a key motive for FXI, our findings demonstrate that for commodity-exporting economies, the endogenous financial pressures generated by real oil shocks are a quantitatively dominant and previously underappreciated rationale for active exchange rate management.

7 Conclusion

In this paper, we extend the standard open-economy framework by incorporating oil to show that commodity-price shocks can be a fundamental, endogenous source of the financial frictions that may justify FXI. We demonstrate theoretically that monetary authorities can achieve a first-best outcome by using interest-rate policy to close the domestic output gap and using FXI to neutralize the uncovered interest parity (UIP) wedge. Our findings thus establish a clear rationale for active exchange rate management in response to real-sector shocks—even in the absence of purely exogenous financial noise.[27]

Nonetheless, the optimal, fully integrated policy we describe may not always be feasible in practice: central banks often face constraints on reserves, governance, or communication, which can limit their ability to implement the first-best. Our quantitative calibration for a representative oil-exporting economy reveals important trade-offs under simpler, suboptimal regimes. A free-floating regime without FXI suffers welfare losses due to volatile risk premia driven by oil price swings, while a hard peg eliminates those premia but suppresses real exchange rate adjustment, shifting volatility into inflation and the output gap. We find that combining a peg with an energy subsidy can, in some cases, outperform a pure float: by smoothing domestic marginal costs in response to oil price shocks, this hybrid policy reduces volatility in inflation and output.

At the same time, our analysis is not intended to provide a comprehensive welfare ranking of exchange rate regimes. In particular, important considerations emphasized in policy discussions—such as the credibility and anchoring role of long-standing fixed exchange rate regimes, their effects on risk premia, capital costs, and financial stability, as

[27] Needless to say that the analytical results are driven by the underlying model assumptions and should be interpreted within that context.

well as the transitional and reputational costs of regime changes—are not explicitly modeled in our framework. As a result, our welfare comparisons abstract from these channels and should not be interpreted as prescriptive guidance to abandon credible exchange rate pegs. Rather, the paper's objective is narrower: to isolate specific transmission mechanisms through which oil price shocks, via net foreign asset dynamics and segmented foreign exchange markets, can generate a policy motive for FXI within a stylized general equilibrium setting.

Consistent with the IMF's 2023 IPF guidance (IMF 2023), our conclusions regarding the use of FXI should be interpreted with appropriate nuance. In the IPF, FXI is recommended only when specific financial frictions—such as shallow foreign-exchange markets or elevated risk premia—materially impair market functioning. Moreover, the use of FXI should be contingent on clear evidence that such risks have intensified and must be supported by adequate reserves, strong institutional and governance frameworks, and transparent communication to ensure policy credibility. In addition, there is a trade-off: using FXI regularly or without caution can undermine market liquidity, constrain reserve capacity for future shocks, and weaken the signaling power of monetary policy. Therefore, while our theoretical and quantitative results highlight the stabilizing role FXI can play in the face of commodity shocks, it is best deployed as a selective, contingent tool, embedded within a broader policy framework that also relies on interest rate policy, sound fiscal measures, and strong institutional capacity.

A Derivation of the Approximate Ramsey Problem

A.1 Quadratic Approximation of the Loss Function

Let us define the labor-to-oil ratio as $L_{Ot} \equiv \frac{L_t}{O_t}$. The Lagrangian for the problem can be expressed as follows:

$$\begin{aligned}\mathcal{L}(x, \lambda, \epsilon) = \sum_{t=0}^{\infty} \beta^t \Bigg\{ & (1-\gamma) \log C_{Ht} + \gamma \log C_{Ft} - L_{Ot} O_t \\ & + \mu_t \left(C^*_{Ht} - C_{Ft} + P^*_{Ot}(O_{wt} - O_t) - \frac{B^*_t}{R^*_t} + B^*_{t-1} \right) \\ & + \psi_t \left(A_t L^{\alpha}_{Ot} O_t - C_{Ht} - C^*_{Ht} \right) \Bigg\},\end{aligned}$$

where

$$x = \{C_{Ht}, C_{Ft}, L_{Ot}, O_t, B^*_t\}_{t=0}^{\infty},$$

$$\lambda = \{\mu_t, \psi_t\}_{t=0}^{\infty},$$

and

$$\epsilon = \left\{ \log\left(\frac{C^*_{Ht}}{\bar{C}^*_H}\right), \log\left(\frac{P^*_{Ot}}{\bar{P}^*_O}\right), \log\left(\frac{O_{wt}}{\bar{O}_{wt}}\right), \log\left(\frac{R^*_t}{\bar{R}^*}\right) \right\}_{t=0}^{\infty}.$$

Using Lemma A.2 from Itskhoki and Mukhin (2023), we can derive the second-order approximation of the loss function around $(\bar{x}, \bar{\lambda}, 0)$ as follows:

$$\tilde{\mathcal{L}} - \mathcal{L} = -\frac{1}{2} dx \nabla^2 \mathcal{L}(\bar{x}, \bar{\lambda}, 0) dx',$$

where $dx \equiv (x - \tilde{x})$.

Taking derivatives and performing some algebra leads us to the following expression for the loss function:

$$\begin{aligned}\tilde{\mathcal{L}} - \mathcal{L} = \frac{1}{2} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Bigg\{ & (1-\gamma) \left(\frac{C_{Ht} - \tilde{C}_{Ht}}{\bar{C}_H}\right)^2 + \gamma \left(\frac{C_{Ft} - \tilde{C}_{Ft}}{\bar{C}_F}\right)^2 \\ & + (1-\alpha)\alpha \bar{\psi} \bar{L}^{\alpha}_O \bar{O} \left(\frac{L_{Ot} - \tilde{L}_{Ot}}{\bar{L}_O}\right)^2 \Bigg\}.\end{aligned}$$

Let us define the wedges in the consumption of domestic and foreign goods as follows:

$$v_t \equiv \log\left(\frac{C_{Ht}}{\tilde{C}_{Ht}}\right) = \frac{C_{Ht} - \tilde{C}_{Ht}}{\bar{C}_H} + \mathcal{O}(\epsilon^2),$$

$$u_t \equiv \log\left(\frac{C_{Ft}}{\tilde{C}_{Ft}}\right) = \frac{C_{Ft} - \tilde{C}_{Ft}}{\bar{C}_F} + \mathcal{O}(\epsilon^2).$$

Additionally, using the first-order conditions (FOCs) with respect to C_{Ft}, L_{Ot}, and O_t in the planner's problem, we can derive:

$$\tilde{C}_{Ft} = \gamma \frac{\alpha}{1-\alpha} \frac{P^*_{Ot}}{\tilde{L}_{Ot}}.$$

