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Foreign Exchange Regimes in (Normal Times and) Times of War: Insights From Ukraine

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ABSTRACT

On February 24, 2022, as Russia invaded, the National Bank of Ukraine switched from a flexible to a fixed-exchange rate regime. Was this optimal? We develop a tractable but carefully calibrated open-economy model of Ukraine with nominal rigidities and frictions in international financial markets. We find that the optimal response to small shocks is exchange rate flexibility, whereas to large (invasion size) shocks, currency depreciation is suboptimal and a Taylor-type rule may fail to admit an equilibrium, prompting the switch to a fixed-exchange rate regime. For robustness, we also consider risk-premium and non-tradable supply shocks, international reserves, and capital controls.

JEL Classification: E44, E52, F31, F41, G01

1 | Introduction

An enduring question in international economics concerns the optimal choice of exchange rate regime. The prevailing wisdom, particularly in the early 2000s, held that pegs were excessively prone to crises and that countries should either adopt hard pegs (e.g., currency unions) or allow free floats. This view implicitly assumes that the choice of exchange rate regime is a one-time decision rather than a state-contingent policy.

On the day of the Russian invasion, Ukraine transitioned from a floating to a fixed exchange rate regime. Eighteen months later, as the war's intensity subsided, the National Bank of Ukraine (NBU) reverted to a floating regime (see Figure 1).

This paper examines whether a state-contingent exchange rate regime can be optimal. We develop a tractable open-economy New Keynesian model incorporating both nominal pricing rigidities and frictions in borrowing on international financial markets. We show that a carefully calibrated version of the model can rationalize the NBU's decision. Specifically, the optimal policy response to small contractionary shocks is to allow exchange

rate flexibility, whereas for large shocks—such as an invasion—significant currency depreciation is suboptimal. Moreover, under a flexible inflation-targeting regime implemented with a Taylor-type rule, an equilibrium nominal exchange rate may fail to exist when the economy is subjected to a large contractionary shock. In this scenario, shifting to a fixed exchange rate regime can restore a nominal anchor.

The key insight of the model is the interaction between two frictions. The first is a standard nominal firm price rigidity: absent additional distortions, policymakers can insulate the economy from external shocks by prioritizing domestic price stability, even at the cost of currency depreciation. However, like many emerging economies, Ukraine relies on external borrowing, predominantly denominated in US Dollars. As a result, large exchange rate fluctuations can destabilize the financial sector. In our model, financial frictions bind only when shocks are sufficiently large, in which case currency depreciation exacerbates banking sector distress.

Our contribution is twofold. First, we develop a stylized analytical framework that formalizes and elucidates these policy

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FIGURE 1 | Changing exchange rate regimes. *Source:* National Bank of Ukraine, www.finance.ua.

trade-offs. Second, despite its tractability, we carefully calibrate the model to the Ukrainian economy to assess the quantitative significance of these mechanisms.

To assess the robustness of our results, we end by extending the model in several directions. First, we broaden the nature and scope of the invasion shock by causing it to not only reduce tradable output but also increase risk premiums on foreign borrowing and disrupt supply in the non-tradable sectors. Second, we introduce foreign exchange reserves and capital controls to the model and assess to what extent the fixed exchange regime was credible and sustainable.

The remainder of the introduction provides additional narrative context for the NBU’s policy decisions in 2022 and situates our contribution within the literature.

1.1 | Context

For many years, Ukraine delayed adopting a floating exchange rate regime due to concerns over macro-financial stability and the effectiveness of monetary policy. These concerns were driven by the country’s open economic structure, underdeveloped financial markets, and the widespread use of administered prices. As a result, the exchange rate remained effectively pegged to the U.S. dollar until 2014.¹

In February 2014, the NBU transitioned to a floating exchange rate regime in response to economic, geopolitical, and financial pressures, including the rapid depletion of foreign exchange reserves, which made maintaining a fixed exchange rate unsustainable. By December 2016, the NBU had formally adopted an inflation-targeting framework aimed at ensuring price stability. In the context of the Mundell-Fleming trilemma, the NBU

pursued an independent monetary policy and free capital movements while allowing the exchange rate to float. By 2021, the NBU had evolved into a modern central bank, balancing post-pandemic economic recovery with inflation control amid Covid-induced global supply chain disruptions.

By late 2021, financial pressures on Ukraine began to intensify as geopolitical tensions escalated. The first signs of strain appeared in the foreign exchange market, where the Hryvnia (UAH) depreciated (see Figure 1). To stabilize the currency, the NBU stepped up its foreign exchange interventions in early 2022. However, the Russian invasion of Ukraine in February 2022 radically altered the monetary landscape, prompting the NBU to rapidly adjust its operations.²

On February 23, 2022, the eve of the invasion, and facing renewed depreciation pressures, the NBU sought to calm markets. However, following Russia’s attack on February 24, the NBU implemented capital controls, restricted foreign currency withdrawals, and shifted to a fixed exchange rate regime (UAH/USD = 29.25).³

The economic shock from the invasion was severe. One-third of businesses ceased operations due to the destruction of production facilities, supply chain disruptions, and soaring production costs. As a result, GDP and tradable goods output contracted by 37% and 41%, respectively, year-over-year at the height of the crisis in 2022q2 (see Figure 2).

A parallel foreign exchange market emerged due to excess demand for foreign currency under the fixed exchange rate system. Figure 1 depicts one such shadow market, where individuals posted buy and sell prices on the finance.ua website.⁴ The shadow rate consistently exceeded the official rate, with the gap widening until July 27, 2022, when the NBU devalued the currency (to UAH/USD = 36.57).

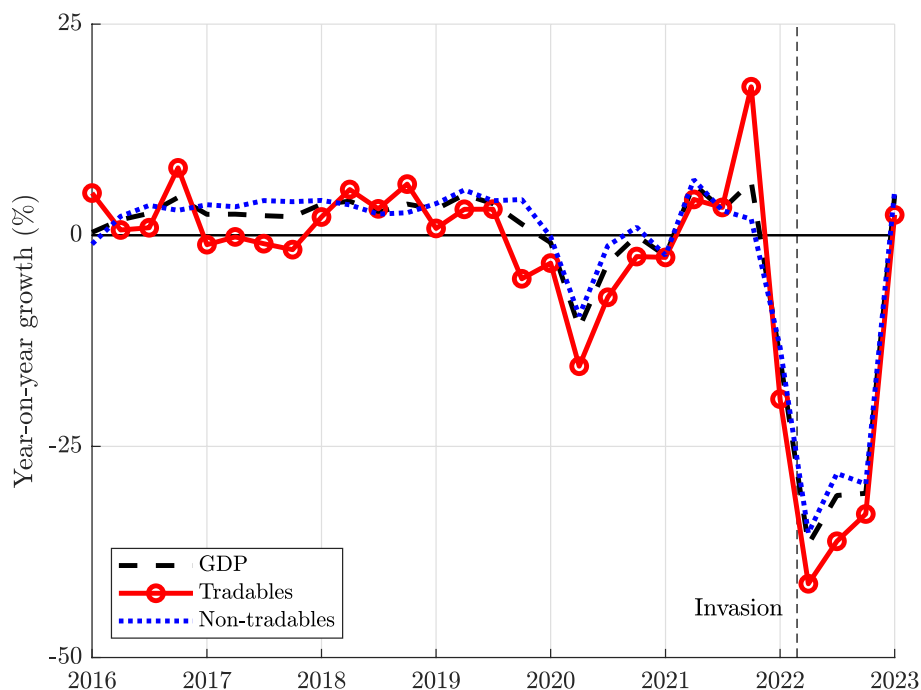


FIGURE 2 | Collapse in economic activity. *Source:* State Statistics Service of Ukraine. Tradables is the sum of Agriculture, forestry and fishing; Mining and quarrying; and Manufacturing. Non-tradables is GDP minus tradables; Taxes on products; and Subsidies on products. All in constant prices.

Despite an interest rate hike (see Appendix A, Figure A1), the gap persisted until October 2022. As international financial support increased and military conditions stabilized, the gap narrowed, reducing devaluation risks. After over a year of maintaining a fixed exchange rate, the NBU returned to a floating regime on October 3, 2023, supported by strengthened reserves, macroeconomic stabilization, and commitments under the IMF Extended Fund Facility.

1.2 | Literature

This paper contributes to four strands of the literature. First, it builds on research examining the role of central banks during wartime. While much of this literature (e.g., Poast 2015; Roselli 2025) focuses on monetary financing, we instead analyze the optimal choice of exchange rate regime in response to large external shocks.

Second, we contribute to studies on the economic consequences of the Russia-Ukraine war (e.g., Gorodnichenko et al. 2022; Liadze et al. 2023; Becker and di Mauro 2024). While much of this literature examines global spillovers—such as disruptions to food and energy markets—or long-term reconstruction policies, we instead conduct a normative analysis of one key monetary policy decision: the NBU’s decision to fix the exchange rate at the onset of the invasion. Using a structural model, we assess whether this policy choice was optimal given the economic constraints Ukraine faced.

Third, our analysis aligns with the Integrated Policy Framework agenda developed at the IMF (e.g., Basu et al. 2020; Adrian et al. 2020).⁵ This framework moves beyond the traditional

Mundell-Fleming paradigm by recognizing the role of financial frictions, currency mismatches, and external borrowing constraints in shaping optimal monetary policy.⁶ Our contribution lies in highlighting the presence of non-linearities that generate state-dependent policy prescriptions: while exchange rate flexibility is desirable in response to small contractionary shocks, large shocks—such as an invasion—can render significant depreciation suboptimal.

Finally, our work connects to the literature on exchange rate interventions under financial frictions, particularly Gabaix and Maggiori (2015). Similar to their framework, we model imperfections in international financial intermediation, but we extend this analysis by incorporating optimal policy responses in the presence of both nominal rigidities and financial constraints.

The remainder of the paper is structured as follows. Section 2 develops the model. Section 3 presents the results. Section 4 concludes.

2 | Model

The environment is a small open economy with frictions in firm price setting and in borrowing on international financial markets. We choose the ingredients of the model with an eye to the main empirical properties of the Ukrainian economy at the onset of the Russian invasion and intentionally make several strong assumptions to keep the policy problem as transparent as possible. Time is discrete, with three periods, $t = -1, 0, 1$, where $t = 0$ marks the invasion. We assume prices are only sticky at $t = 0$, and thus we can interpret $t = 0$

as the short-run and $t = 1$ as the long-run. The economy consists of households, firms, banks, and a monetary authority (the NBU).

2.1 | Households

A representative household has preferences over a tradable consumption good, $C_{T,t}$, and a non-tradable consumption bundle, $C_{N,t}$, and hours worked, N_t . It maximizes

$$\mathbb{E}_t \sum_{t=0}^1 \beta^t (U(C_t) - V(N_t)) \quad (1)$$

where $\beta \in (0, 1)$, $U'(\cdot), V'(\cdot) > 0$, $U''(\cdot) \leq 0$, $V''(\cdot) \geq 0$, and $C_t \equiv C(C_{T,t}, C_{N,t})$ is a consumption composite with $C_1, C_2 > 0$, $C_{11}, C_{22} < 0$ and $C_{12} \geq 0$. Households can borrow (or save), D_t , in the domestic currency from domestic banks at a nominal interest rate, i_t^L .⁷ The budget constraint is given by

$$P_{N,t}C_{N,t} + P_{T,t}C_{T,t} + (1 + i_{t-1}^L)D_{t-1} \leq D_t + W_tN_t + P_{T,t}Y_{T,t} + \tilde{\Phi}_t^F + \Phi_t^B \quad (2)$$

where $P_{T,t}$ and $P_{N,t}$ are the price of tradable and non-tradable goods in domestic currency, respectively, W_t is the nominal wage rate, $Y_{T,t}$ is an (exogenous and stochastic) endowment of tradable goods, and $\tilde{\Phi}_t^F$ and Φ_t^B are firms' and banks' profits, respectively.⁸

Movements in $Y_{T,0}$ can be interpreted either as shocks to the physical availability of tradable goods or as shocks to Ukraine's terms of trade. Our baseline scenario is one in which the Russian invasion leads to a large fall in Ukraine's endowment of tradable goods.

