ECONOMISTS FOR UKRAINE

WORKING PAPER SERIES

WORKING PAPER No. 4 AUGUST 2025

FOREIGN EXCHANGE REGIMES IN (NORMAL TIMES AND) TIMES OF WAR: INSIGHTS FROM UKRAINE

Oliver de Groot and Yevhenii Skok

Economists for Ukraine (Econ4UA)

Website: https://econ4ua.org/ Email: info@econ4ua.org

ABSTRACT

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

On February 24, 2022, as Russia invaded, the National Bank of Ukraine switched from a flexible to a fixed exchange rate regime. Was this policy response optimal? To answer this, we develop an open-economy model with both nominal rigidities and frictions in borrowing on international financial markets. We find that the carefully calibrated model can rationalize the NBU's decision: the optimal response to small shocks is to allow exchange rate flexibility, whereas in response to large shocks—such as an invasion—currency depreciation is suboptimal. For robustness, we consider tradable endowment, risk-premium, and non-tradable supply shocks, and add subsistence consumption.

JEL CLASSIFICATION: E44, E52, F31, F41, G01
KEYWORDS: Currency crises, Exchange rates, Monetary policy, Emerging markets

Oliver de Groot
University of Liverpool & CEPR
School of Management
Liverpool, United Kingdom
oliverdegroot@gmail.com

Yevhenii Skok
University of Liverpool
School of Management
Liverpool, United Kingdom
evgeny.skok@gmail.com

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) returned to a floating regime (see Figure 1).

This paper examines whether such a state-contingent exchange rate policy is 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.

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, often denominated in U.S. 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 these policy trade-offs. Second, despite its tractability, we carefully calibrate the model to the Ukrainian economy to assess the quantitative significance of these mechanisms.

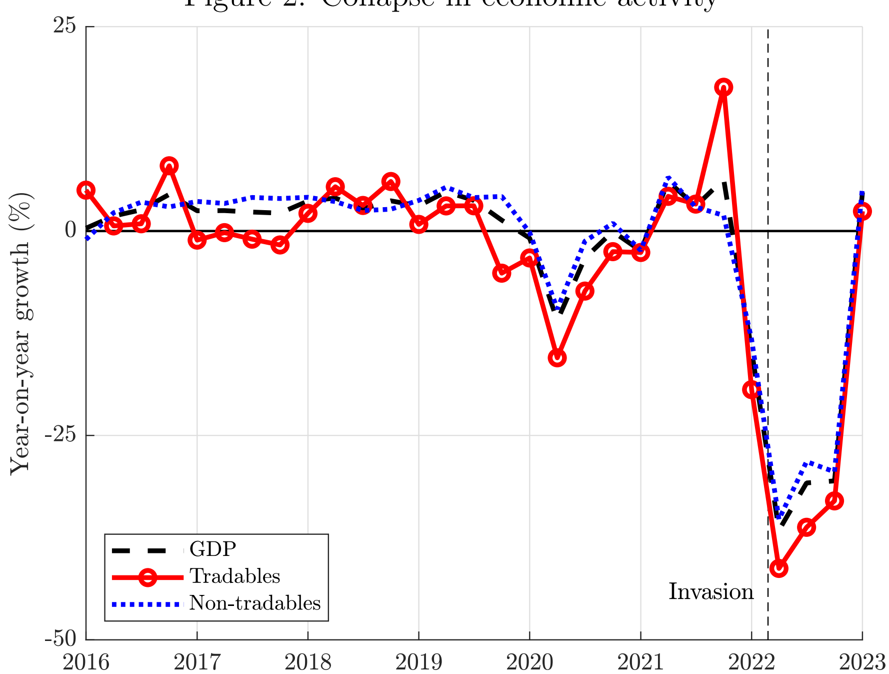
The remainder of the introduction provides additional narrative context for the NBU's policy decisions in 2022 and situates our contribution within the literature.

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

Figure 1: Changing exchange rate regimes

Source: National Bank of Ukraine, www.finance.ua

Figure 2: Collapse in economic activity



Source: State Statistics Service of Ukraine. Note: 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.

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 began 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). Fixing the exchange rate was necessary to prevent uncontrolled depreciation driven by a flight to foreign currency.[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

[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,b, 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.

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).