From the optimality conditions of firms and households in equations (2) and (7), we see that

$$C_{Ft} = \gamma \frac{\alpha}{1-\alpha} \frac{P^*_{Ot}}{L_{Ot}}.$$

As a result, we have

$$\log\left(\frac{L_{Ot}}{\tilde{L}_{Ot}}\right) = -u_t,$$

which indicates that the wedge in the consumption of foreign goods and the wedge in the labor-to-oil ratio are equal in magnitude but opposite in sign. Intuitively, the consumption of foreign goods is influenced by the exchange rate and how much households are compensated for the disutility of labor, which is reflected in the wage rate (equation (2)). Simultaneously, the labor-to-oil ratio depends on the relative cost of labor and oil as production inputs, captured by the oil price-to-wage ratio (equation (7)). Thus, changes in the consumption of foreign goods due to exchange rate fluctuations or changes in the wages are mirrored by opposite changes in the labor-to-oil ratio, driven by shifts in the cost structure of production.

Using the last equation, the loss function can be expressed as:

$$\tilde{\mathcal{L}} - \mathcal{L} = \frac{1}{2}\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ (1-\gamma) v_t^2 + (\gamma + (1-\alpha)\alpha\bar{\psi}\bar{L}_O^{\alpha}\bar{O})\, u_t^2 \right\}.$$

Given that $\bar{\psi} = \frac{1-\gamma}{\bar{C}_H}$ and $\bar{Y}_H \equiv \bar{L}_O^{\alpha}\bar{O} = \bar{C}_H + \bar{C}^*_H$, the weight on the wedge in the consumption of foreign good is given by:

$$\gamma + (1-\alpha)\alpha(1-\gamma)\frac{\bar{Y}_H}{\bar{C}_H},$$

which increases with the share of export goods in home country's output. When share of oil in production is zero ($\alpha = 0$), the loss function is identical to one derived in Itskhoki and Mukhin (2023).

A.2 Linear Approximation of Constraints

For each variable Y_t with none-zero steady state $\bar{Y}$, we define the log deviation from the steady state y_t as:

$$Y_t = \bar{Y}e^{\nu y_t} \text{ for } \nu = 1.$$

For Y_t^* with zero value for steady state, we define the deviation from steady state proportional to the steady state home production $\bar{Y}_H$:

$$Y_t^* = \bar{Y}_H \nu y_t^* \text{ for } \nu = 1.$$

As in Itskhoki and Mukhin (2023), we take the first order Taylor approximation of the equilibrium system in ν around $\nu = 0$ and evaluate it at $\nu = 1$.

First Best The first best allocations are $\{\tilde{C}_{Ht}, \tilde{C}_{Ft}, \tilde{L}_{Ot}, \tilde{O}_t, \tilde{Q}_t, \tilde{B}_t^*\}$ that satisfy the following conditions:

$$\tilde{Q}_t \equiv \frac{\gamma}{1-\gamma}\frac{\tilde{C}_{Ht}}{\tilde{C}_{Ft}},$$

$$\tilde{C}_{Ht} + C_{Ht}^* = A_t \tilde{L}_{Ot}^{\alpha}\tilde{O}_t,$$

$$\frac{\tilde{B}_t^*}{R_t^*} - \tilde{B}_{t-1}^* = C_{Ht}^* - \tilde{C}_{Ft} + P_{Ot}^*(O_{wt} - \tilde{O}_t),$$

$$\beta R_t^* \mathbb{E}_t \frac{\tilde{C}_{Ft}}{\tilde{C}_{Ft+1}} = 1,$$

$$\tilde{C}_{Ht} = (1-\gamma)\alpha A_t (\tilde{L}_{Ot})^{\alpha-1},$$

$$\tilde{C}_{Ft} = \gamma \frac{\alpha}{1-\alpha}\frac{P_{Ot}^*}{\tilde{L}_{Ot}}.$$

The first order Taylor approximation of these equations in ν:

$$\tilde{q}_t = \tilde{c}_{Ht} - \tilde{c}_{Ft},$$

$$\frac{\bar{C}_H}{\bar{Y}_H}\tilde{c}_{Ht} + \frac{\bar{C}_H^*}{\bar{Y}_H}c_{Ht}^* = a_t + \alpha \tilde{l}_{ot} + \tilde{o}_t,$$

$$\beta \tilde{b}_t^* - \tilde{b}_{t-1}^* = \frac{1}{\bar{Y}_H}\left(\bar{C}_H^* c_{Ht}^* - \bar{C}_F \tilde{c}_{Ft} + (\bar{O}_w - \bar{O})p_{Ot}^* + \bar{P}_O^* \bar{O}_w o_{wt} - \bar{P}_O^* \bar{O}\tilde{o}_t\right),$$

$$\mathbb{E}_t(\tilde{c}_{Ft+1} - \tilde{c}_{Ft}) = r_t^*,$$

$$\tilde{c}_{Ht} = a_t + (\alpha - 1)\tilde{l}_{ot},$$

$$\tilde{c}_{Ft} = p^*_{Ot} - \tilde{l}_{ot}.$$

We can also derive $\tilde{q}_t$ using the last two equations, along with the equation for the natural real exchange rate and the Euler equation:

$$\tilde{q}_t = a_t - (1-\alpha)p^*_{Ot} + \alpha \sum_{i=0}^{\infty} \mathbb{E}_t r^*_{t+i}.$$

Equilibrium Conditions Let us list all the equilibrium conditions here for our reference:

$$\frac{\gamma}{1-\gamma}\frac{C_{Ht}}{C_{Ft}} = \varepsilon_t,$$

$$C_{Ht} + C^*_{Ht} = A_t L^{\alpha}_{Ot} O_t,$$

$$L_{Ot} = \frac{\alpha}{1-\alpha}\frac{\gamma P^*_{Ot}}{C_{Ft}},$$

$$\frac{B^*_t}{R^*_t} - B^*_{t-1} = P^*_{Ht}C^*_{Ht} - P^*_{Ft}C_{Ft} + P^*_{Ot}(O_{wt} - O_t),$$

$$\mathbb{E}_t \beta \left[\frac{C_{Ft}}{C_{Ft+1}} R^*_t\right] = 1 + \frac{B^*_t - N^*_t - F^*_t}{R^*_t}\omega \text{var}_t(R_t \frac{\varepsilon_t}{\varepsilon_{t+1}}).$$