We denote E_t , the nominal exchange rate, expressed as the Ukrainian Hryvnia (the home currency) over US Dollars (the foreign currency), or UAH/USD. Thus, an increase in E_t is a depreciation of the Ukrainian currency. We assume that the law of one price holds for tradable goods. This implies $P_{T,t} = P_{T,t}^* E_t$. We assume the foreign currency price of tradables is constant and normalized to $P_{T,t}^* = 1$. Thus, the nominal price of tradables equals the nominal exchange rate.

$$P_{T,t} = E_t \quad (3)$$

The first-order conditions of the household problem are given by

$$\frac{C_{2,t}(\cdot)}{C_{1,t}(\cdot)} = \frac{P_{N,t}}{E_t} \quad (4)$$

$$\frac{V'(N_t)}{U'(\cdot)C_{2,t}(\cdot)} = \frac{W_t}{P_{N,t}} \quad (5)$$

and

$$1 = \mathbb{E}_t \beta \frac{U'_{t+1}(\cdot)C_{1,t+1}(\cdot)}{U'_t(\cdot)C_{1,t}(\cdot)} \frac{E_t}{E_{t+1}} (1 + i_t^L) \quad (6)$$

Since the model is just two periods, there are two copies of Equations (4) and (5) and one copy of Equation (6) in the system of equilibrium conditions. Equation (4) describes the

household's demand for non-tradable goods as a function of the relative price of non-tradable goods in terms of tradable goods, $P_{N,t}/E_t$, and the level of tradable consumption, $C_{T,t}$. Given $C_{T,t}$, the demand for non-tradable goods is decreasing in the relative price, $P_{N,t}/E_t$. An increase in the consumption of tradable goods shifts the demand schedule for non-tradable goods outwards.

2.2 | Firms

The supply side of the economy follows a canonical New Keynesian structure. Two types of firms produce non-tradable goods—intermediate and final goods firms. Intermediate goods, Y_t^I , are produced by intermediate goods firms out of labor according to

$$Y_t^I = A_t F(N_t) \quad (7)$$

where $F'(\cdot) > 0$ and $F''(\cdot) \leq 0$ and A_t is productivity. It sells the intermediate good to final goods firms in a competitive market by solving

$$\max_{N_t} P_t^I A_t F(N_t) - W_t N_t \quad (8)$$

Optimality ensures

$$P_t^I = \frac{W_t}{A_t F'(N_t)} \quad (9)$$

A unit continuum of final goods firms are indexed by j . They convert intermediate goods into differentiated final goods one-for-one. Non-tradable consumption, $C_{N,t}$, is a CES aggregate of differentiated final goods: $C_{N,t} = \left(\int_0^1 C_{N,t}(j)^{1-1/\epsilon} \right)^{1/\epsilon}$. Hence, final goods firms face the following downward-sloping demand curve: $Y_{N,t}(j) = (P_{N,t}(j)/P_{N,t})^{-\epsilon} Y_{N,t}$, where $\epsilon > 1$ is the elasticity of substitution across varieties.

At $t = 0$, we assume that a fraction $\theta \in [0, 1]$ of firms are unable to change their prices and must set $P_{N,t}(j) = P_{N,t-1}$. The remainder, $1 - \theta$, can re-optimize. All final goods firms can re-optimize prices in $t = 1$.⁹ Thus, re-optimizers solve

$$\max_{P_{N,t}(j)} \Phi_t^F(j) = \left(P_{N,t}(j) - (1 - \phi) \frac{W_t}{A_t F'(N_t)} \right) \left(\frac{P_{N,t}(j)}{P_{N,t}} \right)^{-\epsilon} Y_{N,t} \quad (10)$$

where ϕ is a labor subsidy. This is set as $(1 - \phi) = 1 - 1/\epsilon$, removing the steady state distortion arising from monopolistic competition. The first-order condition for re-optimizers is given by

$$P_{N,t}(j) = \frac{W_t}{A_t F'(N_t)} \quad (11)$$

Thus, all re-optimizing firms set the same price, namely $P_{N,t}(j) = P_t^I$. The aggregate price level in $t = 0$ and $t = 1$ is given by

$$P_{N,0} = \left(\theta P_{N,-1}^{1-\epsilon} + (1 - \theta) (P_0^I)^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}} \quad (12)$$

$$P_{N,1} = P_1^I \quad (13)$$

2.3 | Banks

Domestically owned banks receive (exogenous) equity injections, \mathcal{N}_t , from households; raise funding on international financial markets, F_t (expressed in USD) which is repaid at the interest rate, i_t^* ; either lend domestically to households or hold nominal risk-free government bonds, B_t , that pay i_t ; and transfer unretained profits back to households. The balance sheet is given by

$$D_t + B_t = E_t F_t + \mathcal{N}_t \quad (14)$$

The banker's objective is to maximize the present discounted value of end-of-period profits.

$$\max_{D_t, B_t} \mathbb{E}_t \mathcal{D}_{t,t+1} \left((1+i_t^L) D_t + (1+i_t) B_t - (1+i_t^*) E_{t+1} F_t \right) \quad (15)$$

(where $\mathcal{D}_{t,t+1}$ is the household's stochastic discount factor), subject to the balance sheet constraint and the following leverage constraint:

$$\frac{D_t}{\mathcal{N}_t} \leq \Theta, \quad \text{where } \Theta \geq 1 \quad (16)$$

We assume that government bonds are in zero supply, so B_t only serves to model how banks set the domestic lending rate in response to movements in the risk-free (policy) interest rate. Since banks are indifferent between lending to households and holding risk-free government bonds, $i_t^L = i_t$. If the leverage constraint does not bind, the bank's first-order condition is given by

$$\mathbb{E}_t \mathcal{D}_{t,t+1} \left((1+i_t) - (1+i_t^*) \frac{E_{t+1}}{E_t} \right) = 0 \quad (17)$$

which is the Uncovered Interest Parity (UIP) condition.¹⁰ If, instead, the leverage constraint does bind, the UIP condition is replaced by

$$\frac{D_t}{\mathcal{N}_t} = \Theta \quad (18)$$

and the UIP condition does not hold.

A fraction $\omega \in [0, 1]$ of profits is transferred lump sum to the households. The remainder is retained by banks as net worth. Hence, net worth in $t = 0$ is given by

$$\mathcal{N}_0 = (1+i_{-1}) D_{-1} - (1+i_{-1}^*) \frac{E_0}{E_{-1}} (D_{-1} - \mathcal{N}_{-1}) \quad (19)$$

Since the only time 0 variable on the right-hand side of Equation (19) is E_0 , this equation makes clear that any depreciation of the exchange rate in $t = 0$ impacts the net worth that banks have in $t = 0$. If net worth is too low, this can cause the leverage constraint to bind and hamper lending to households.

2.4 | The Monetary Authority

In the model, the National Bank of Ukraine can set either the nominal risk-free "policy" interest rate, i_t , or the nominal exchange

rate, E_t . In the baseline, we abstract from modeling capital controls or the quantity of foreign exchange reserves. As a result, in line with the Mundell–Flemming trilemma, the NBU cannot set i_t and E_t independently.¹¹ We assume that the NBU can follow one of three possible policy regimes. Under Regime 1, the NBU follows an inflation-targeting regime using the following Taylor-type rule:

$$1+i_t = \beta \Pi_t^{\phi_\pi} \left(\frac{GDP_t}{GDP_{t-1}} \right)^{\phi_y} \quad (20)$$

We calibrate the Taylor rule parameters to standard values: $\phi_\pi = 1.5$ and $\phi_y = 0.25$.

Under Regime 2, the NBU sets the nominal exchange rate optimally. That is, the NBU chooses E_0 to maximize Equation (1) subject to all the price sector equilibrium constraints. Under this regime, the policy interest rate works as a passive instrument and is set (endogenously) based on the decision regarding the exchange rate.¹² Finally, under Regime 3, the NBU imposes a fixed exchange rate regime at $E_0 = 1$. We will discuss the equilibrium interest rates that occur under the fixed exchange rate regime when we present the results in Section 3.

2.5 | Closing the Model

The aggregate resource constraint of the economy is given by

$$0 = (\mathcal{N}_{-1} - D_{-1}) + \frac{1}{1+i^*} (Y_{T,0} - C_{T,0}) + \frac{1}{(1+i^*)^2} (Y_{T,1} - C_{T,1}) \quad (21)$$

with its derivation in Appendix B. The link between consumption and production is given by

$$Y_{N,t} = C_{N,t} = \frac{1}{PD_t} A_t F(N_t) \quad (22)$$

where

$$PD_t = \theta \left(\frac{P_{N,t-1}}{P_{N,0}} \right)^{-\epsilon} + (1-\theta) \left(\frac{P_0^I}{P_{N,0}} \right)^{-\epsilon} \quad (23)$$

is the distortion arising from price dispersion. Finally, for the baseline numerical results, we select the following functional forms:

$$U(C_t) = \log(C_t) \quad (24)$$

$$V(N_t) = \chi N_t \quad (25)$$

$$C(C_{T,t}, C_{N,t}) = C_{T,t}^\alpha C_{N,t}^{1-\alpha}, \quad \text{and} \quad (26)$$

$$F(N_t) = N_t \quad (27)$$

There are three points of note regarding these functional forms. One, it implies that tradable and non-tradable consumption are additively separable for household welfare and that the intra- and intertemporal elasticities of substitution are equal and set to unity. This restriction simplifies solving the equilibrium because equilibrium external debt and tradable consumption are

TABLE 1 | Calibration.

i^*	α	β	θ	ε	Θ	D_{-1}	\mathcal{N}_{-1}	$P_{N,-1}$	A_0	A_1	$Y_{T,0}$	$Y_{T,1}$
0.10	0.47	0.91	1/3	9	12.5	0.44	0.044	0.53	1	1	1	1.48

independent of the level of non-tradable output in the case of only nominal frictions. It means that any welfare differences across exchange regimes can be attributed to the effects of the exchange rate policy on the non-tradable sector and not on the dynamics of external debt.

Two, it implies workers face a constant marginal disutility of labor and that the production function is linear in labor. Under these assumptions, the number of hours worked adjusts automatically to support goods market equilibrium, so we can determine equilibrium prices and quantities in the goods markets without explicitly solving for labor hours first.

Finally, since the dis-utility of labor is linear and prices in the tradable sector are flexible, we can add tradable production without affecting the equilibrium as long as labor is perfectly substitutable across sectors and tradable production is also linear in labor. In that case, $Y_{T,t} = A_{T,t}N_{T,t}$ and productivity, $A_{T,t}$, would be the exogenous and stochastic term that falls in the event of the Russian invasion.

2.5.1 | The Efficient Equilibrium

We conclude the model description by characterizing the efficient allocation in which prices are fully flexible and the financial sector leverage constraint does not exist. In this case, the equilibrium is defined by

$$\chi C_{N,t} / (1 - \alpha) = A_t \quad \text{for } t = 0, 1 \quad (28)$$

$$1 = \beta \frac{C_{T,0}}{C_{T,1}} (1 + i^*) \quad (29)$$

$$D_{-1} - \mathcal{N}_{-1} = \frac{1}{1 + i^*} (Y_{T,0} - C_{T,0}) + \frac{1}{(1 + i^*)^2} (Y_{T,1} - C_{T,1}) \quad (30)$$

for $\{C_{T,0}, C_{T,1}, C_{N,0}, C_{N,1}\}$. Note that equilibrium in the non-tradable goods sector is disconnected from equilibrium in the tradable goods sector. A fall in the tradable endowment, $Y_{T,0}$, leads to an increase in borrowing and a less than one-for-one fall in consumption of the tradable consumption good. Hours worked and consumption of the non-tradable good remain unchanged.

2.5.2 | Monetary Policy Shocks

Since this paper addresses the design of monetary policy under extreme conditions, it is first useful to verify that the model behaves sensibly in response to small policy shocks.