Despite an interest rate hike (see Appendix A, Figure 5), 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.

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). 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. 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.

[4] The gap between the official and shadow exchange rates serves as a proxy for exchange rate pressure.

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 (Ukraine) with frictions in firm price setting and in borrowing on international financial markets. There are two periods, $t = 0, 1$. The economy consists of households, firms, and banks.

2.1 Households

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

$$\mathbb{E}_t \sum_{t=0}^{1} \beta^t \left(U\left(C_t\right) - V\left(N_t\right)\right), \tag{2.1}$$

where $\beta \in (0, 1)$, $U'(\cdot), V'(\cdot) > 0$, $U''(\cdot) < 0$, $V''(\cdot) > 0$, and

$$C_t = \mathcal{C}\left(C_{T,t}, C_{N,t}\right), \tag{2.2}$$

is a consumption composite with $\mathcal{C}_1, \mathcal{C}_2 > 0$, $\mathcal{C}_{11}, \mathcal{C}_{22} < 0$ and $\mathcal{C}_{12} > 0$. Households can borrow, D_t, from domestic banks at a nominal interest rate, i_t. The budget constraint is given by

$$P_{N,t}C_{N,t} + P_{T,t}C_{T,t} + (1 + i_{t-1})\, D_{t-1} + \mathcal{N}_t \leq D_t + W_t N_t + P_{T,t}Y_{T,t} + \Phi_t^F + \Phi_t^B, \tag{2.3}$$

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

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 normalize $P^*_{T,t} = 1$, thus

$$P_{T,t} = E_t. \tag{2.4}$$

The first-order conditions are given by

$$\frac{\mathcal{C}_{2,t}(\cdot)}{\mathcal{C}_{1,t}(\cdot)} = \frac{P_{N,t}}{E_t}, \tag{2.5}$$

$$\frac{V'(N_t)}{U'(\cdot)\,\mathcal{C}_{2,t}(\cdot)} = \frac{W_t}{P_{N,t}}, \tag{2.6}$$

and

$$1 = \mathbb{E}_t \beta \frac{U'_{t+1}(\cdot)\,\mathcal{C}_{1,t+1}(\cdot)}{U'_t(\cdot)\,\mathcal{C}_{1,t}(\cdot)} \frac{E_t}{E_{t+1}} (1 + i_t). \tag{2.7}$$

Since the model is just two periods, there are two copies of (2.5) and (2.6) and one copy of (2.7) in the system of equilibrium conditions.

2.2 Firms

There are two types of firms that produce non-tradable goods—intermediate and final goods firms. Intermediate goods, Y^I_t, are produced by intermediate goods firms out of labor according to

$$Y^I_t = A_t F(N_t), \tag{2.8}$$

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

$$\max_{N_t} P^I_t A_t F(N_t) - W_t N_t. \tag{2.9}$$

Optimality ensures

$$P^I_t = \frac{W_t}{A_t F'(N_t)}. \tag{2.10}$$

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: $C_{N,t} = \left(\int_0^1 C_{N,t}(j)^{1-1/\varepsilon}\right)^{\frac{1}{1-1/\varepsilon}}$. Hence, final goods firms face the following downward-sloping demand curve: $Y_{N,t}(j) = \left(P_{N,t}(j)/P_{N,t}\right)^{-\varepsilon} Y_{N,t}$, where $\varepsilon > 1$ is the elasticity of substitution across varieties.

We assume that in $t = 0$, 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 $t = 1$. Thus, re-optimizers solve

$$\max_{P_{N,t}(j)} \Phi_t^F(j) = \left(P_{N,t}(j) - (1-\phi)\frac{W_t}{A_t F'(N_t)}\right)\left(\frac{P_{N,t}(j)}{P_{N,t}}\right)^{-\varepsilon} Y_{N,t}, \tag{2.11}$$