Rewriting the equilibrium equations in terms of deviation from first best :

$$e_t = \tilde{q}_t + c_{Ht} - \tilde{c}_{Ht} - (c_{Ft} - \tilde{c}_{Ft}),$$

$$\frac{\bar{C}_H}{\bar{Y}_H}(c_{Ht} - \tilde{c}_{Ht}) = \alpha(l_{ot} - \tilde{l}_{ot}) + o_t - \tilde{o}_t,$$

$$l_{ot} - \tilde{l}_{ot} = -(c_{Ft} - \tilde{c}_{Ft}),$$

$$\beta b^*_t - b^*_{t-1} = \frac{-1}{\bar{Y}_H}\left(\bar{C}_F(c_{Ft} - \tilde{c}_{Ft}) + \bar{P}^*_O \bar{O}(o_t - \tilde{o}_t)\right),$$

where we used

$$B^*_t - \tilde{B}^*_t = \bar{Y}_H \nu b^*_t.$$

Defining $\omega_0 = \omega/\nu^2$ and the following proportional deviations:

$$N^*_t - \tilde{B}^*_t = \bar{Y}_H \nu n^*_t, \;\; F^*_t = \bar{Y}_H \nu f^*_t.$$

with some algebra we get:[28]

$$\mathbb{E}_t(c_{Ft} - \tilde{c}_{Ft} - (c_{Ft+1} - \tilde{c}_{Ft+1})) = \bar{\omega}\text{var}_t(\Delta e_{t+1})(b_t^* - n_t^* - f_t^*),$$

where $\bar{\omega} = \frac{\omega_0}{\beta}\bar{Y}_H$.

Using all the derivation we had so far and the definitions of u_t and v_t, we can derive the approximate Ramsey problem.

$$\min_{u_t, v_t, f_t^*, b_t^*, e_t, o_t} \frac{1}{2}\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ (1-\gamma)v_t^2 + \left(\gamma + (1-\alpha)\alpha(1-\gamma)\frac{\bar{Y}_H}{\bar{C}_H}\right) u_t^2 \right\}$$

$$\begin{aligned} s.t. \quad & e_t = \tilde{q}_t + v_t - u_t, \\ & \frac{\bar{C}_H}{\bar{Y}_H} v_t = -\alpha u_t + o_t - \tilde{o}_t, \\ & \beta b_t^* - b_{t-1}^* = \frac{-1}{\bar{Y}_H}\left(\bar{C}_F u_t + \bar{P}_O^* \bar{O}(o_t - \tilde{o}_t)\right), \\ & \mathbb{E}_t \Delta u_{t+1} = \bar{\omega}\text{var}_t(\Delta e_{t+1})(n_t^* + f_t^* - b_t^*). \end{aligned}$$

As Itskhoki and Mukhin (2023) shows, the solution to this approximate equilibrium system characterizes an $O(\nu)$ accurate dynamics of the non-linear equilibrium system.

B Proofs

B.1 Proposition 1

Let us write down the Lagrangian for the optimization problem:

$$\begin{aligned} l_0 = & \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{2}(1-\gamma)v_t^2 + \frac{1}{2}\left(\gamma + (1-\alpha)\alpha(1-\gamma)\frac{\bar{Y}_H}{\bar{C}_H}\right) u_t^2 \right. \\ & - \mu_t \left(\frac{-1}{\bar{Y}_H}\left((\bar{C}_F + \alpha \bar{P}_O^* \bar{O})u_t + (\frac{\bar{P}_O^* \bar{O}\bar{C}_H}{\bar{Y}_H})v_t \right) - \beta b_t^* + b_{t-1}^* \right) \\ & - \psi_t \left(\mathbb{E}_t \Delta u_{t+1} - \bar{\omega}\sigma_t^2(n_t^* + f_t^* - b_t^*) \right) \\ & \left. - \lambda_t \left(\sigma_t^2 - E_t(\tilde{q}_{t+1} + v_{t+1} - u_{t+1})^2 + (E_t(\tilde{q}_{t+1} + v_{t+1} - u_{t+1}))^2 \right) \right\}. \end{aligned}$$

[28]Refer to page 48 of Itskhoki and Mukhin (2023) for more details.

FOCs with respect to v_t, u_t, σ_t^2, and b_t^* are

$$(1-\gamma)v_t + \frac{\bar{P}_O^*\bar{O}\bar{C}_H}{\bar{Y}_H^2}\mu_t + 2\beta^{-1}\lambda_{t-1}(e_t - E_{t-1}e_t) = 0,$$

$$(\gamma + (1-\alpha)\alpha\bar{\psi}\bar{L}^\alpha\bar{O}^{1-\alpha})u_t + \frac{\bar{C}_F + \alpha\bar{P}_O^*\bar{O}}{\bar{Y}_H}\mu_t - \beta^{-1}\psi_{t-1} + \psi_t - 2\beta^{-1}\lambda_{t-1}(e_t - E_{t-1}e_t) = 0,$$

$$\lambda_t = \psi_t\bar{\omega}(n_t^* + f_t^* - b_t^*),$$

$$\beta(\mu_t - E_t\mu_{t+1}) = \psi_t\bar{\omega}\sigma_t^2.$$

When f_t^* is available as a tool, then $\psi_t = 0$ for all t. As a result, $\lambda_t = 0$ and $E_t\Delta\mu_{t+1} = 0$ for all t. Simplifying the equations above:

$$(1-\gamma)v_t + \frac{\bar{P}_O^*\bar{O}}{\bar{Y}_H^2}\mu_t = 0,$$

$$(\gamma + (1-\alpha)\alpha\bar{\psi}\bar{L}^\alpha\bar{O}^{1-\alpha})u_t + \frac{\bar{C}_F + \alpha\bar{P}_O^*\bar{O}}{\bar{Y}_H}\mu_t = 0.$$

Given these equations, it is easy to show that $E_tu_{t+1} = E_tv_{t+1} = 0$. Using this result and the home budget constraint gives $b_t^* = 0$ for all t. Simplifying the budget constraint:

$$(\bar{C}_F + \alpha\bar{P}_O^*\bar{O})u_t + (\frac{\bar{P}_O^*\bar{O}\bar{C}_H}{\bar{Y}_H})v_t = 0.$$

Solving the last three equations, we find $u_t = v_t = \mu_t = 0$ for all t. Since $E_tu_{t+1} = 0$, using the risk sharing constraint $f_t^* = b_t^* - n_t^* = -n_t^*$.

As defined earlier, $n_t^* = \frac{1}{\bar{Y}_H\nu}(N_t^* - \tilde{B}_t^*)$. This means that n_t^* depends on both noise trader shocks and the movements in the first-best NFA position $\tilde{B}_t^*$. Shocks to the the oil price can affect $\tilde{B}_t^*$ directly and therefore demands a respond from the government to ensure the first-best allocation.