Proposition 1. *In response to small monetary policy shocks, ξ_0 .*

$$\frac{\partial P_{N,0} / P_{N,0}}{\partial \xi_0} \propto - (1 - \theta) < 0 \quad (31)$$

$$\frac{\partial C_{N,0} / C_{N,0}}{\partial \xi_0} \propto - \theta < 0 \quad (32)$$

The derivation of the results in Proposition 1 is provided in Appendix E. The proposition states that a monetary tightening reduces both inflation and output. The relative magnitude of the inflation response vis-à-vis the output response depends on the Calvo parameter, θ . When $\theta = 0$ (full price flexibility), we have monetary neutrality and when $\theta = 1$, prices are fully fixed.

2.6 | Calibration

The baseline steady-state calibration is summarized in Table 1. Each period is calibrated to 1 year. We set the utility weight on labor to $\chi = 0.25$ and normalize the productivity of non-tradable production to $A_0 = A_1 = 1$. The tradable endowment in period 0 is also normalized to $Y_{T,0} = 1$. The calibration ensures that the optimal exchange rate in steady state is normalized to $E_0 = 1$.

In steady state, the nominal policy interest rate is set to $i = 10\%$, corresponding to the NBU's “policy” interest rate at the onset of the invasion. We also set $i^* = 10\%$, the interest rate at which banks can borrow internationally in US Dollars. This is a premium over the Federal funds rate, which was still at the effective lower bound in early 2022.¹³ The subjective discount factor is given by $\beta = 1 / (1 + i^*)$. We calibrate our steady state by targeting two empirical moments. First, the ratio of tradable output to total output, $Y_T / (Y_T + Y_N)$, was 32% in Ukraine in 2021.¹⁴ Second, according to Lane and Milesi-Ferretti (2018), the net foreign asset-to-GDP ratio, D / GDP , was -14% in Ukraine in 2021 (where $GDP_t = Y_{T,t} + Y_{N,t}$). We calibrate α (the weight on tradable consumption in utility) and $Y_{T,1}$ (the tradable endowment in period 1) to match these two empirical moments, yielding $\alpha = 0.47$ and $Y_{T,1} = 1.48$.

From the flexible-price equilibrium, we obtain the non-tradable price level, $P_N = 0.53$, and set $P_{N,-1} = P_N$, ensuring that firms have no incentive to adjust prices in steady state. Regarding firms' pricing behavior, we set the probability of a firm not able to adjust its price to $\theta = 1/3$, implying an average price adjustment interval of 1.5 years. We also set the elasticity of substitution across varieties to $\varepsilon = 9$, following Galí (2015), which corresponds to a markup of 12.5%.

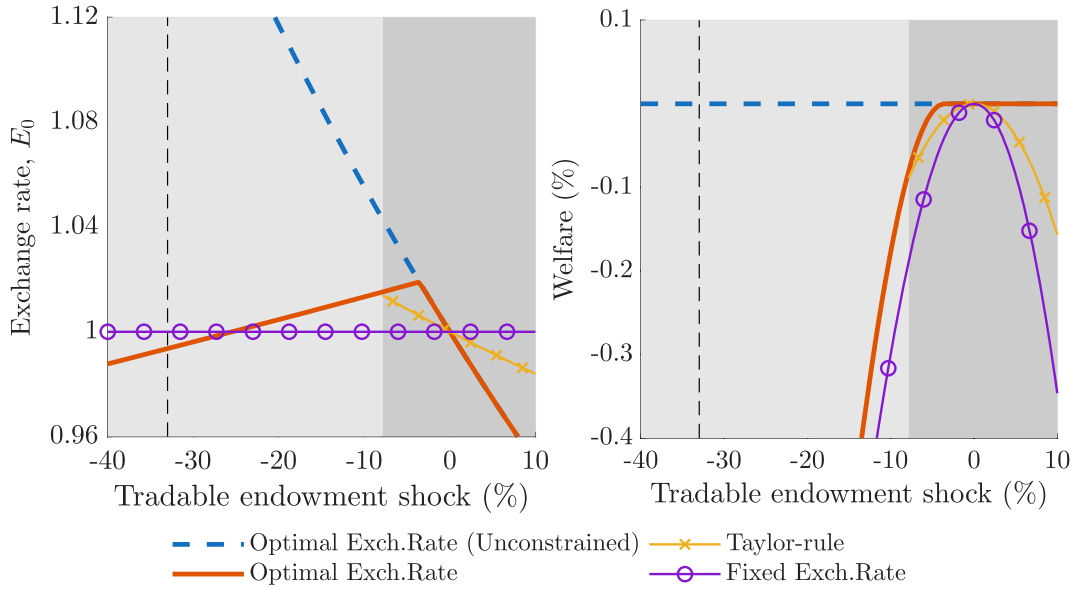


FIGURE 3 | Response to the tradable endowment shock. Welfare is calculated as the percentage of $C_{T,0}$ that the household would forgo in the efficient equilibrium so as to be indifferent to receiving the actual allocation. For example, a -10% change in the tradable endowment under the scenario with both nominal and financial frictions and with the optimal exchange rate, the household would forgo 0.25% of the efficient level of $C_{T,0}$. The light gray shading indicates the region of shock size for which no equilibrium exists under the Taylor-rule.

At the end of 2021, Ukraine’s banking system had a regulatory capital-to-net asset ratio of 10% , exceeding the regulatory minimum of 8% . Translating this into the model’s leverage constraint, we set $\Theta = 12.5$ and $D/\mathcal{N} = 10$, ensuring that the financial friction does not bind in steady state.¹⁵ Given the level of GDP in the flexible-price steady state, this calibration implies $D_{-1} = 0.44$ and $\mathcal{N}_{-1} = 0.044$.

Three additional empirical observations are noteworthy. First, GDP and tradable output contracted by -29% and -33% , respectively, between 2021 and 2022, leading us to adopt -33% as our baseline crisis scenario. Second, the nominal UAH/USD exchange rate was fixed at 29.25 at the onset of the crisis, which we normalize to $E_0 = 1$. The subsequent devaluation in June 2022 to 36.57 corresponds to $E_0 = 1.25$, implying a 25% depreciation. Third, at the start of 2022, bank liabilities denominated in foreign currency amounted to 11.25% of GDP, aligning with our model’s assumption that net foreign liabilities are denominated in foreign currency.

Finally, for our baseline scenario, we consider shocks to the tradable endowment, $Y_{T,0}$. In the robustness exercises, we add correlated shocks of either i_t^* (“risk-premium” shocks) or ε (non-tradable “cost-push” shocks).

3 | Results

Figures 3 and 4 present the baseline results based on the calibration of the model outlined in Section 2.6. In each panel, the x-axis is the magnitude of the $t = 0$ tradable endowment shock. Zero marks the steady state and the dashed vertical line at -33% marks the year-over-year fall in tradable output experienced by Ukraine in 2022q2. Figure 3 shows the exchange rate and welfare, and Figure 4 shows other variables of interest such as GDP, inflation, bank leverage, and the “policy” interest rate.

First, we analyze the role of the nominal firm price rigidity in isolation. Second, we extend our analysis to include the friction related to borrowing on international financial markets. Third, we conduct several robustness exercises related to the nature of the “invasion shock” and some of the features of the model.

3.1 | Nominal Rigidities Only

For now, we abstract from the frictions in borrowing on international financial markets. The equilibrium consists of seven variables: $\{C_{T,0}, C_{T,1}, C_{N,0}, C_{N,1}, P_0^I, P_{N,0}, E_0\}$ and the following equations:

$$\chi C_{N,0} / (1 - \alpha) = A_0 \frac{P_0^I}{P_{N,0}} \quad (33)$$

$$\chi C_{N,1} / (1 - \alpha) = A_1 \quad (34)$$

$$P_{N,0} = \left(\theta P_{N,-1}^{1-\varepsilon} + (1-\theta)(P_0^I)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}} \quad (35)$$

$$\frac{(1 - \alpha)C_{T,0}}{\alpha C_{N,0}} = \frac{P_{N,0}}{E_0} \quad (36)$$

$$1 = \beta \frac{C_{T,0}}{C_{T,1}} (1 + i^*) \quad (37)$$

$$0 = (\mathcal{N}_{-1} - D_{-1}) + \frac{1}{1 + i^*} (Y_{T,0} - C_{T,0}) + \frac{1}{(1 + i^*)^2} (Y_{T,1} - C_{T,1}) \quad (38)$$

where the system is closed, either by solving for E_0 to maximize household welfare (Regime 2) or by setting E_0 to a fixed value (Regime 3), or by imposing the Taylor rule (Regime 1).

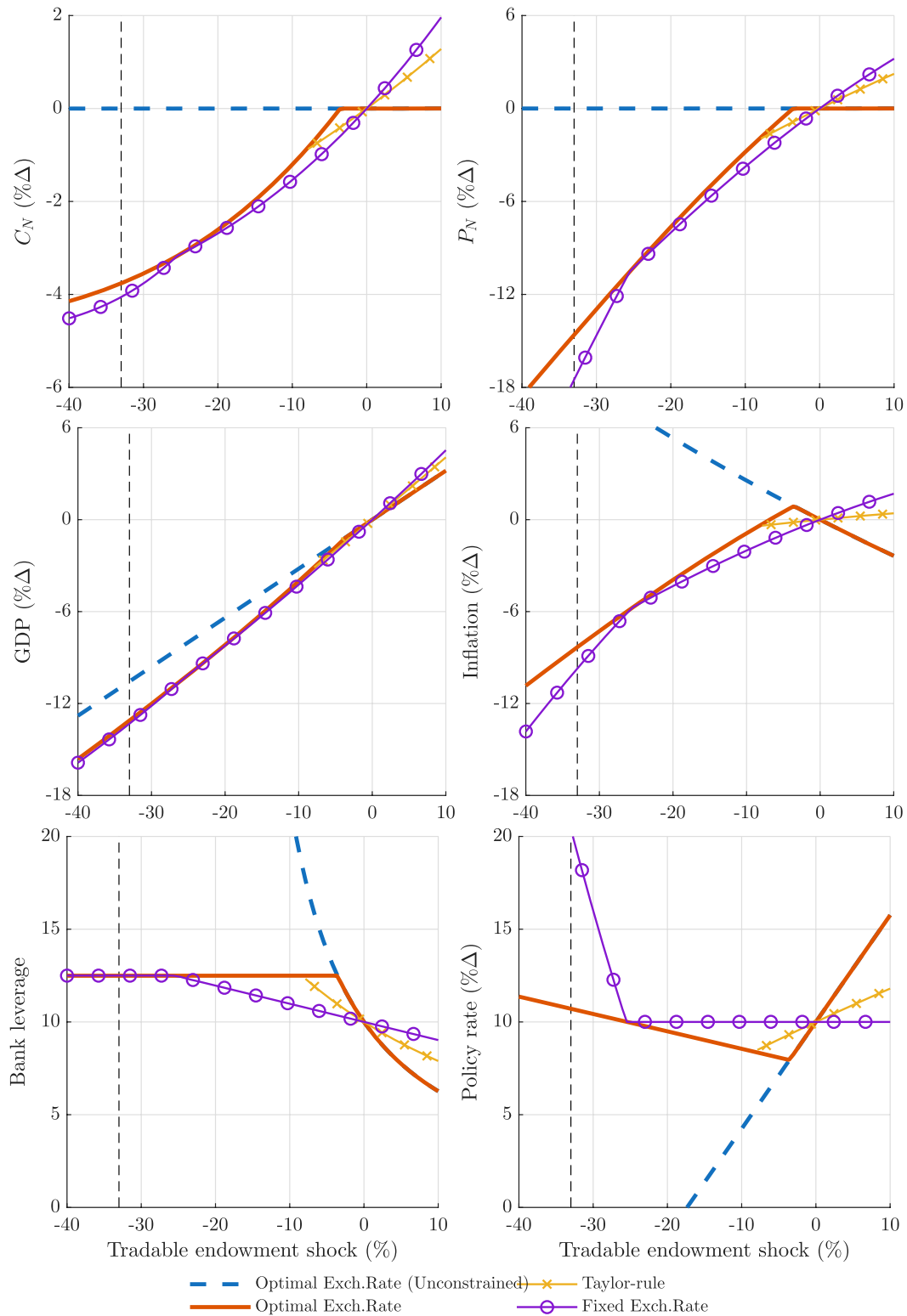


FIGURE 4 | Response to the tradable endowment shock: More variables.