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

$$P_{N,t}(j) = \frac{W_t}{A_t F'(N_t)}. \tag{2.12}$$

Thus, all re-optimizing firms set the same price. The aggregate price level in $t = 0$ and $t = 1$ is given by

$$P_{N,0} = \left(\theta P_{N,-1}^{1-\varepsilon} + (1-\theta)\left(P_0^I\right)^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}, \tag{2.13}$$

$$P_{N,1} = P_1^I. \tag{2.14}$$

2.3 Banks

Domestically owned banks receive (exogenous) equity injections, $\mathcal{N}_t$, from households; raise funding on international capital markets, F_t (expressed in USD) which is repaid at the world interest rate, i_t^*; lend domestically; and transfer unretained profits back to households. The balance sheet is given by

$$D_t = E_t F_t + \mathcal{N}_t. \tag{2.15}$$

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

$$\max_{D_t} \mathbb{E}_t \mathcal{D}_{t,t+1}\left((1+i_t) D_t - (1+i_t^*) E_{t+1} F_t\right), \tag{2.16}$$

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

$$\frac{D_t}{\mathcal{N}_t} \leq \Theta, \quad \text{where} \quad \Theta \geq 1. \tag{2.17}$$

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

$$\mathcal{N}_0 = (1-\omega)\left(\left(1+i_{-1}\right)D_{-1} - \left(1+i^*_{-1}\right)\frac{E_0}{E_{-1}}\left(D_{-1}-\mathcal{N}_{-1}\right)\right). \tag{2.18}$$

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 the leverage constraint does not bind, the bank's first-order condition can be combined with the household Euler equation (2.7) and re-written as

$$1 = \mathbb{E}_t \beta \frac{U'_{t+1}\left(\cdot\right)\mathcal{C}_{1,t+1}\left(\cdot\right)}{U'_t\left(\cdot\right)\mathcal{C}_{1,t}\left(\cdot\right)}\left(1+i^*_t\right). \tag{2.19}$$

If, instead, the leverage constraint does bind, the household Euler equation is replaced by

$$\frac{D_t}{\mathcal{N}_t} = \Theta. \tag{2.20}$$

2.4 Closing the model

The aggregate resource constraint of the economy is given by

$$0 = \left(\tilde{Y}_{T,0} - C_{T,0}\right) + \frac{1}{\left(1+i^*_0\right)}\left(Y_{T,1}-C_{T,1}\right), \tag{2.21}$$

where $\tilde{Y}_{T,0} \equiv Y_{T,0} - \left(1+i^*_{-1}\right)\frac{1}{E_{-1}}\left(D_{-1}-\mathcal{N}_{-1}\right)$ (see Appendix B for the derivation). The link between consumption and production is given by

$$Y_{N,t} = C_{N,t} = \frac{1}{PD_t}A_t F\left(N_t\right), \tag{2.22}$$

where

$$PD_t = \theta \left(\frac{P_{N,-1}}{P_{N,0}} \right)^{-\varepsilon} + (1-\theta) \left(\frac{P_0^I}{P_{N,0}} \right)^{-\varepsilon} \tag{2.23}$$

is the distortion arising from price dispersion. The monetary authority sets the exchange rate, E_0. This is either set optimally, or we introduce a fixed exchange rate regime. Finally, for the baseline numerical results, we select the following functional forms:

$$U(C_t) = C_t, \tag{2.24}$$

$$V(N_t) = \chi N_t, \tag{2.25}$$

$$\mathcal{C}(C_{T,t}, C_{N,t}) = \alpha \log(C_{T,t}) + (1-\alpha)\log(C_{N,t}), \quad \text{and} \tag{2.26}$$

$$F(N_t) = N_t. \tag{2.27}$$

This implies that tradable and non-tradable consumption are additively separable for household welfare. For simplicity, we also assume a constant marginal disutility of labor and a production function that is linear in labor. In one of our robustness exercises, we consider the effect of introducing a non-zero subsistence level of tradable consumption, capturing the importance of access to food and energy for human survival during times of war.

2.5 Calibration

The baseline steady-state calibration is summarized in Table 1. Each period is calibrated to one 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 $\tilde{Y}_{T,0} = 1$. The calibration ensures that the optimal exchange rate in the steady state is normalized to $E_0 = 1$.

In steady state, the interest rate is set to $i^* = 10\%$, corresponding to the National Bank of Ukraine's key policy interest rate at the onset of the invasion. 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.[5] Second, according to Lane and Milesi-Ferretti (2018), the net foreign asset-to-GDP ratio, D/GDP, was −14% in Ukraine in 2021.[6] We calibrate α (the weight

[5]Tradable output is defined as the sum of Agriculture, Forestry and Fishing; Mining and Quarrying; and Manufacturing.