B.2 Proposition 2

When the exchange rate is fixed, we have $\text{var}_t(\Delta e_{t+1}) = 0$, which implies that $\mathbb{E}_t\Delta u_{t+1} = 0$. Additionally, using the relationship $e_t = \tilde{q}_t + v_t - u_t$, we can derive:

$$v_t = \mathbb{E}_t\Delta\tilde{q}_{t+1} + \mathbb{E}_t\nu_{t+1}.$$

By solving this equation forward and assuming that $\tilde{q}_\infty = 0$, we arrive at the conclusion that $v_t = -\tilde{q}_t$ and as a result $u_t = 0$.

C Model with Expatriates Workers

In some oil-rich countries, particularly in the Gulf Cooperation Council (GCC), labor markets are characterized by a heavy reliance on expatriate workers. Based on GCC-Stat data, expatriates accounted for 78% of the labor force in GCC countries in 2024Q2. Does this reliance alter the dynamics of a currency peg? Could it mitigate the associated welfare losses, or might it instead exacerbate them? To address these questions, we introduce a simple modification to the baseline model.

Let us denote domestic workers as L_{Ht} and foreign workers as L_{Ft}. In this revised version of the model, the firm's problem is:

$$\max_{C_{Ht}, L_{Ht}, L_{Ft}, O_t} C_{Ht} + \varepsilon_t P^*_{Ht} C^*_{Ht} - W_t L_{Ht} - \varepsilon_t W^*_t L_{Ft} - \varepsilon_t P^*_{Ot} O_t,$$

subject to

$$C_{Ht} + C^*_{Ht} = A_t \left(L^{\sigma}_{Ht} L^{1-\sigma}_{Ft} \right)^{\alpha} O^{1-\alpha}_t. \tag{20}$$

Expatriate labor is treated as an imported production input in this model. It is assumed that expatriate workers do not consume domestically produced goods. Instead, all of their earnings are sent back to their home countries as remittances. Thus, their presence contributes to the domestic economy's production, but their consumption patterns do not affect domestic demand for home-produced goods.[29]

C.1 Quadratic Approximation of the Loss Function

Let us define the following ratios: $L_{HFt} \equiv \frac{L_{Ht}}{L_{Ft}}$ and $L_{FOt} \equiv \frac{L_{Ft}}{O_t}$. The Lagrangian for the problem can be expressed as follows:

[29] This assumption can be easily relaxed. When expatriate workers also demand non-tradable goods, increasing the use of expatriate labor introduces an additional policy consideration, particularly if prices in the non-tradable sector are not fully sticky.

$$\mathcal{L}(x,\lambda,\epsilon) = \sum_{t=0}^{\infty}\beta^t\Bigg\{(1-\gamma)\log C_{Ht} + \gamma\log C_{Ft} - L_{HFt}L_{Ft}O_t$$
$$+\mu_t\left(C^*_{Ht} - C_{Ft} + P^*_{Ot}(O_{wt}-O_t) - W^*_t L_{FO}O_t - \frac{B^*_t}{R^*_t} + B^*_{t-1}\right)$$
$$+\psi_t\left(A_t L^{\sigma\alpha}_{HFt}L^{\alpha}_{FOt}O_t - C_{Ht} - C^*_{Ht}\right)\Bigg\}.$$

Before we proceed and derive the second-order approximation of the loss function, we derive the equilibrium conditions for the firm's optimization problem given in equation (20). The FOC conditions with respect to L_{HFt}, L_{FOt}, O_t, and C_{Ht} result

$$W_t L^{1-\alpha}_{FOt} = A_t\sigma\alpha L^{\alpha\sigma-1}_{HFt},$$

$$(\frac{1}{\sigma}-1)W_t L_{HFt} = \varepsilon_t W^*_t,$$

$$(\frac{1}{\sigma\alpha}-1)W_t L_{HFt} = \frac{\varepsilon_t P^*_{Ot}}{L_{FOt}} + \varepsilon_t W^*_t.$$

The last two equations result:

$$L_{FOt} = \frac{\alpha(1-\sigma)}{1-\alpha}\frac{P^*_{Ot}}{W^*_t},$$

which is equal to the first-best allocation of L_{FOt}. Thus, $l_{FOt} - \tilde{l}_{FOt} = 0$. Also, using the households optimality conditions ($C_{Ft} = \gamma\frac{W_t}{\varepsilon_t}$), we can derive

$$(\frac{1}{\sigma}-1)\frac{1}{\gamma}L_{HFt} = \frac{W^*_t}{C_{Ft}}.$$

It is easy to show that a similar equation can be derived for the first-best allocation

$$(\frac{1}{\sigma}-1)\frac{1}{\gamma}\tilde{L}_{HFt} = \frac{W^*_t}{\tilde{C}_{Ft}}.$$

Consequently, $\tilde{l}_{HFt} - l_{HFt} = -(\tilde{c}_{Ft} - c_{Ft})$.

Using these results and following similar steps as in appendix A, we can derive the second order approximation of the loss function as follows:

$$\tilde{\mathcal{L}} - \mathcal{L} = \frac{1}{2}\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Bigg\{ (1-\gamma) \left(\frac{C_{Ht} - \tilde{C}_{Ht}}{\bar{C}_H} \right)^2 + \gamma \left(\frac{C_{Ft} - \tilde{C}_{Ft}}{\bar{C}_F} \right)^2 + (1-\sigma\alpha)\sigma\alpha(1-\gamma)\frac{\bar{Y}_H}{\bar{C}_H} \left(\frac{L_{HFt} - \tilde{L}_{HFt}}{\bar{L}_{HF}} \right)^2 \Bigg\}.$$

Using the definition of wedges, we can simplify this loss function and arrive at equation (21):

$$\frac{1}{2}\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ (1-\gamma)v_t^2 + \left(\gamma + (1-\sigma\alpha)\sigma\alpha(1-\gamma)\frac{\bar{Y}_H}{\bar{C}_H} \right) u_t^2 \right\}. \tag{21}$$

In this case, the share of expatriate workers in the production will affect the weight on the wedge for the foreign good consumption. The optimal policy is still able to eliminate both gaps and achieve the first-best allocation.

To evaluate the welfare loss associated with a currency peg in comparison to the previous scenario, we need to derive $\tilde{q}_t$:

$$\tilde{q}_t = a_t - (1-\alpha)p^*_{Ot} + \sigma\alpha \sum_{i=0}^{\infty} \mathbb{E}_t r^*_{t+i} - \alpha(1-\sigma)w^*_t.$$

In this model, $\tilde{q}_t$ is influenced by the volatility of foreign wages as well. Assuming foreign wages remain constant, as σ approaches zero—indicating a reduced labor share of households in relation to expatriates—the effect of foreign rate volatility on welfare loss from pegging the currency diminishes. However, the influence of oil price volatility on welfare loss under a peg remains unchanged.