The equilibrium in which the exchange rate, E_0 , is chosen optimally (Regime 2) is the dashed-blue line in Figures 3 and 4. The downward-sloping exchange rate curve indicates that the optimal policymaker wants to depreciate the currency when the tradable endowment falls. The flat welfare curve (calculated in consumption-equivalent terms relative to the efficient flexible price equilibrium) illustrates that the “divine coincidence”

holds, as the economy attains the same level of welfare as in the efficient flexible price equilibrium.

Consider a fall in $Y_{T,0}$. Equations (37) and (38) continue to determine $C_{T,0}$ as in the flexible price equilibrium. Then, by Equation (36), the central bank can raise E_0 (i.e., depreciate the currency) such that consumption of the non-tradable good

and domestic prices remain unchanged, preventing the price-adjustment friction from binding: $P_{N,0} = P_0^I = P_{N,-1}$. In this case, the ratio of prices drops out from the right-hand side of Equation (33). This result represents the “divine coincidence” as the policymaker can replicate the efficient flexible price equilibrium.

The Taylor-rule (yellow line with \times markers) under Regime 1 implies a qualitatively similar (i.e., downward sloping) response curve, indicating that the Taylor-rule prescribes a lowering of the policy rate (and a weakening of the currency) in response to a small negative tradable shock. This is not surprising given that both inflation and GDP fall in response to the shock.¹⁶ However, the response of the exchange rate is smaller under the Taylor-rule. A Taylor-rule could replicate the optimal policy equilibrium by instead aggressively targeting non-tradable price inflation.¹⁷

Now, suppose instead that the exchange rate is fixed under Regime 3 (purple line with \circ markers). Consumption smoothing of tradable goods implies a fall in $C_{T,0}$ in response to a fall in $Y_{T,0}$. Given a fixed level of non-tradable consumption, $C_{N,0}$, the relative price of non-tradable goods must therefore decrease, by Equation (36). In the absence of a nominal exchange rate appreciation, this adjustment must occur through either a decline in the price of non-tradable goods or a reduction in non-tradable consumption. Under flexible price adjustment, this would occur entirely through price changes. However, because prices are sticky, they adjust downward but not sufficiently, resulting in an inefficient decline in $C_{N,0}$ and a drop in domestic inflation. With only nominal frictions, a fixed exchange rate regime is always suboptimal compared to an appropriate depreciation in response to a fall in the tradable endowment.

Finally, although auxiliary to the equilibrium model, we can compute the domestic policy rate (in the bottom-right panel of Figure 4). The optimal exchange rate depreciation naturally corresponds to a reduction in the policy interest rate, whereas under the fixed exchange rate regime, the policy rate remains tied to the world interest rate, i^* .

3.2 | Both Nominal and Financial Frictions

Next, we reintroduce the frictions in borrowing on international financial markets. Our baseline calibration implies that, in steady state, the financial system is unconstrained. Thus, as in the section above, in response to small shocks, the optimal response is a depreciation of the nominal exchange rate. Since banks have borrowed in foreign currency, this fall in the exchange rate causes a decline in bank profits from legacy liabilities, and thus a reduction in net worth, \mathcal{N}_0 , of banks in period 0. The contraction in the tradable endowment also creates a desire for households to borrow more, increasing D , to smooth consumption of tradable goods. If this fall in \mathcal{N}_0 and increase in D is small enough that the leverage constraint does not bind, then the equilibrium allocation remains unchanged from the model with a frictionless banking sector.

However, if the shock is large enough, the unconstrained optimal rise in E_0 causes such a significant decline in \mathcal{N}_0 that the

leverage constraint binds and banks cannot borrow on international markets to finance the desired borrowing of households. As a result, the policymaker faces a trade-off, since a depreciation of the exchange rate, while beneficial for ensuring domestic price stability, causes a sudden stop in capital flows (and creates a suboptimal allocation of tradable consumption across $t = 0$ and $t = 1$).

Returning to Figures 3 and 4, the solid red line shows the equilibrium under the optimal determination of the exchange rate in the presence of both nominal and financial frictions. In response to small negative tradable endowment shocks, the optimal response is to allow the exchange rate to depreciate. However, once the negative shocks exceed a certain size (approximately -5%), the policymaker no longer wants a large depreciation because of its effect on banks' financing frictions. When the shock is -33% (i.e., calibrated to the post-invasion drop in tradable output), the optimal policy actually calls for a modest appreciation (of 1%) rather than a 18% depreciation (the dashed blue line). Thus, the optimal policy response closely approximates the NBU's approach of imposing a fixed exchange rate regime.¹⁸

Nevertheless, a strict fixed exchange rate regime remains suboptimal. In particular, we plot the policy rate (which equals the interest rate faced by households, i^t) in the bottom-right panel of Figure 4. This demonstrates that, under such a scheme, the domestic interest rate is almost 9 percentage points higher than under the optimal modest appreciation policy, in which the policymaker would have tightened the policy rate by only 1 percentage point.

Returning to Figure 3, the plots are split into two regions of light and dark gray. The light gray region—when the shock is more severe than approximately -9% —indicates the region for which no equilibrium exists under the Taylor-rule policy. This is akin to the “fear of floating” idea rationalized in Bianchi and Coulibaly (2023). To understand the reason, see Figure 5. In the absence of the financial friction, the household Euler equation (and UIP condition) imposes a partial equilibrium negative relationship between the nominal exchange rate and the policy rate. However, since a weaker exchange rate is expansionary, the Taylor-rule-prescribed policy rate is increasing in the nominal exchange rate. Thus, in general equilibrium, there is a unique equilibrium interest rate and exchange rate pair that satisfies both these partial equilibrium conditions (see the solid lines in the figure). However, when the shock is large and negative, the partial equilibrium conditions are given by the dotted lines in the figure. Two things happen. First, the Taylor rule curve shifts down (prescribing a lower policy rate for any given exchange rate). Second, when E_0 is higher, the leverage constraint on banks binds, causing the household Euler equation to impose a partial equilibrium positive relationship between the nominal exchange rate and the policy rate. As a result, there is no exchange rate that satisfies both conditions.

The policy implication of this result is that in response to small shocks, a flexible inflation-targeting regime described by a Taylor-rule dominates over a fixed exchange regime, but when there is a severe negative shock (such as the Russian invasion

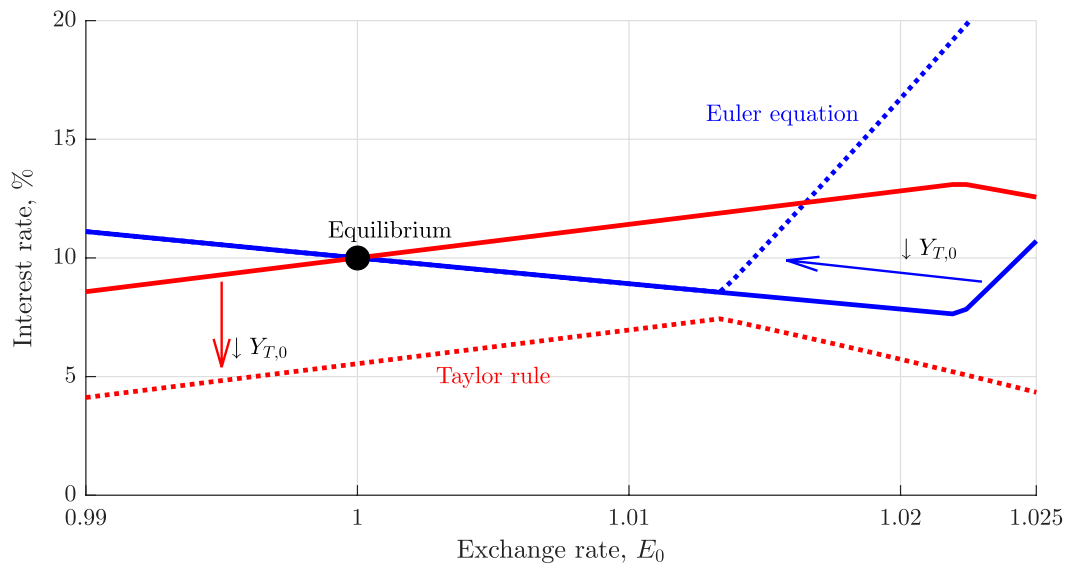


FIGURE 5 | Fear of floating. The solid lines are drawn for the steady state in which $Y_{T,0} = 1$. The equilibrium nominal exchange rate is $E_0 = 1$. The dotted lines are drawn for the case in which $Y_{T,0} = 0.9$ (a shock of -10%). In this case, no equilibrium exchange rate exists that is consistent with both the household Euler equation and the Taylor-rule implied policy rate.

of Ukraine), fixing the exchange rate is imperative to provide a nominal anchor to the economy.

3.3 | Robustness

In the Appendix, we present three robustness checks that extend the baseline model to account for additional factors and alternative assumptions that could influence the optimal policy response during times of crisis. Below, we provide a brief description of each.

3.3.1 | Foreign Exchange Reserves & Capital Controls

In Appendix C, we add official foreign exchange reserves to the model and calculate the loss of reserves required to maintain a fixed exchange rate and unchanged domestic interest rates. We find that under our invasion-size shock, the NBU would have lost between 10% and 66% of its stock of foreign exchange reserves, depending on the severity of capital controls imposed on foreign exchange transactions. Thus, the model views the currency peg imposed by the NBU as unsustainable. Absent foreign exchange interventions, we show that strict capital controls cause a sharp increase in domestic interest rates to offset the increased demand by the private sector for borrowing externally.

3.3.2 | Correlated Risk-Premium Shocks

In Appendix F, we account for the decline in Ukraine’s creditworthiness and the increased risk premium demanded by international investors for lending to Ukraine. In particular, we calibrate the relationship between the fall in tradable output and the rise in the risk premium using two alternative methods. Using a ratings-based default spread, we estimate a 6.70 percentage point rise in borrowing costs, leading to a marginally stronger

optimal exchange rate than in the baseline. Alternatively, using Argentina as a reference, we estimate a smaller rise in borrowing costs (2.90 percentage points). However, the results remain largely unchanged from the baseline, with the optimal exchange rate slightly closer to a fixed regime than in the baseline.

3.3.3 | Correlated Non-Tradable Supply Shocks

In Appendix G, we introduce non-tradable supply shocks to better capture the fall in GDP and the rise in inflation observed in the data. The shock increases prices via markups and decreases demand for non-tradable consumption. Thus, it creates a more meaningful policy trade-off between price stability and output stabilization. As a result, in this scenario, the equilibrium outcomes and policy prescription differ qualitatively from the baseline. However, optimal policy still prescribes a hump-shaped policy response with modest currency depreciation for both small and very large negative shocks and a larger depreciation for moderate-size shocks.¹⁹

4 | Conclusion

The National Bank of Ukraine employed capital controls as an active policy tool at the onset of the Russian invasion to maintain a fixed exchange rate. Later, it transitioned back to a floating (albeit managed) exchange rate regime.

We develop a simple model in which standard monetary policy (i.e., flexible inflation targeting with a Taylor-type rule) and exchange rate flexibility are optimal during “normal” times, when the economy experiences only “normal” shocks. However, in response to a large negative shock, when financial stability issues arise due to a currency mismatch on banks’ balance sheets, a depreciation of the currency can heighten those risks, and the Taylor-rule no longer acts as a suitable nominal anchor. In this

environment, it becomes essential to impose a fixed exchange rate regime to re-establish a nominal anchor for the economy. This episode offers a valuable lesson for other central banks during periods of heightened risks.