[6]GDP is defined as $Y = Y_T + Y_N$.

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 $Y_{T,1} = 1.92$.

From the flexible-price equilibrium, we obtain the non-tradable price level, $P_N = 0.77$, 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%.

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 $D/N = 10$, ensuring that the financial friction does not bind in steady state. Given the level of GDP in the flexible-price steady state, this calibration implies $D_{-1} = 0.44$ and $N_{-1} = 0.044$. Finally, we assume that the fraction of bank profits transferred to households as lump sum dividends is given by $\omega = 1 - \beta = 0.09$.

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, $\tilde{Y}_{T,0}$. In the robustness exercises we add correlated shocks of either i_t^* ("risk-premium" shocks) or ε (non-tradable "cost-push" shocks).

Table 1: Calibration

i^*	α	β	θ	ε	Θ	ω	D_{-1}	N_{-1}	$P_{N,-1}$	A_0	A_1	$\tilde{Y}_{T,0}$	$Y_{T,1}$
0.10	0.47	0.91	1/3	9	12.5	0.09	0.44	0.044	0.77	1	1	1	1.92

2.6 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

$$\chi C_{N,t}/\left(1-\alpha\right) = A_t \quad \text{for} \quad t = 0, 1 \tag{2.28}$$

$$1 = \beta \frac{C_{T,0}}{C_{T,1}} \left(1 + i^*\right), \tag{2.29}$$

$$0 = \left(\tilde{Y}_{T,0} - C_{T,0}\right) + \frac{1}{\left(1 + i^*\right)} \left(Y_{T,1} - C_{T,1}\right), \tag{2.30}$$

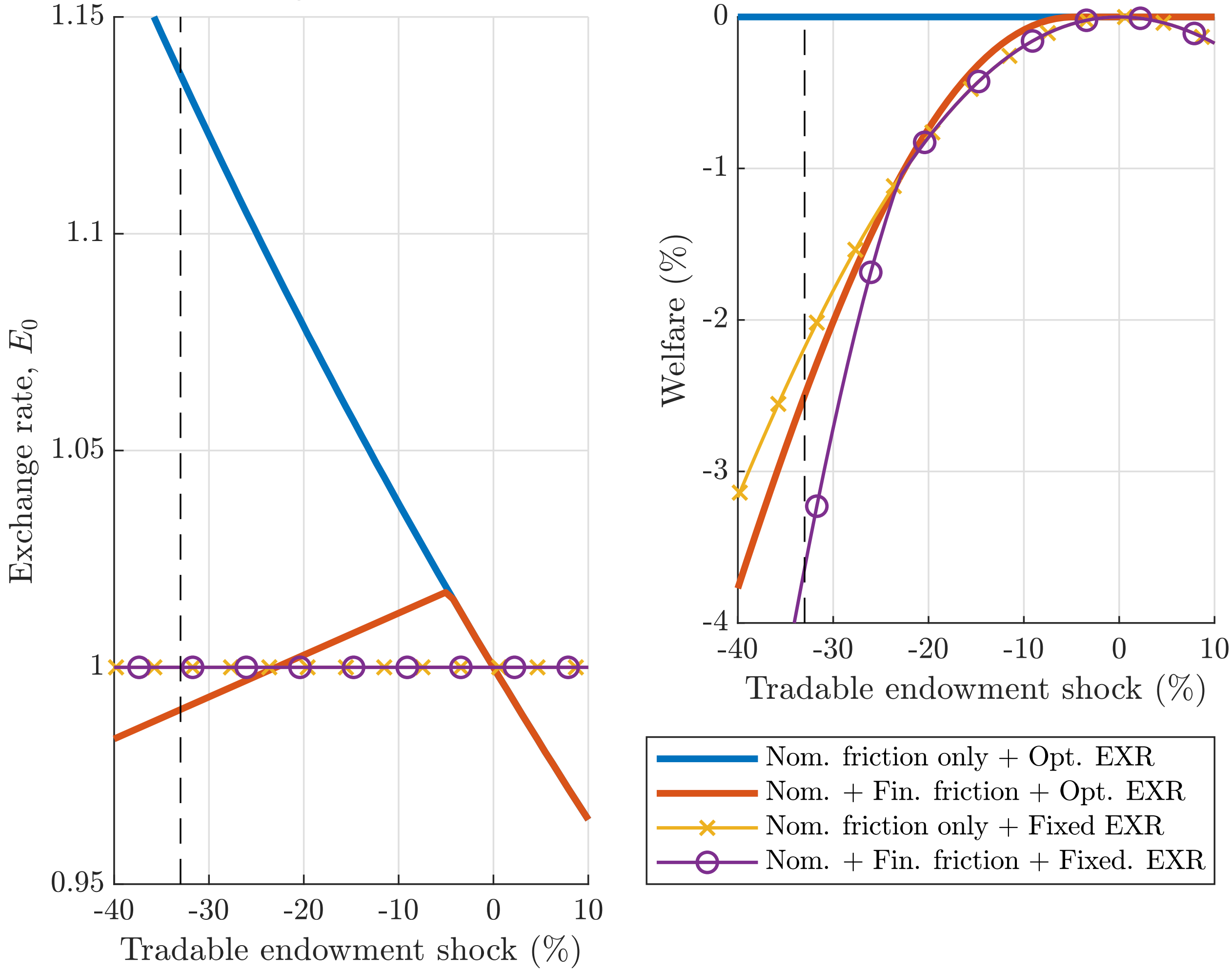
for $\{C_{T,0}, C_{T,1}, C_{N,0}, C_{N,1}\}$. Note that equilibrium in the non-tradable goods sector is disconnected from equilibrium in the tradable goods sector. A fall in the tradable endowment, $Y_{T,0}$, leads to an increase in borrowing and a less than one-for-one fall in consumption of the tradable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