D The Extended Model

D.1 Quadratic Approximation of the Loss Function

$$
\begin{aligned}
\mathcal{L}(x,\lambda,\epsilon) = \sum_{t=0}^{\infty}\beta^t \Bigg\{ & (1-\gamma)\log C_{Ht} + \gamma \log C_{Ft} - L_{Ot}O_t \\
& + \mu_t \left({P^*_{Ht}}^{1-\epsilon_X} C^*_t - P^*_{Ft}C_{Ft} + P^*_{Ot}(O_{wt}-O_t) - \frac{B^*_t}{R^*_t} + B^*_{t-1} \right) \\
& + \psi_t \left(A_t L^{\alpha}_{Ot} O_t - \int_0^1 p_{iHt}^{-\epsilon_H} di C_{Ht} - {P^*_{Ht}}^{-\epsilon_X} C^*_t \right) \\
& + \Gamma_t \left(1 - \left(\int_0^1 p_{iHt}^{1-\epsilon_H} di \right)^{\frac{1}{1-\epsilon_H}} \right) \Bigg\},
\end{aligned}
$$

where

$$x = \{C_{Ht}, C_{Ft}, L_{Ot}, O_t, B^*_t, P^*_{Ht}, \{p_{iHt}\}_{i=0}^1\}_{t=0}^{\infty},$$

$$\lambda = \{\mu_t, \psi_t\, \Gamma_t\}_{t=0}^{\infty},$$

and

$$\epsilon = \left\{ \log\left(\frac{C^*_{Ht}}{\bar{C}^*_H}\right), \log\left(\frac{P^*_{Ot}}{\bar{P}^*_O}\right), \log\left(\frac{O_{wt}}{\bar{O}_{wt}}\right), \log\left(\frac{R^*_t}{\bar{R}^*}\right) \right\}_{t=0}^{\infty}.$$

Finally $p_{iHt} = \frac{P_{iHt}}{P_{Ht}}$. Following similar steps in Appendix A:

$$
\begin{aligned}
\tilde{\mathcal{L}} - \mathcal{L} = \frac{1}{2}\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Bigg\{ & (1-\gamma)\left(\frac{C_{Ht}-\tilde{C}_{Ht}}{\bar{C}_H}\right)^2 + \gamma \left(\frac{C_{Ft}-\tilde{C}_{Ft}}{\bar{C}_F}\right)^2 \\
& + (1-\alpha)\alpha\bar{\psi}\bar{L}^{\alpha}_O\bar{O}\left(\frac{L_{Ot}-\tilde{L}_{Ot}}{\bar{L}_O}\right)^2 - 2\epsilon_H(1-\gamma)\left(\frac{C_{Ht}-\tilde{C}_{Ht}}{\bar{C}_H}\right)\left(\int_0^1 (p_{iHt}-1)di\right) \\
& + (1-\gamma)\epsilon_H(\epsilon_H+1)\left(\int_0^1 (p_{iHt}-1)^2 di\right) + \epsilon_X \bar{\psi}\bar{C}^*_H \left(\frac{P^*_{Ht}-\tilde{P}^*_{Ht}}{\bar{P}^*_H}\right)^2 \Bigg\}.
\end{aligned}
$$

Next, we provide some lemmas to simplify the loss function:

Lemma D.1. *$\int_0^1 (p_{iHt}-1)di = \frac{\epsilon_H}{2} E_i \hat{p}^2_{iHt}$ and $\int_0^1 (p_{iHt}-1)^2 di = E_i \hat{p}^2_{iHt}$, where $\hat{p}_{iHt} =$* $\log p_{iHt}$

Proof.

$$\begin{aligned}\int_0^1 (p_{iHt}-1)di &= \int_0^1 (\hat{p}_{iHt}+\frac{1}{2}\hat{p}_{iHt}^2)di\\ &= \frac{\epsilon_H-1}{2}E_i\hat{p}_{iHt}^2+\frac{1}{2}E_i\hat{p}_{iHt}^2\\ &= \frac{\epsilon_H}{2}E_i\hat{p}_{iHt}^2.\end{aligned}$$

The first equality comes from the second-order approximation of $p_{iHt}=1+\hat{p}_{iHt}+\frac{1}{2}\hat{p}_{iHt}^2$. For the second one, noting that $\int_0^1 p_{iHt}^{1-\epsilon_H}\,di=1$, and using the second-order approximation, we can write

$$p_{iHt}^{1-\epsilon_H}=1+(1-\epsilon_H)\hat{p}_{iHt}+\frac{(1-\epsilon_H)^2}{2}\hat{p}_{iHt}^2.$$

Substituting this into the price equation, we get

$$E_i\hat{p}_{iHt}=\frac{\epsilon_H-1}{2}E_i\hat{p}_{iHt}^2.$$

It is easy to show that $\int_0^1(p_{iHt}-1)^2di=E_i\hat{p}_{iHt}^2$ using the second-order approximation of p_{iHt} and dropping the higher order terms.

□

Lemma D.2. $E_i\hat{p}_{iHt}^2=var_i\{\log p_{iHt}\}$

Proof. Gali (2015), Chapter 4. □

Lemma D.3. $\sum_{t=0}^{\infty}\beta^t var_i\{\log p_{iHt}\}=\frac{\theta}{(1-\beta\theta)(1-\theta)}\sum_{t=0}^{\infty}\beta^t\pi_t^2$

Proof. Michael (2003), Chapter 6. □

Lemma D.4. $\left(\frac{C_{Ht}-\tilde{C}_{Ht}}{\bar{C}_H}\right)\left(\int_0^1(p_{iHt}-1)di\right)=0$*, up to second order.*

Proof. Using lemma D.1, $\left(\frac{C_{Ht}-\tilde{C}_{Ht}}{\bar{C}_H}\right)\left(\int_0^1(p_{iHt}-1)di\right)=\frac{\epsilon_H}{2}\left(\frac{C_{Ht}-\tilde{C}_{Ht}}{\bar{C}_H}\right)E_i\hat{p}_{iHt}^2$, which is a third-order object. □

Using the lemmas, we can get the loss function:

$$\tilde{\mathcal{L}}-\mathcal{L}=\frac{1}{2}\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left\{(1-\gamma)(v_t^2+\chi_1\pi_t^2)+\chi_2u_t^2+\epsilon_X(1-\gamma)\frac{\bar{C}_H^*}{\bar{C}_H}(p_{Ht}^*-\tilde{p}_{Ht}^*)^2\right\},$$

where $\chi_1=\frac{\theta}{(1-\beta\theta)(1-\theta)}\epsilon_H(\epsilon_H+1)$, $\chi_2=\gamma+\alpha(1-\alpha)(1-\gamma)\frac{\bar{Y}}{\bar{C}_H}$. We also used $l_{ot}-\tilde{l}_{ot}=-u_t$. Moreover, we will show in next part that $p_{Ht}^*-\tilde{p}_{Ht}^*=\alpha u_t$, and we can get the loss function in equation (19).