We conclude by emphasizing that our model is highly stylized and abstracts from several important considerations. First, our normative analysis is based on a standard criterion—maximizing household welfare. However, in times of existential risk, it is not clear that this welfare criterion appropriately captures those risks. Second, we do not account for tradable goods production or the choice of trade invoicing currency. Additionally, we only briefly address the question of whether an exchange rate peg is sustainable given the central bank's foreign exchange reserves.²⁰ Incorporating these features and examining how they would alter the optimal policy prescription is an important avenue for future research.

In a follow-up paper, de Groot and Skok (2025), we consider two further issues that were relevant considerations for the NBU and the exchange rate at the time of the invasion. First, the defense of the country required a huge increase in fiscal expenditures on military equipment. This equipment largely came in the form of US-dollar-denominated imports. Second, there was concern that a sharp rise in the cost of (tradable) goods such as food and energy would put poorer households in Ukraine close to subsistence consumption levels.

Author Contributions

All authors contributed equally to all the sections.

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Endnotes

- ¹ The NBU outlined the transition to inflation targeting (IT), which functions efficiently alongside a floating exchange rate, in its 2005 Monetary Policy Guidelines.
- ² For a detailed discussion of the monetary and financial risks facing Ukraine, as well as the policy responses undertaken by the NBU during the first year of the war, see de Groot and Skok (2022a, 2022b, 2023).
- ³ Temporary exchange rate fixes during military conflicts have been used by Israel (1985–2005), Serbia (2000–2003), Iraq (2004–2006), and Georgia (2008) to stabilize currency markets and contain inflation.
- ⁴ The gap between the official and shadow exchange rates serves as a proxy for exchange rate pressure.
- ⁵ The former takes an analytical approach with a finite number of periods, as we do; the latter takes a quantitative approach with an infinite-horizon medium-scale DSGE model. Itskhoki and Mukhin (2023) similarly study optimal exchange rate policy in a stylized infinite-horizon model using a linear-quadratic approximation.
- ⁶ Our paper speaks to two further strands of the literature: on “original sin”, when a country is unable to borrow externally in its own

currency (see Eichengreen et al. (2005)'s original findings and Eichengreen et al. (2023) for an update) and “fear of floating”, that countries that say they allow their exchange rate to float mostly do not (see Calvo and Reinhart (2002)'s original findings and Bianchi and Coulibaly (2023) for a recent theoretical contribution).

- ⁷ Since our model features a representative household and no domestic storage technology—i.e., no endogenous physical capital formation—any borrowing or saving in equilibrium is ultimately vis-à-vis the rest of the world, intermediated by the banks in our model.
- ⁸ To be precise, $\tilde{\Phi}_t^F$ are firm profits net of lump sum taxes that pay for a labor subsidy to firms. Thus, $\tilde{\Phi}_t^F \equiv \Phi_t^F - T_t$. The firm problem is defined in Section 2.2.
- ⁹ This assumption implies that time in the model can, in principle, be infinite. It is the assumption that prices are sticky for only one period that ensures the monetary policy problem is static rather than dynamic.
- ¹⁰ In period $t = 1$, prices are fully flexible and the nominal exchange rate is independent of policy. As a result only the relative price of tradable to non-tradable prices is determined in equilibrium. We therefore normalize $E_1 = 1$. The UIP condition then reduces to $(1 + i) = (1 + i^*) / E_0$.
- ¹¹ Appendix C extends the model to account for capital controls and foreign exchange reserves.
- ¹² In the model, this regime is isomorphic to the NBU choosing i to maximize Equation (1) and then backing out the implied E_0 .
- ¹³ Foreign currency borrowing interest rates for Ukrainian borrowers were closer to 4% in early 2022. However, this also reflects substantial differences in inflation in the two countries. Our model assumes Ukraine's inflation rate is zero in steady state.
- ¹⁴ Tradable output is defined as the sum of Agriculture, Forestry and Fishing; Mining and Quarrying; and Manufacturing.
- ¹⁵ The capital-to-net asset ratio in the data is equivalent to the inverse of the asset-to-net worth ratio in the model. Thus, for example, an 8% ratio becomes $1 / 0.08$, which equals 12.5.
- ¹⁶ Focus for now on “small” negative shocks. The absence of the yellow line for larger negative shocks will be explained in the next subsection.
- ¹⁷ The normative prescription to target non-tradable price inflation arises because non-tradable prices are more “sticky” in the model than tradable prices. This is akin to the idea that a central bank should focus on “core” inflation and not react to short-lived and more volatile components of the consumer price index (such as food and energy). See Aoki (2001).
- ¹⁸ We treat the leverage constraint in the model as a regulatory constraint. In that regard, a counter-cyclical regulatory constraint—which would be eased in response to large adverse shocks—would alleviate some of the problems. This mirrors the NBU's actions after the invasion (National Bank of Ukraine 2022): it expanded banks' access to refinancing loans, eased capital and liquidity requirements, and refrained from sanctioning banks for violating prudential standards. However, it is not clear that a market-based constraint (arising, for example, from moral hazard) might not instead become the binding constraint in such a scenario.
- ¹⁹ Our analysis has, thus far, not considered a contractionary TFP shocks to the non-tradable sector as a relevant shock for our analysis. Just like in the canonical New-Keynesian model (see Galí 2015), a contractionary TFP shock causes potential output to decline and thus inflation pressures to build. A standard Taylor rule would thus prescribe a tightening of policy, and under optimal policy, an appropriate appreciation of the nominal exchange rate could replicate the flexible price equilibrium. If one wanted to model the decline in labor supply (due to migration or because of military conscription) in the model, this could be achieved by increasing χ , the disutility weight on labor.

In our model, this would be isomorphic to a fall in A_0 as can be seen from Equation (28).

²⁰ Evidence from the shadow market for UAH/USD suggests that tremendous pressure was exerted on the UAH official exchange rate. It remains unclear whether the peg would have been sustainable without financial support from foreign governments and international financial institutions. Ultimately, the NBU devalued its currency by 25% just a few months later.

²¹ This model of a potential currency crisis is a “third-generation” model where the crisis is associated with a crisis in the financial sector. In contrast, in first-generation currency crisis models economic fundamentals and fiscal sustainability are the primary drivers whereas in second-generation models multiple equilibria and self-fulfilling expectations play a central role. See Burnside et al. (2016) for a detailed overview of the taxonomy of currency crisis models.

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Appendix A

Data

Figure A1 plots the NBU's policy rate. The NBU kept the key policy rate unchanged at the onset of the invasion. In the face of surging inflation, on June 3, 2022, it raised the key policy rate by 15 percentage points from 10% to 25%, prior to the devaluation of the exchange rate on July 21, 2022. Another reason for the sharp increase in the interest rate was the need to remove excess liquidity in the financial system and soften

the demand for foreign currency, which could lead to a significant depreciation of the national currency. The NBU began easing the policy rate in July 2023, ahead of its decision to move to a managed float in October 2023 amid macroeconomic improvements.

Figure A2 plots the return on equity (left axis) and return on assets (right axis) for deposit-taking banks in Ukraine. Both measures fell sharply in the months after the invasion, with the sector posting negative returns. This was the result of (1) increased loan loss provisions (to cover



FIGURE A1 | NBU key policy interest rate. Source: National Bank of Ukraine.

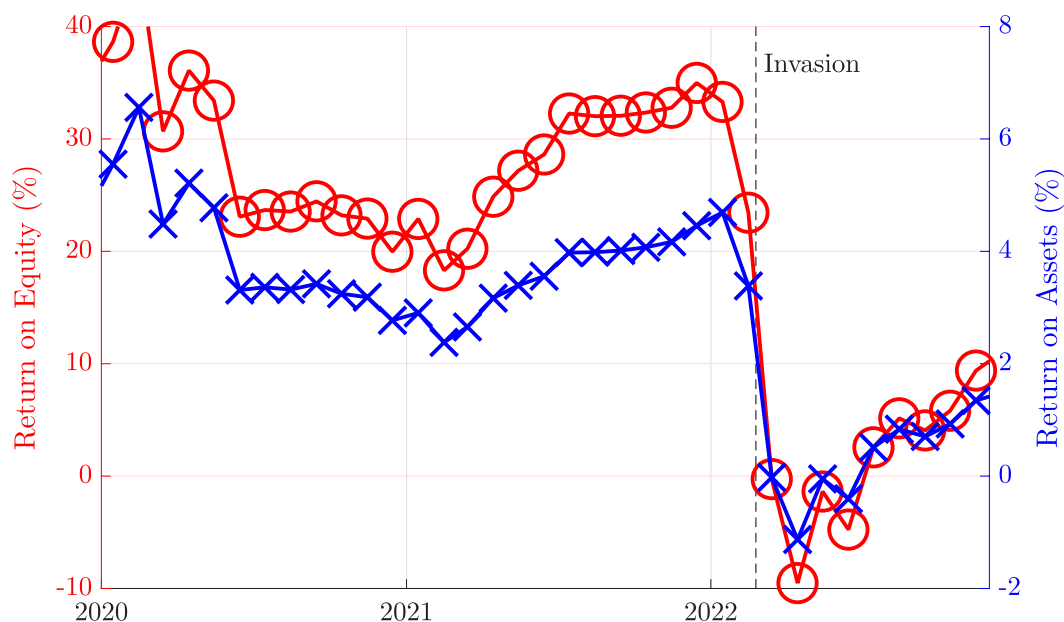


FIGURE A2 | Banks' financial health. Source: National Bank of Ukraine.

expected losses from loans that borrower could no longer repay due to war conditions), (2) a reduction in the value of banks' loan portfolio due to impaired borrowers' ability to repay loans, and (3) direct operational losses because of destroyed physical infrastructure forcing banks to write off assets in occupied or heavily damaged regions. Despite this, the financial sector, with the support from the NBU, remained resilient. This resilience was in part due to banks' earnings from central bank deposit certificates when interest rates were hiked from 10% to 25% in June 2022.

Appendix B

Aggregate Resource Constraint

The household budget constraint is given by

$$P_{N,t}C_{N,t} + P_{T,t}C_{T,t} + (1+i_{t-1})D_{t-1} = D_t + W_tN_t + P_{T,t}Y_{T,t} + \tilde{\Phi}_t^F + \Phi_t^B \quad (\text{B.1})$$

It is straightforward (although rather tedious) to show that revenue from non-tradable consumption is accounted for as follows:

$$P_{N,0}C_{N,0} = W_0N_0 + \Phi_0^F - T_0 \quad (\text{B.2})$$

Hence, the budget constraint simplifies to

$$P_{T,t}C_{T,t} + (1+i_{t-1})D_{t-1} = D_t + P_{T,t}Y_{T,t} + \Phi_t^B \quad (\text{B.3})$$

Since the model has two periods, $\Phi_0^B = 0$ and $D_1 = 0$, and we have

$$E_0C_{T,0} + (1+i_{-1})D_{-1} = D_0 + E_0Y_{T,0} \quad (\text{B.4})$$

$$E_1C_{T,1} + (1+i_0)D_0 = E_1Y_{T,1} + \left((1+i_0)D_0 - (1+i_0^*)\frac{E_1}{E_0}(D_0 - \mathcal{N}_0) \right) \quad (\text{B.5})$$

Rewriting the first constraint and simplifying the second give

$$C_{T,0} + (1+i_{-1})\frac{1}{E_0}D_{-1} = \frac{1}{E_0}D_0 + Y_{T,0} \quad (\text{B.6})$$

$$C_{T,1} = Y_{T,1} - (1+i_0^*)\frac{1}{E_0}(D_0 - \mathcal{N}_0) \quad (\text{B.7})$$

Combining by removing D_0/E_0 gives

$$(1+i_{-1})\frac{D_{-1}}{E_0} - \frac{\mathcal{N}_0}{E_0} = (Y_{T,0} - C_{T,0}) + \frac{1}{(1+i_0^*)}(Y_{T,1} - C_{T,1}) \quad (\text{B.8})$$

Finally, substituting for \mathcal{N}_0 and simplifying once more gives

$$(1+i_{-1}^*)\frac{1}{E_{-1}}(D_{-1} - \mathcal{N}_{-1}) = (Y_{T,0} - C_{T,0}) + \frac{1}{(1+i_0^*)}(Y_{T,1} - C_{T,1}) \quad (\text{B.9})$$

Normalizing $E_{-1} = 1$ and rearranging gives Equation (21).