3 Results

Figures 3 and 4 present the baseline results based on the calibration of the model outlined in Section 2.5. 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.

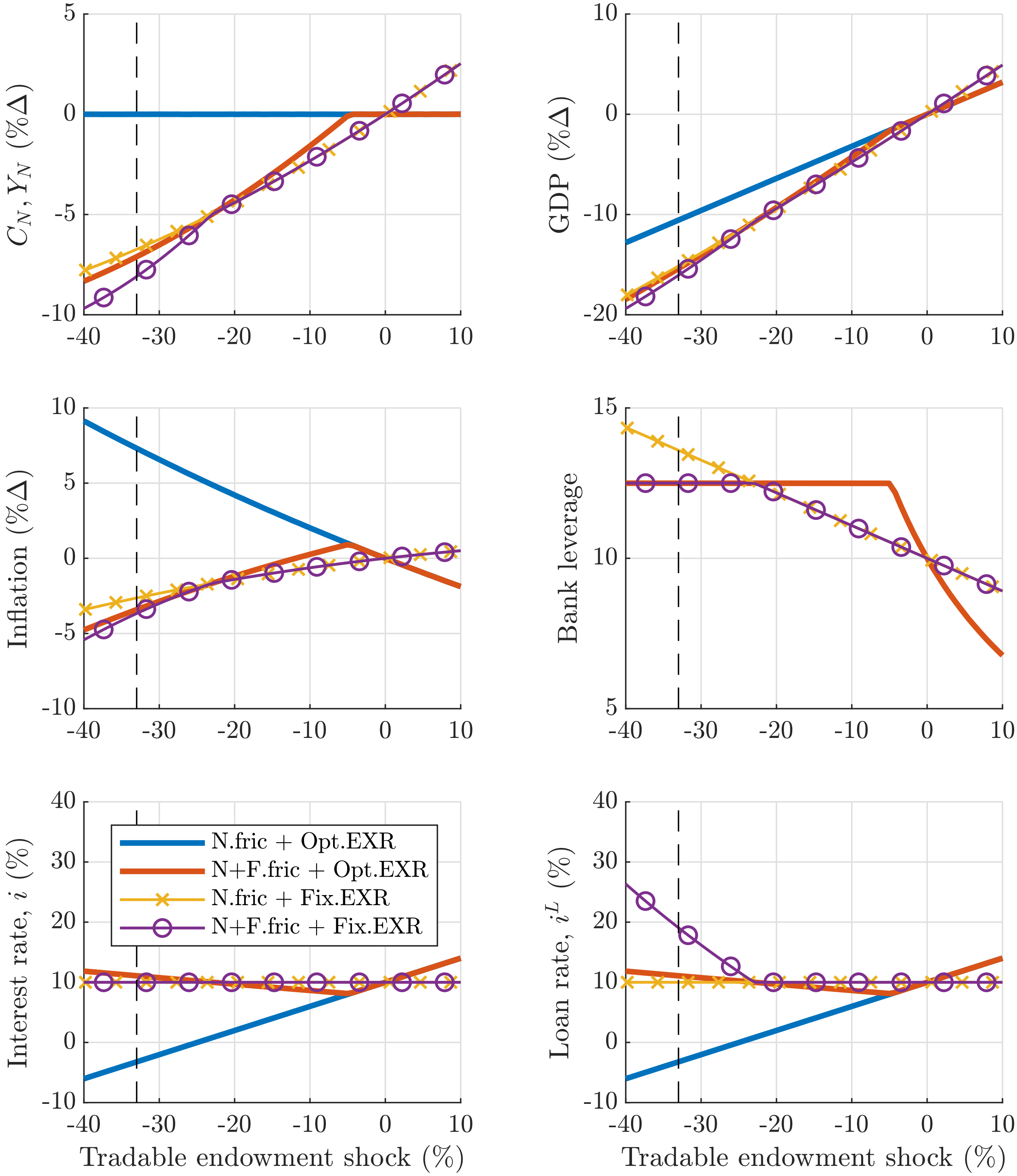
First, we analyze the role of the nominal firm price rigidity in isolation. Second, we extend our analysis to include the friction related to borrowing on international financial markets. Third, we conduct several robustness exercises related to the nature of the "invasion shock" and some of the features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