D.2 Linear Approximation of Constraints

First Best The first best allocations are $\{\tilde{C}_{Ht}, \tilde{C}_{Ft}, \tilde{L}_t, \tilde{O}_t, \tilde{Q}_t, \tilde{B}_t^*, P_{Ht}^*, \{p_{iHt}\}_{i=0}^1\}$ that satisfy the following conditions:

$$\tilde{Q}_t \equiv \frac{\gamma}{1-\gamma}\frac{\tilde{C}_{Ht}}{\tilde{C}_{Ft}},$$

$$\tilde{C}_{Ht} + C_{Ht}^* = A_t \tilde{L}_{Ot}^{\alpha} \tilde{O}_t,$$

$$\frac{\tilde{B}_t^*}{R_t^*} - \tilde{B}_{t-1}^* = \left(\tilde{P}_{Ht}^*\right)^{1-\epsilon_X} C_t^* - P_{Ft}^* \tilde{C}_{Ft} + P_{Ot}^*(O_{wt} - \tilde{O}_t),$$

$$\beta R_t^* \mathbb{E}_t \frac{P_{Ft}^* \tilde{C}_{Ft}}{P_{Ft+1}^* \tilde{C}_{Ft+1}} = 1,$$

$$\tilde{C}_{Ht} = (1-\gamma)\alpha A_t (\tilde{L}_{Ot})^{\alpha-1},$$

$$P_{Ft}^* \tilde{C}_{Ft} = \gamma \frac{\alpha}{1-\alpha}\frac{P_{Ot}^*}{\tilde{L}_{Ot}},$$

$$\tilde{P}_{Ht}^* = \frac{\epsilon_X}{\epsilon_X - 1}\frac{P_{Ot}^*}{(1-\alpha)A_t \tilde{L}_{Ot}^{\alpha}},$$

$$\tilde{p}_{iHt} = 1, \quad \forall i \in [0,1].$$

Equilibrium Conditions

$$\varepsilon_t \frac{P_{Ft}^*}{P_{Ht}} = \frac{\gamma}{1-\gamma}\frac{C_{Ht}}{C_{Ft}},$$

$$A_t L_t^{\alpha} O_t^{1-\alpha} = P_{Ht}^{*\,-\epsilon_X} C_t^* + \Phi_t C_{Ht}, \quad \Phi_t = \int_0^1 p_{iHt}^{-\epsilon_H} di,$$

$$\frac{B_t^*}{R_t^*} - B_{t-1}^* = P_{Ht}^{*\,1-\epsilon_X} C_t^* - P_{Ft}^* C_{Ft} + P_{Ot}^*(O_{wt} - O_t),$$

$$\mathbb{E}_t \beta \left[\frac{P_{Ft}^* C_{Ft}}{P_{Ft+1}^* C_{Ft+1}} R_t^*\right] = 1 + \frac{B_t^* - N_t^* - F_t^*}{R_t^*}\omega \mathrm{var}_t(R_t \frac{\varepsilon_t}{\varepsilon_{t+1}}),$$

$$P_{Ft}^* C_{Ft} = \gamma \frac{\alpha}{1-\alpha}\frac{P_{Ot}^*}{L_{Ot}},$$

$$P_{Ht}^* = \frac{\epsilon_X}{\epsilon_X - 1}\frac{P_{Ot}^*}{(1-\alpha)A_t L_{Ot}^{\alpha}}.$$

Now, we need to express the equations in terms of logarithmic deviations from the first-best scenario. Using the first equilibrium condition:

$$\Delta e_t = \Delta \tilde{q}_t + \Delta c_{Ht} - \Delta \tilde{c}_{Ht} - (\Delta c_{Ft} - \Delta \tilde{c}_{Ft}) + \pi_t - \Delta p^*_{Ft}.$$

To reformulate the resource allocation conditions that incorporate a measure of price dispersion, we require the following lemma:

Lemma D.5. $\log \Phi_t = 0$, *up to first order.*

Using this lemma:

$$\frac{\bar{C}_H}{\bar{Y}}(c_{Ht} - \tilde{c}_{Ht}) - \epsilon_x \frac{\bar{C}^*_H}{\bar{Y}}(p^*_{Ht} - \tilde{p}^*_{Ht}) = \alpha(l_{ot} - \tilde{l}_{ot}) + o_t - \tilde{o}_t.$$

The home budget constraint can be expressed as:

$$\beta b^*_t - b^*_{t-1} = \frac{-1}{\bar{Y}}\left(\bar{C}^*_H(\epsilon_X - 1)(p^*_{Ht} - \tilde{p}^*_{Ht}) + \bar{C}_F(c_{Ft} - \tilde{c}_{Ft}) + \bar{P}^*_O \bar{O}(o_t - \tilde{o}_t)\right),$$

where we used $B^*_t - \tilde{B}^*_t = \bar{Y}\nu b^*_t$. Defining $\omega_0 = \omega/\nu$ and the following proportional deviations: $N^*_t - \tilde{B}^*_t = \bar{Y}\nu n^*_t$ and $F^*_t = \bar{Y}\nu f^*_t$, we can get:

$$\mathbb{E}_t(c_{Ft} - \tilde{c}_{Ft} - (c_{Ft+1} - \tilde{c}_{Ft+1})) = \bar{\omega}\mathrm{var}_t(\Delta e_{t+1})(b^*_t - n^*_t - f^*_t),$$

where $\bar{\omega} = \frac{\omega_0}{\beta}\bar{Y}_H$. Moreover,

$$l_{ot} - \tilde{l}_{ot} = -(c_{Ft} - \tilde{c}_{Ft}),$$

$$p^*_{Ht} - \tilde{p}^*_{Ht} = -\alpha(l_{ot} - \tilde{l}_{ot}).$$

We also need to use the NKPC:

$$\pi_t = \frac{(1-\theta)(1-\beta\theta)}{\theta}(p_{It} - p_{Ht}) + \beta\mathbb{E}_t\pi_{t+1},$$

$$p_{It} - p_{Ht} = c_{Ht} - \tilde{c}_{Ht} + (1-\alpha)(l_{ot} - \tilde{l}_{ot}).$$

Using $v_t \equiv \log(C_{Ht}/\tilde{C}_{Ht}) = \frac{C_{Ht} - \tilde{C}_{Ht}}{\bar{C}_H} + \mathcal{O}(\varepsilon^2)$, $u_t \equiv \log(C_{Ft}/\tilde{C}_{Ft}) = \frac{C_{Ft} - \tilde{C}_{Ft}}{\bar{C}_F} + \mathcal{O}(\varepsilon^2)$, we can simplify social planner's problem as shown in equation (19).