Appendix C

Foreign Exchange Reserves & Capital Controls

Foreign Exchange Reserves

To model official foreign exchange reserves, S_t , we suppose the following:

$$F^B + E_0S_0 = E_0(1+i^{US})S_{-1} \quad (\text{C.1})$$

$$T_1 = E_1(1+i^{US})S_0 + (1+i_{-1})F_0 \quad (\text{C.2})$$

$$S_0 \geq 0 \quad (\text{C.3})$$

That is, the central bank enters period 0 with a stock of US dollar assets, S_{-1} . It can then reinvest into US dollar assets, S_0 , or sell some of those assets to lend to the domestic banking system, F^B . In period 1, all outstanding foreign exchange reserves are sold and the proceeds transferred lump sum to the household, T_1 . Finally, we impose a non-negativity constraint on foreign exchange reserves.

Since the balance sheet of the banking system is $D = E_0F + F^B + \mathcal{N}_0$, we can calculate D/\mathcal{N}_0 for the solution of the model with no financial friction and a fixed exchange rate. If $D/\mathcal{N}_0 \leq \Phi$, the financial friction would not bind and the exchange rate peg is sustainable. If $D/\mathcal{N}_0 > \Phi$, we can calculate the F^B that solves $\Phi = (D - F^B)/\mathcal{N}_0$. If that F^B is such that the non-negativity constraint, $S_0 \geq 0$ is not violated, then the exchange rate peg is sustainable. In this case, the central bank has used its foreign exchange reserves to bolster the peg. If instead, the constraint is violated, the central would exhaust its foreign exchange reserves and the peg is unsustainable without a rise in domestic interest rates.²¹

In 2021, Ukraine's GDP was approximately US\$200bn, and at the beginning of 2022, the NBU's net foreign exchange reserves totaled approximately US\$21bn, or 10% of GDP. Figure C1 plots the loss of foreign exchange reserves in defending the currency peg without a rise in domestic interest rates when no capital controls are imposed (solid-blue line). For the invasion shock (-33%), the loss of foreign exchange reserves would be approximately 1% of GDP or 10% of the pre-invasion stock. The dashed red line calculates the same loss of foreign exchange reserves under strict capital controls (more capital controls below). In this case, the invasion shock results in the stock of foreign exchange reserves falling to 4% of GDP (or by 2/3 of the pre-invasion stock).

Capital Controls

The NBU imposed strict capital controls on 24 February 2022 and has since adjusted them—gradually easing some measures, with occasional tightenings as needed. In this experiment, we introduce strict capital controls by fixing banks' US dollar funding to its steady state value, $F_0 = F_0^{SS}$. Figure C2 replicates Figure 4 from the main text but adds the green line with \square markers, which denotes the fixed exchange rate regime with strict capital controls. Since a fall in $Y_{T,0}$ increases households demand for borrowing (and hence banks' demand for US dollar funding), domestic interest rates (i.e., both the policy rate, i , and the loan rate, i^L) must rise sharply to ensure equilibrium in the market for loanable funds. As a result, non-tradable production falls more sharply and inflation is weaker relative to the case without strict capital controls (purple line with \circ markers).

Appendix D

Solution

Replication codes are available on the authors' webpages.

Steady State

We begin by describing how the steady state is calculated. We set $A_t = 1$ for $t = 0, 1$ and $Y_{T,0} = 1$ and solve seven unknowns

$\left\{ C_{N,t}^{SS}, C_{T,t}^{SS}, \alpha, Y_{T,1}, \mathcal{N}_{-1} \right\}_{t=0}^1$ with a system of seven equations:

$$\chi C_{N,t}^{SS} / (1 - \alpha) = 1 \quad \text{for } t = 0, 1 \quad (\text{D.1})$$

$$1 = \beta \frac{C_{T,0}^{SS}}{C_{T,1}^{SS}} (1 + i^*) \quad (\text{D.2})$$

$$0 = (\mathcal{N}_{-1} - D_{-1}) + \frac{1}{1 + i^*} \left(1 - C_{T,0}^{SS} \right) + \frac{1}{(1 + i^*)^2} \left(Y_{T,1} - C_{T,1}^{SS} \right) \quad (\text{D.3})$$

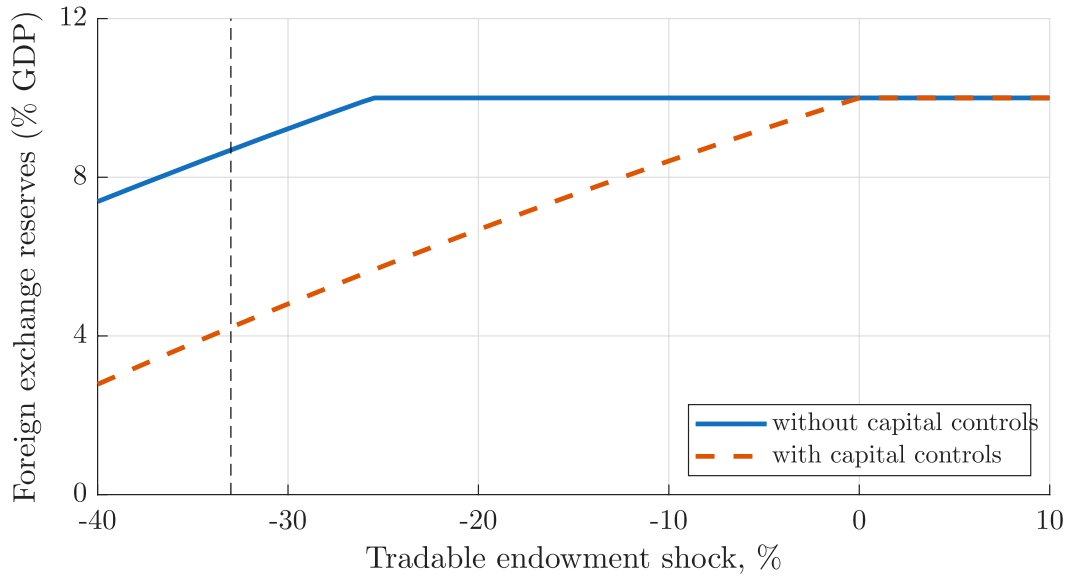


FIGURE C1 | Defending the fixed exchange rate regime. The line is based on the baseline scenario in the main text and plots the stock of official foreign exchange reserves required to maintain a fixed exchange rate without an increase in domestic interest rates. The steady stock of reserves is calibrated to 10% of GDP. If the line falls below zero, the fixed exchange rate regime is unsustainable.

$$\text{target1} = \frac{1}{1 + C_{N,0}^{ss}} \quad (\text{D.4})$$

$$\text{target2} = \frac{C_{T,0}^{ss} - 1}{1 + C_{N,0}^{ss}} \quad (\text{D.5})$$

$$\text{target3} = \frac{D_{-1}}{\mathcal{N}_{-1}} = \frac{D_0}{\mathcal{N}_0} \quad (\text{D.6})$$

where “target1” is the tradable output-to-GDP ratio, “target2” is the net-foreign liabilities-to-GDP ratio, and “target3” is the leverage ratio. Moreover, in steady state, $\mathcal{N}_0 = (1 + i^*)\mathcal{N}_{-1}$ which means $D_0 = (1 + i^*)D_{-1}$ and $C_0^{ss} = Y_{T,0}^{ss} = 1$. This gives us three structural parameters, α , $Y_{T,1}$, and \mathcal{N}_{-1} . By setting $E_0 = 1$ in steady state, we can calculate the price level of the non-tradable good as.

$$P_{N,0}^{ss} = \frac{1 - \alpha}{\alpha} \frac{C_{T,0}}{C_{N,0}} \quad (\text{D.7})$$

We then set $P_{N,-1} = P_{N,0}^{ss}$, to ensure that the steady state of the model with nominal price frictions coincides with the flexible price steady state. Ex-post, we check that $\alpha \in (0, 1)$. If it is not, simply lower the disutility of labor parameter, χ .

Flexible Price Equilibrium

The equations that solve the flexible price equilibrium are given in Equations (28–30).

Equilibrium With Nominal Frictions Only

The equations that solve the nominal frictions equilibrium are given in Equations (33–38). Under the fixed exchange rate regime, we simply set $E_0 = 1$ and solve the system of equations. Under the optimal policy regime, we solve Equations (33–38) under a range of E_0 values and select the one that maximizes the welfare function Equation (1). Finally, under the Taylor-rule regime, we instead select the value of E_0 that is consistent with the Taylor rule Equation (20).

Equilibrium With a Binding Leverage Constraint

For any given E_0 , we first solve the equilibrium under nominal frictions only. We then check that $D_0 / \mathcal{N}_0 \leq \Theta$. If the leverage constraint is violated, we resolve by replacing Equation (37) with $D_0 / \mathcal{N}_0 = \Theta$ in the system of equations. The domestic interest rate, i or i^t , is solved auxiliary to the main system of equations using the household Euler equation.

Appendix E

Effects of Standard Monetary Policy Shocks

The monetary policy instrument is isomorphically the nominal interest rate or the nominal exchange rate. In particular, the UIP condition is given by

$$1 + i = \frac{E_1}{E_0} (1 + i_t^*) \quad (\text{E.1})$$

where $E_1 = 1$ without loss of generality since period 1 is frictionless. The Taylor rule can be written as

$$1 + i_t = \beta \Pi_t^{\phi_x} \left(\frac{GDP_t}{GDP_{t-1}} \right)^{\phi_y} \xi_t \quad (\text{E.2})$$

where ξ_t is an *iid* monetary policy shock. Since this is not an infinite horizon model, the Taylor principle does not apply in this setting. As such, for simplicity, we can set $\phi_x = \phi_y = 0$. Thus, combining the UIP condition with the Taylor rule we get

$$E_0 = \frac{1}{\xi_0} \quad (\text{E.3})$$

The equations which describe equilibrium in the model (with only nominal frictions) can be simplified to

$$\frac{\chi}{1 - \alpha} P_{N,0}(\xi_0) C_{N,0}(\xi_0) = P_0^I(\xi_0) \quad (\text{E.4})$$

$$P_{N,0}(\xi_0)^{1-\epsilon} = \theta P_{N,-1}^{1-\epsilon} + (1 - \theta) (P_0^I(\xi_0))^{1-\epsilon} \quad (\text{E.5})$$