Figure 3: Response to the tradable endowment shock



Note: 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 -40% change in the tradable endowment under the scenario with both Nominal and Financial frictions and with the Exchange rate (EXR) set optimally, the household would forgo 2.5% of the efficient level of $C_{T,0}$.

Figure 4: Response to the tradable endowment shock: More variables



Note: Line colors and styles correspond to the same scenarios as in Figure 3.

3.1 Nominal rigidities only

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

$$\chi C_{N,0}/\left(1-\alpha\right) = A_0 \frac{P_0^I}{P_{N,0}}, \tag{3.1}$$

$$\chi C_{N,1}/\left(1-\alpha\right) = A_1, \tag{3.2}$$

$$P_{N,0} = \left(\theta P_{N,-1}^{1-\varepsilon} + \left(1-\theta\right)\left(P_0^I\right)^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}, \tag{3.3}$$

$$\frac{\left(1-\alpha\right)C_{T,0}}{\alpha C_{N,0}} = \frac{P_{N,0}}{E_0}, \tag{3.4}$$

$$1 = \beta \frac{C_{T,0}}{C_{T,1}}\left(1+i^*\right), \tag{3.5}$$

$$0 = \left(\tilde{Y}_{T,0} - C_{T,0}\right) + \frac{1}{\left(1+i^*\right)}\left(Y_{T,1} - C_{T,1}\right), \tag{3.6}$$

where the system is closed, either by solving for E_0 to maximize household welfare, or by setting E_0 to a fixed value. The equilibrium in which the exchange rate, E_0, is chosen optimally is represented by the solid blue line in Figures 3 and 4. The downward-sloping exchange rate curve indicates that the optimal policymaker prefers 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 equilibrium.

Consider a fall in $Y_{T,0}$. Equations (3.5) and (3.6) continue to determine $C_{T,0}$ as in the flexible price equilibrium. Then, by equation (3.4), 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 (3.1). This result represents the "divine coincidence" as the policymaker can replicate the efficient flexible price equilibrium.

Now, suppose instead that the exchange rate is fixed, represented by the yellow line with $\times$ markers. Consumption smoothing of tradable goods implies a fall in $C_{T,0}$. Given a fixed level of non-tradable consumption, $C_{N,0}$, the relative price of non-tradable goods must decrease. 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 (denoted as i in the bottom-left 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 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 overcoming nominal frictions in non-tradable goods pricing, 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 2%) rather than a 13% depreciation. Thus, the optimal policy response closely approximates the NBU's approach of imposing a fixed exchange rate regime.