E A Two-Sector Model with Non-Tradables

The Household's Problem:

$$\max_{C_{Nt},C_{Tt},L_t,B_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[(1-\gamma)\log C_{Nt} + \gamma \log C_{Tt} - \psi_l \frac{L_t^{1+\sigma_l}}{1+\sigma_l} \right],$$

subject to:

$$P_{Nt}C_{Nt} + P_{Tt}C_{Tt} + \frac{B_t}{R_t} = B_{t-1} + W_t L_t + \Pi_t + T_t + P_{Ot}O_{wt}.$$

The Firm's problem:

$$\max_{Y_{jt},L_{jt},O_{jt}} P_{jt}Y_{jt} - W_t L_{jt} - P_{Ot}O_{jt}$$

$$Y_{jt} = A_{jt}L_{jt}^{\alpha_j} O_{jt}^{1-\alpha_j}$$

where $j \in \{N, T\}$. The financial sector is as described in the main text. Assume $P_{Nt} = P^*_{Tt} = 1$ for all t, with $P_{Tt} = \varepsilon_t P^*_{Tt}$ and $P_{Ot} = \varepsilon_t P^*_{Ot}$. Defining $L_{jOt} \equiv \frac{L_{jt}}{O_{jt}}$, the equilibrium conditions are:

$$\frac{\gamma}{1-\gamma}\frac{C_{Nt}}{C_{Tt}} = \varepsilon_t,$$

$$C_{Nt} = A_{Nt}L_{NOt}^{\alpha_N}O_{Nt}, \quad Y_{Tt} = A_{Tt}L_{TOt}^{\alpha_T}O_{Tt},$$

$$\frac{B^*_t}{R^*_t} - B^*_{t-1} = Y_{Tt} - C_{Tt} + P^*_{Ot}(O_{wt} - O_{Nt} - O_{Tt}),$$

$$\mathbb{E}_t\beta\left[\frac{C_{Tt}}{C_{Tt+1}}R^*_t\right] = 1 + \frac{B^*_t - N^*_t - F^*_t}{R^*_t}\omega \text{var}_t(R_t\frac{\varepsilon_t}{\varepsilon_{t+1}}),$$

$$(1-\alpha_N)A_{Nt}L_{NOt}^{\alpha_N} = \varepsilon_t P^*_{Ot}, \quad (1-\alpha_T)A_{Tt}L_{TOt}^{\alpha_T} = P^*_{Ot},$$

$$A_{Nt}\alpha_N L_{NOt}^{\alpha_N-1} = \frac{\psi_l L_t^{\sigma_l}C_{Nt}}{1-\gamma}, \quad A_{Tt}\alpha_T L_{TOt}^{\alpha_T-1} = \frac{\psi_l L_t^{\sigma_l}C_{Tt}}{\gamma},$$

$$L_t = L_{NOt}O_{Nt} + L_{TOt}O_{Tt}.$$

The list of equations for the first-best allocation are similar, except that ε_t is replaced by $Q_t \equiv \frac{\gamma}{1-\gamma}\frac{\tilde{C}_{Nt}}{\tilde{C}_{Tt}}$, and the Euler condition becomes $\mathbb{E}_t\left[\beta\frac{\tilde{C}_{Tt}}{\tilde{C}_{Tt+1}}R^*_t\right] = 1$. Defining the gaps $v_t = \log C_{Nt} - \log \tilde{C}_{Nt}$, $u_t = \log C_{Tt} - \log \tilde{C}_{Tt}$, $\Delta l_{jOt} = \log L_{jOt} - \log \tilde{L}_{jOt}$, and $\Delta o_{jt} = \log O_{jt} - \log \tilde{O}_{Nt}$:

$$e_t - q_t = v_t - u_t,$$

$$v_t = \alpha_N \Delta l_{NOt} + \Delta o_{Nt}, \quad \Delta y_{Tt} = \alpha_T \Delta l_{TOt} + \Delta o_{Tt},$$

$$\beta b_t^* - b_{t-1}^* = \frac{1}{\bar{Y}_T} \left(\bar{Y}_T \Delta y_{Tt} - \bar{C}_T u_t - \bar{P}_O^* \bar{O}_N \Delta o_{Nt} - \bar{P}_O^* \bar{O}_T \Delta o_{Tt} \right)$$

$$\mathbb{E}_t \Delta u_{t+1} = \bar{\omega} \mathrm{var}_t(\Delta e_{t+1})(n_t^* + f_t^* - b_t^*)$$

$$\alpha_N \Delta l_{NOt} = e_t - q_t, \quad \alpha_T \Delta l_{TOt} = 0,$$

$$(\alpha_N - 1)\Delta l_{NOt} = \sigma_l \Delta L_t + v_t, \quad (\alpha_T - 1)\Delta l_{TOt} = \sigma_l \Delta L_t + u_t,$$

$$\Delta L_t = \frac{\bar{L}_N}{\bar{L}} (\Delta l_{NOt} + \Delta o_{Nt}) + \frac{\bar{L}_T}{\bar{L}} (\Delta l_{TOt} + \Delta o_{Tt}).$$

Following similar steps in appendix A, we can have the quadratic approximation of the loss function:

$$\tilde{\mathcal{L}} - \mathcal{L} = \frac{1}{2} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t x_t H_{xx} x_t'$$

where $x_t = (v_t, u_t, \Delta l_{NOt}, \Delta l_{TOt}, \Delta o_{Nt}, \Delta o_{Tt})$.