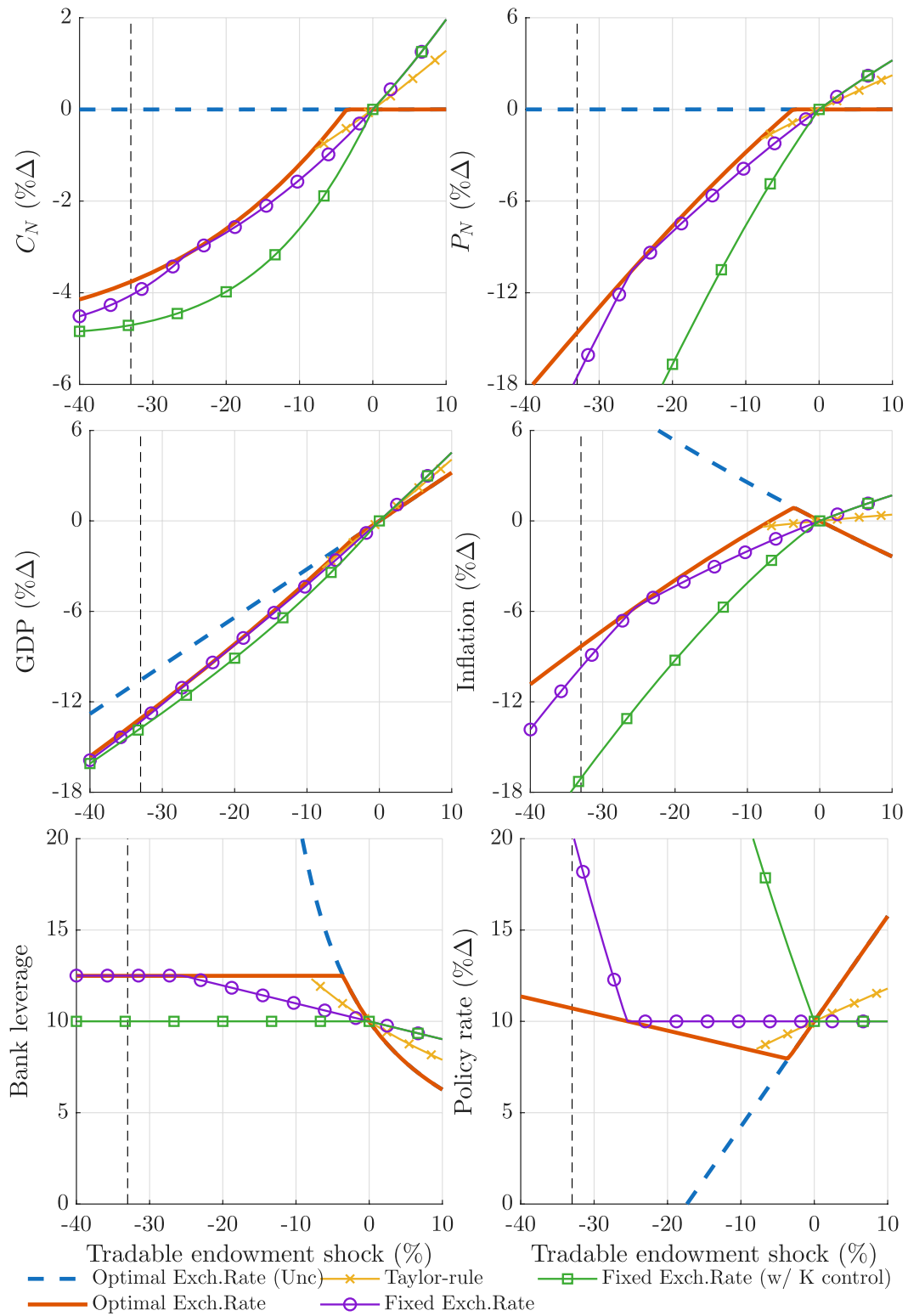


FIGURE C2 | Fixed exchange rate with capital controls. The green line with square markers shows the fixed-exchange rate regime where strict capital controls are imposed such that foreign currency borrowing is unchanged from the steady state level. The other lines are the same as the main text.

$$\frac{(1-\alpha)}{\alpha} C_{T,0} = C_{N,0}(\xi_0) P_{N,0}(\xi_0) \xi_0 \quad (\text{E.6})$$

Differentiating and evaluating at $\xi_0 = 1$ (the flexible price steady state) gives

$$\frac{\chi}{1-\alpha} \left(\frac{\partial P_{N,0}}{\partial \xi_0} C_{N,0} + P_{N,0} \frac{\partial C_{N,0}}{\partial \xi_0} \right) = \frac{\partial P_0^I}{\partial \xi_0} \quad (\text{E.7})$$

$$\frac{\partial P_{N,0}}{\partial \xi_0} = (1-\theta) \frac{\partial P_0^I}{\partial \xi_0} \quad (\text{E.8})$$

$$0 = \frac{\partial P_{N,0}}{\partial \xi_0} C_{N,0} + P_{N,0} \frac{\partial C_{N,0}/C_{N,0}}{\partial \xi_0} + 1 \quad (\text{E.9})$$

This means we get

$$\frac{\partial P_{N,0}/P_{N,0}}{\partial \xi_0} = -\frac{1}{P_{N,0} C_{N,0}} (1-\theta) < 0 \quad (\text{E.10})$$

$$\frac{\partial C_{N,0}/C_{N,0}}{\partial \xi_0} = -\frac{1}{P_{N,0} C_{N,0}} \theta < 0 \quad (\text{E.11})$$

When $\theta = 0$ (full price flexibility), we have monetary neutrality, and when $\theta = 1$, prices are fully fixed.

Appendix F

Scenario With Correlated Shocks to the Risk Premium

In our baseline results, the interest rate that Ukrainian banks can borrow at on world markets is fixed at the interest rate, i^* . In this extension, we assume the existence of a country-specific and state-contingent risk premium. In particular, we correlate the risk-premium faced by

Ukraine with the endowment of tradable goods shock. As there is limited data on the spread between the interest rates paid on Ukrainian government debt and those of US Treasury bonds, we take two alternative approaches.

Ratings-Based Default Spread Data

Figure F1 plots a ratings-based default spread for Ukraine from Damodaran (2013). This dataset is only updated annually on 1-January each year. From January 2022 (pre-invasion) to January 2023 (post-invasion) Moody's downgraded its rating from B3 to Caa3 and the estimated default spread jumped from 5.53% to 12.24%, a rise of 6.70 percentage points. Using an elastic interest rate function of the form

$$i_t^* = i^* + \psi (\exp(1 - Y_{T,t}) - 1) \quad (\text{F.1})$$

plus the change in tradable output and the change in the default spread, we can back out a value for ψ of 0.17. Figure F2 presents the results, which are largely unchanged. The optimal exchange rate when the change in tradable output is -33% and the country risk premium has risen by 6.70% is a little closer to "fixed" than in the baseline. In particular, the model prescribes an appreciation of only 1% .

Use of Data From an Alternative Emerging Market Economy

Since the previous approach was based on just two data points, 12 months apart, in this subsection, we instead use time-series evidence from an alternative emerging market economy—Argentina. In Uribe and Schmitt-Grohé (2017) Chapter 9, the estimated impact of a tradable output shock is given as follows:

$$\begin{bmatrix} \ln Y_{T,t} \\ \ln \frac{1+i_t^*}{1+i^*} \end{bmatrix} = \begin{bmatrix} 1.23 \\ -0.08 \end{bmatrix} \varepsilon_t \quad (\text{F.2})$$

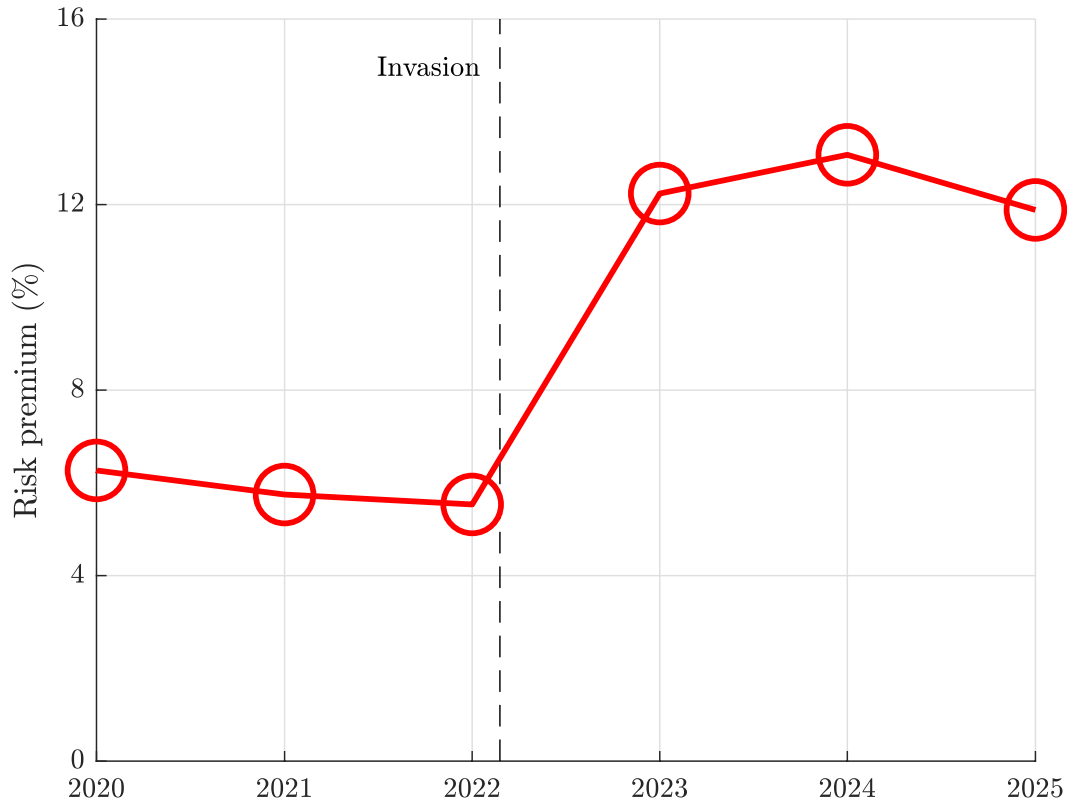


FIGURE F1 | Ratings-based default spread. Source: Aswath Damodaran (<https://pages.stern.nyu.edu/~adamodar/>).

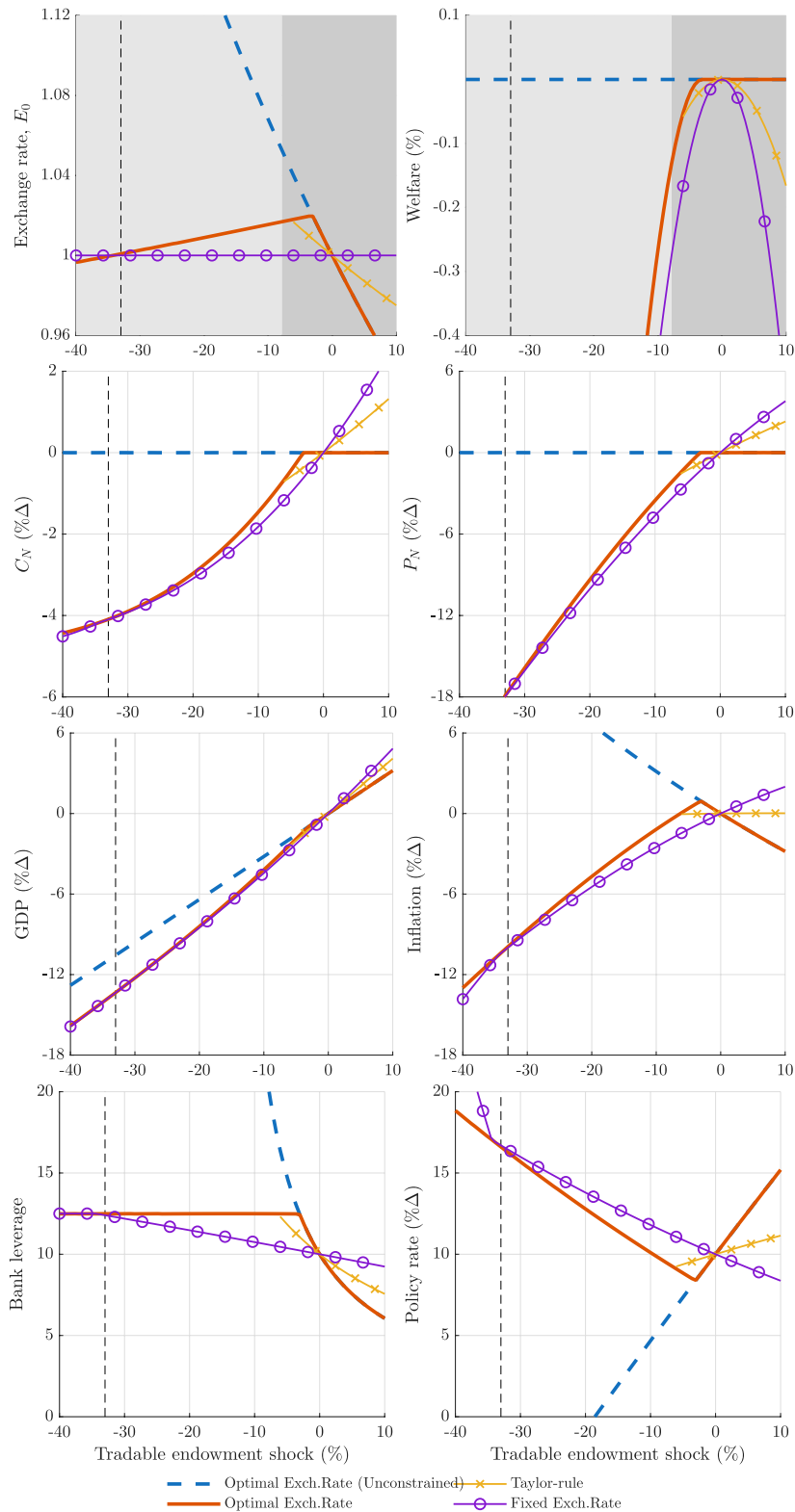


FIGURE F2 | Response to tradable endowment and risk-premium shock. Based on the elastic-interest rate function.