Nevertheless, a strict fixed exchange rate regime remains suboptimal. In particular, we plot the implied rate on bank loans, i^L, in the bottom-right panel of Figure 4, shown by the purple line with ∘ markers. This demonstrates that, under such a scheme, the loan rate is almost 6 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.

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.

Subsistence consumption. In Appendix C, we introduce a subsistence consumption level to better account for the importance of access to certain (tradable) goods, such as food and energy, during catastrophic events such as war. This modification increases the marginal utility of tradable consumption as output falls, amplifying the exchange rate response to endowment shocks. As a result, the policymaker intervenes earlier, halting depreciation at a smaller endowment shock than in the baseline.

Correlated risk-premium shocks. In Appendix D, 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.

Correlated non-tradable supply shocks. In Appendix E, 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 modest currency depreciation for small shocks but an appreciation when tradable output falls sharply.

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 and exchange rate flexibility are optimal during "normal" times, when the economy experiences only "normal" shocks. However, in response to a large negative shock, it becomes optimal to prevent a significant depreciation due to frictions in borrowing on international financial markets. This episode offers valuable lessons for other central banks during periods of heightened risk.

We conclude by emphasizing that our model is highly stylized and abstracts from several important considerations. In particular, we do not account for tradable goods production or the choice of trade invoicing currency. Additionally, we sidestep the question of whether an exchange rate peg is sustainable given the central bank's foreign exchange reserves.[7] Incorporating these features and examining how they would alter the optimal policy prescription is an important avenue for future research.

[7] 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 percent just a few months later.

References

Adrian, M. T., Erceg, C. J., Lindé, J., Zabczyk, P. and Zhou, M. J. (2020). A quantitative model for the integrated policy framework, *IMF working paper* .

Basu, M. S. S., Boz, M. E., Gopinath, M. G., Roch, M. F. and Unsal, M. F. D. (2020). A conceptual model for the integrated policy framework, *IMF working paper* .

Becker, T. and di Mauro, Y. G. B. W. (2024). How to rebuild ukraine: A synthesis and critical review of policy proposals, *forthcoming in Annual Review of Economics* .

Damodaran, A. et al. (2013). Equity risk premiums (erp): Determinants, estimation and implications–the 2013 edition, *Managing and measuring risk: Emerging global standards and regulations after the financial crisis* pp. 343–455.

de Groot, O. and Skok, Y. (2022a). War in ukraine: The financial defence, `https://cepr.org/voxeu/columns/war-ukraine-financial-defence`. VoxEU column 17 March 2022.

de Groot, O. and Skok, Y. (2022b). War in ukraine: Ukraine's monetary-financial vulnerabilities, `https://cepr.org/voxeu/columns/war-ukraine-ukraines-monetary-financial-vulnerabilities`. VoxEU column 15 November 2022.

de Groot, O. and Skok, Y. (2023). Ensuring monetary-financial stability for successful recovery, *in* Y. Gorodnichenko and S. Stepanchuk (eds), *Ukraine's Road to Recovery.*

Gabaix, X. and Maggiori, M. (2015). International liquidity and exchange rate dynamics, *The Quarterly Journal of Economics* **130**(3): 1369–1420.

Galí, J. (2015). *Monetary policy, inflation, and the business cycle: An introduction to the new Keynesian framework and its applications*, Princeton University Press.

Gorodnichenko, Y., Sologoub, I. and Weder, B. (2022). *Rebuilding Ukraine: principles and policies*, CEPR Press.

Lane, P. R. and Milesi-Ferretti, G. M. (2018). The external wealth of nations revisited: international financial integration in the aftermath of the global financial crisis, *IMF Economic Review* **66**: 189–222.

Liadze, I., Macchiarelli, C., Mortimer-Lee, P. and Sanchez Juanino, P. (2023). Economic costs of the russia-ukraine war, *The World Economy* **46**(4): 874–886.

Poast, P. (2015). Central banks at war, *International organization* **69**(1): 63–95.

Roselli, A. (2025). Central bank at war: Subservient to the government, *The Political Economy of Central Banking: A Short History of the Changing Role of Central Banks*, Springer, pp. 87–105.

Uribe, M. and Schmitt-Grohé, S. (2017). *Open economy macroeconomics*, Princeton University Press.