$$H_{xx} = \begin{bmatrix} 1-\gamma & 0 & 0 & 0 & 0 & 0 \\ 0 & \gamma & 0 & 0 & 0 & 0 \\ 0 & 0 & a\bar{L}_N^2 + (1-\gamma)\alpha_N(1-\alpha_N) & a\bar{L}_T\bar{L}_N & a\bar{L}_N^2 & a\bar{L}_T\bar{L}_N \\ 0 & 0 & a\bar{L}_N\bar{L}_T & a\bar{L}_T^2 + \frac{\bar{Y}_T}{\bar{C}_T}\gamma\alpha_T(1-\alpha_T) & a\bar{L}_N\bar{L}_T & a\bar{L}_T^2 \\ 0 & 0 & a\bar{L}_N^2 & a\bar{L}_N\bar{L}_T & a\bar{L}_N^2 & a\bar{L}_N\bar{L}_T \\ 0 & 0 & a\bar{L}_N\bar{L}_T & a\bar{L}_T^2 & a\bar{L}_N\bar{L}_T & a\bar{L}_T^2 \end{bmatrix},$$

where $a = \psi_l \sigma_l \bar{L}^{\sigma_l - 1}$. The Hessian matrix H_{xx} is positive semidefinite, which implies that the loss function is non-negative for any non-zero vector x_t. It is straightforward to verify that $x_t = \mathbf{0}$ satisfies the constraints, so the policymaker can achieve the minimum loss of zero by fully closing the gaps.[30]

[30] The solution is also unique.

F CES Production Function

We explore the role of the elasticity of substitution between labor and oil in the production function. As noted by Baqaee and Farhi (2019), oil is often treated as an inelastic input across various industries. Consequently, employing a Cobb-Douglas production function may not accurately capture the production dynamics. To address this, we instead assume a CES production function in our baseline model, which is given by:

$$Y_{Ht} = A_t \left(\alpha(a_L L_t)^{\sigma} + (1-\alpha)(a_O O_t)^{\sigma}\right)^{\frac{1}{\sigma}}.$$

In this formulation, the degree of substitutability between labor and oil is governed by σ. When $\sigma = 0$, the model reduces to the Cobb-Douglas case. As $\sigma \to -\infty$, the function approaches a Leontief production function, where output becomes:

$$Y_{Ht} = A_t \min\{a_L L_t, a_O O_t\}.$$

This adjustment allows for more flexibility in capturing the role of oil as an input and its interaction with labor in production, offering a broader lens through which to assess the effects of oil price volatility on the economy.

Following similar steps in Appendix A, the objective function of the Ramsey problem in this case is:

$$\frac{1}{2}\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{(1-\gamma)v_t^2 + \chi u_t^2\right\},$$

where

$$\chi = \gamma + \frac{1-\gamma}{1-\sigma}\frac{\bar{Y}_H}{\bar{C}_H}\frac{\alpha a_L^{\sigma}\bar{L}^{\sigma}}{\bar{Y}_H^{\sigma}}\left(1 - \frac{\alpha a_L^{\sigma}\bar{L}^{\sigma}}{\bar{Y}_H^{\sigma}}\right).$$

The only different constraint from the baseline problem (equation (16)) is the following:

$$\frac{\bar{C}_H}{\bar{Y}_H}v_t = -\frac{\alpha}{1-\sigma}u_t + o_t - \tilde{o}_t.$$

In this case, the first-best allocation is again achievable through optimal monetary policy and FXI, even in the limit case where oil and labor are not substitutable ($\sigma \to -\infty$). The weight on the wedge in the consumption of foreign goods decreases as the two inputs become less substitutable.

G Market Depth and the Welfare Loss

To better understand the role of financial frictions, we examine how welfare outcomes vary with different values of the financial friction parameter, ω. Recall that the UIP wedge scales with market depth according to

$$\mathbb{E}_t(\Delta u_{t+1}) = \bar{\omega}\text{var}_t(\Delta e_{t+1})(n_t^* + f_t^* - b_t^*),$$

implying that a higher ω amplifies the volatility of currency premia for a given flow or NFA configuration. Since oil price shocks generate first-order fluctuations in the trade balance and the NFA position, a higher ω leads to larger and more volatile movements in the currency premium. As a result, welfare losses under the no FXI regime increase sharply and monotonically with ω.[31]

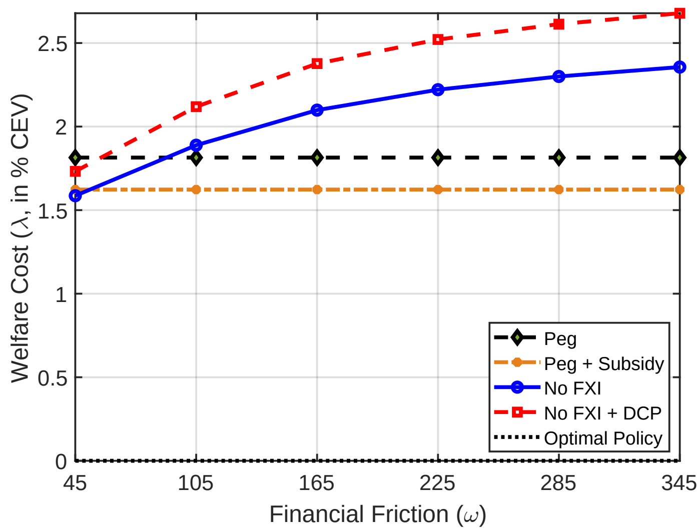


Figure G1: Welfare Costs and Financial Frictions (ω)

Note: This figure examines how welfare costs respond to the severity of financial market imperfections when all shocks, including oil price shocks, are active. Welfare costs are measured as a percentage consumption-equivalent loss relative to the first-best allocation. The figure varies the financial friction parameter (ω), benchmarked at 345.

When oil shocks are present, the external margin becomes first-order: greater financial frictions (shallower FX markets) magnify the UIP wedge, leading to excessive exchange rate volatility and substantial welfare losses under a floating regime. In contrast, the peg and peg + subsidy regimes are largely insensitive to changes in ω. By fixing the exchange

[31] The increase is even stronger under DCP, as non-oil export revenues do not adjust with the exchange rate and thus provide no natural hedge against oil price movements.

rate, these regimes effectively eliminate the UIP wedge, leaving their welfare performance determined mainly by domestic distortions—namely, the output and inflation wedges (v_t, π_t). Importantly, these domestic wedges depend on the natural real exchange rate, $\tilde{q}_t$, which is driven only by real fundamental shocks (such as productivity and oil price shocks) and not by financial noise. As a result, the welfare losses under pegged regimes remain stable across different levels of financial market depth.

This robustness exercise reinforces the main message: the case for foreign exchange intervention strengthens as financial markets become shallower and oil price shocks play a more prominent role. The welfare cost of a no FXI regime originates primarily from the unmanaged UIP risk premium, which becomes increasingly costly when currency markets are imperfect.

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