Rearranging, this gives the relation

$$i_0^* = Y_{T,0}^{-0.065} (1 + i^*) - 1 \quad (\text{F.3})$$

For a 33% drop in tradable output, this results in the interest rate spread rising by 2.90 percentage points (less than half of the rise suggested by the first approach). Figure F3 presents the results, which are largely unchanged from the baseline. The optimal exchange rate in response to a 33% drop in tradable output is again marginally closer to $E_0 = 1$ than in the baseline.

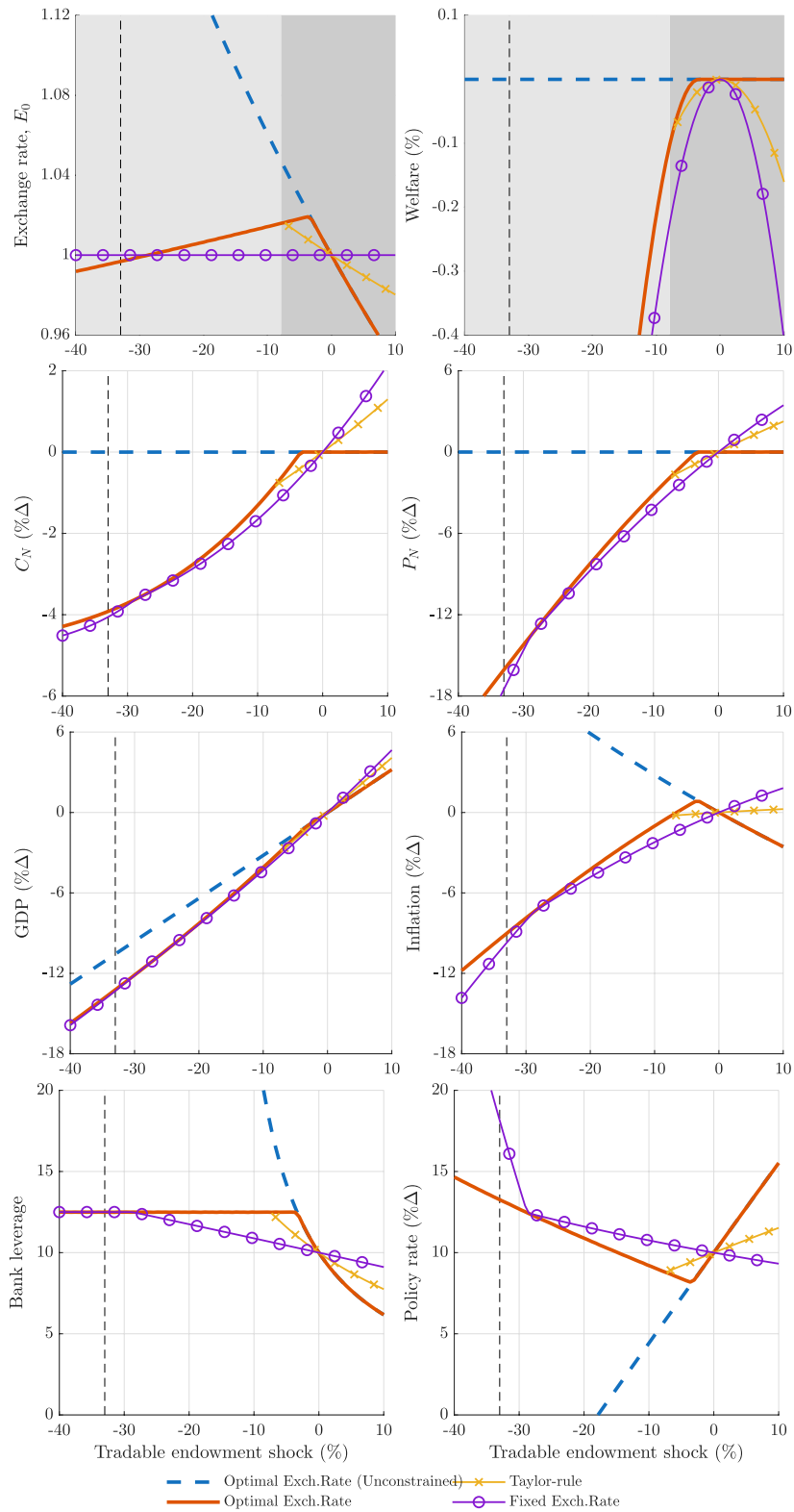


FIGURE F3 | Response to tradable endowment and risk-premium shock. Based on the correlation of tradable output and interest rates for Argentina.

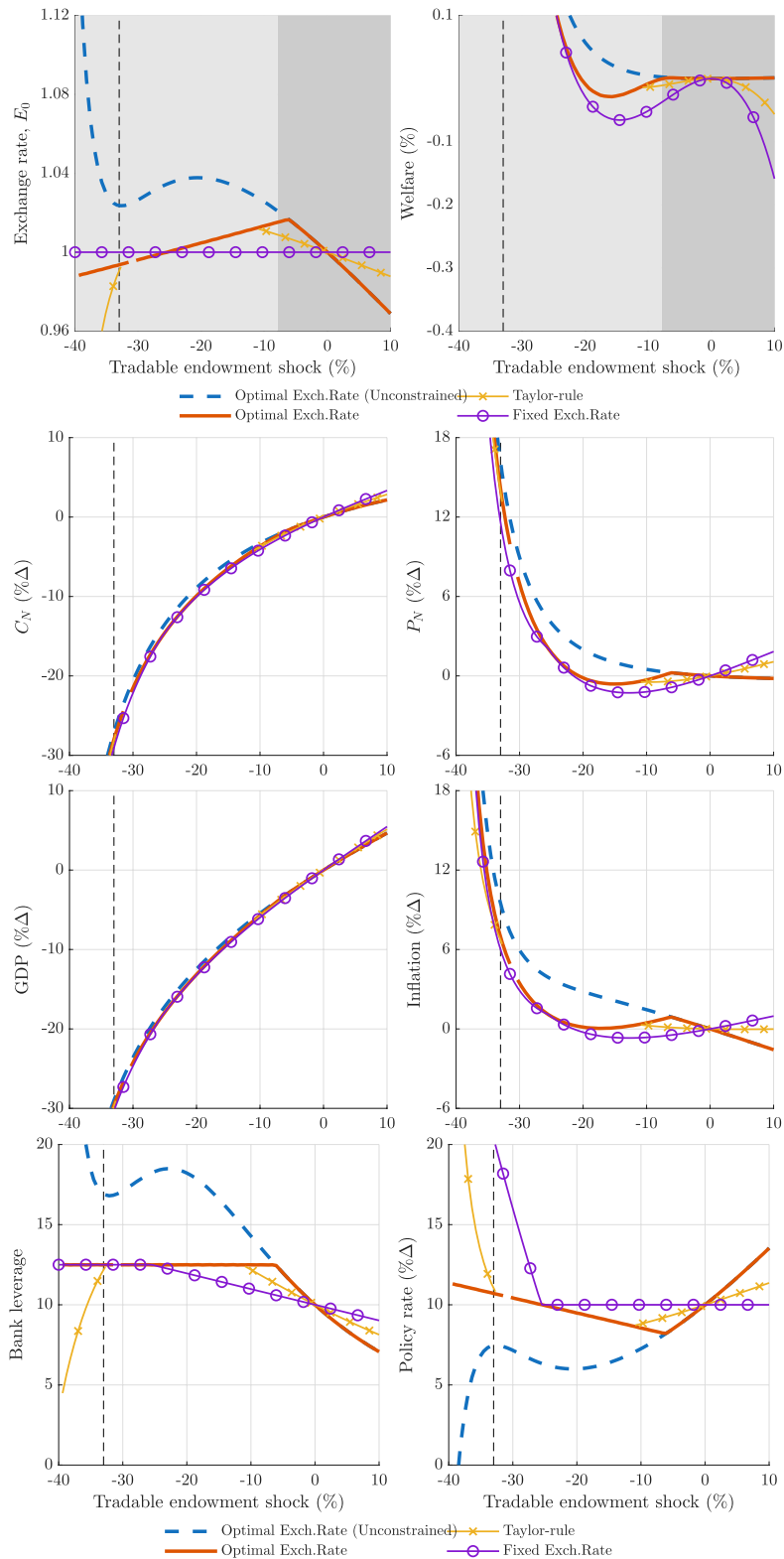


FIGURE G1 | Response to tradable endowment and risk-premium shock. Based on the correlation of tradable output and interest rates for Argentina.

Appendix G

Scenario With Correlated Non-Tradable Supply Shocks

Our baseline results attribute the effect of the invasion solely to tradable production. However, the invasion also led to a decline in non-tradable production. Consequently, our baseline underestimates both

the fall in GDP and the rise in inflation (since, in the baseline scenario, the price of non-tradable goods either remains unchanged or decreases).

To better align the model with the observed GDP and inflation data, we introduce a supply-side shock, which we model as an increase in firms' markups (equivalently, a decline in the elasticity of substitution across

goods). Revisiting the firm's first-order pricing condition, Equation (11), while allowing for time variation in ε , we obtain

$$P_{N,t}(j) = (1 - \phi) \frac{\varepsilon_t}{\varepsilon_t - 1} \frac{W_t}{A_t F'(N_t)} \quad (\text{G.1})$$

Hence, the aggregate price level becomes,

$$P_{N,0} = \left(\theta P_{N,-1}^{1-\varepsilon_t} + (1-\theta) \left((1-\phi) \frac{\varepsilon_t}{\varepsilon_t - 1} P_0^I \right)^{1-\varepsilon_t} \right)^{\frac{1}{1-\varepsilon_t}} \quad (\text{G.2})$$

In the flexible-price equilibrium (which is no longer efficient), the equilibrium condition becomes,

$$\chi C_{N,0} / (1 - \alpha) = \frac{1}{1 - \phi} \frac{\varepsilon_t - 1}{\varepsilon_t} A_0 \quad (\text{G.3})$$

At $Y_{T,0} = 0.67$ (i.e., in the -33% scenario), we set $\varepsilon = 2.45$, which (under the fixed exchange rate and financial constraint binding regime) gives $\% \Delta GDP_0 = -29.0$ (matching the data). This corresponds to a rise in mark-ups from 12.5% to 69% . If we use a linear relationship of the form,

$$\varepsilon = 9 + \chi (Y_{T,0} - 1) \quad (\text{G.4})$$

we obtain $\chi = 19.8$. The results are reported in Figure G1. In this setting, the optimal policy prescription diverges significantly from the baseline. In particular, in the absence of financial frictions, the policymaker faces a meaningful trade-off between stabilizing non-tradable price inflation and maintaining non-tradable output. The blue line (optimal exchange rate absent financial frictions) is non-monotonic, with a smaller depreciation when tradable output declines by 33% than for more modest declines. The resulting changes in non-tradable output and inflation are -29% and 6% , respectively. Interestingly, in the presence of nominal frictions, the equilibrium can yield higher welfare than the flexible-price equilibrium, which itself is no longer efficient.