A Data

Figure 5 plots the NBU's key 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 5: Policy interest rates

Source: National Bank of Ukraine

B Aggregate resource constraint

The household budget constraint is given by

$$P_{N,t}C_{N,t} + P_{T,t}C_{T,t} + (1 + i_{t-1})\, D_{t-1} + \mathcal{N}_t = D_t + W_t N_t + P_{T,t}Y_{T,t} + \Phi_t^F + \Phi_t^B. \qquad \text{(B.1)}$$

Profits from non-tradable production simplify the constraint to

$$P_{T,t}C_{T,t} + (1 + i_{t-1})\, D_{t-1} + \mathcal{N}_t = D_t + P_{T,t}Y_{T,t} + \Phi_t^B. \qquad \text{(B.2)}$$

Since the model has two periods, then $\mathcal{N}_0 = \Phi_0^B$ and $\mathcal{N}_1 = D_1 = 0$, and we have

$$E_0 C_{T,0} + (1 + i_{-1})\, D_{-1} = D_0 + E_0 Y_{T,0}, \qquad \text{(B.3)}$$

$$E_1 C_{T,1} + (1 + i_0)\, D_0 = E_1 Y_{T,1} + \left((1 + i_0)\, D_0 - (1 + i_0^*) \frac{E_1}{E_0} (D_0 - \mathcal{N}_0) \right). \qquad \text{(B.4)}$$

Rewriting the first constraint and simplifying the second give

$$C_{T,0} + (1 + i_{-1}) \frac{1}{E_0} D_{-1} = \frac{D_0}{E_0} + Y_{T,0}, \qquad \text{(B.5)}$$

$$C_{T,1} = Y_{T,1} - (1 + i_0^*) \frac{1}{E_0} (D_0 - \mathcal{N}_0)\,. \qquad \text{(B.6)}$$

Combining by removing D_0/E_0 gives

$$(1 + i_{-1}) \frac{D_{-1}}{E_0} - \frac{\mathcal{N}_0}{E_0} = (Y_{T,0} - C_{T,0}) + \frac{1}{(1 + i_0^*)} (Y_{T,1} - C_{T,1})\,. \qquad \text{(B.7)}$$

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

$$\left(1 + i_{-1}^*\right) \frac{1}{E_{-1}} (D_{-1} - \mathcal{N}_{-1}) = (Y_{T,0} - C_{T,0}) + \frac{1}{(1 + i_0^*)} (Y_{T,1} - C_{T,1})\,. \qquad \text{(B.8)}$$

Since the endowment is exogenous, we can rewrite it as simply

$$0 = \left(\tilde{Y}_{T,0} - C_{T,0}\right) + \frac{1}{(1 + i_0^*)} (Y_{T,1} - C_{T,1})\,. \qquad \text{(B.9)}$$

C Scenario with subsistence consumption

One extension we consider is to introduce a non-zero level of subsistence consumption of the tradable good. This is to capture the importance of access to food and energy for human survival during times of war. In this regard, we change the functional form of the consumption aggregator as follows:

$$\mathcal{C}\left(C_{T,t}, C_{N,t}\right) = \alpha \frac{1}{1-\bar{C}} \log\left(C_{T,t} - \bar{C}_T\right) + (1-\alpha)\log\left(C_{N,t}\right). \tag{C.1}$$

We calibrate the share of subsistence consumption $\bar{C}_T$ at 35% of aggregate steady state consumption in period 0. Figures 6 and 7 present the results. The introduction of positive subsistence level increases marginal utility of tradable consumption more as tradable output falls, leading to a stronger exchange rate response to endowment shocks compared to the baseline (i.e., the blue line is steeper than in the baseline in the main text). With subsistence consumption taken into account, the policymaker halts currency depreciation at a smaller endowment shock (-3.5%) compared to the baseline (-5%).[8]

D 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 world interest rate, i^*. In this extension, we assume the existence of a country-specific 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.

D.1 Ratings-based default spread data

Figure 8 plots a ratings-based default spread for Ukraine from Damodaran et al. (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

[8]This is the kink point in the red line, which shows the optimal determination of the exchange rate in the presence of both nominal and financial frictions.

Figure 6: Response to tradable endowment shock with subsistence consumption

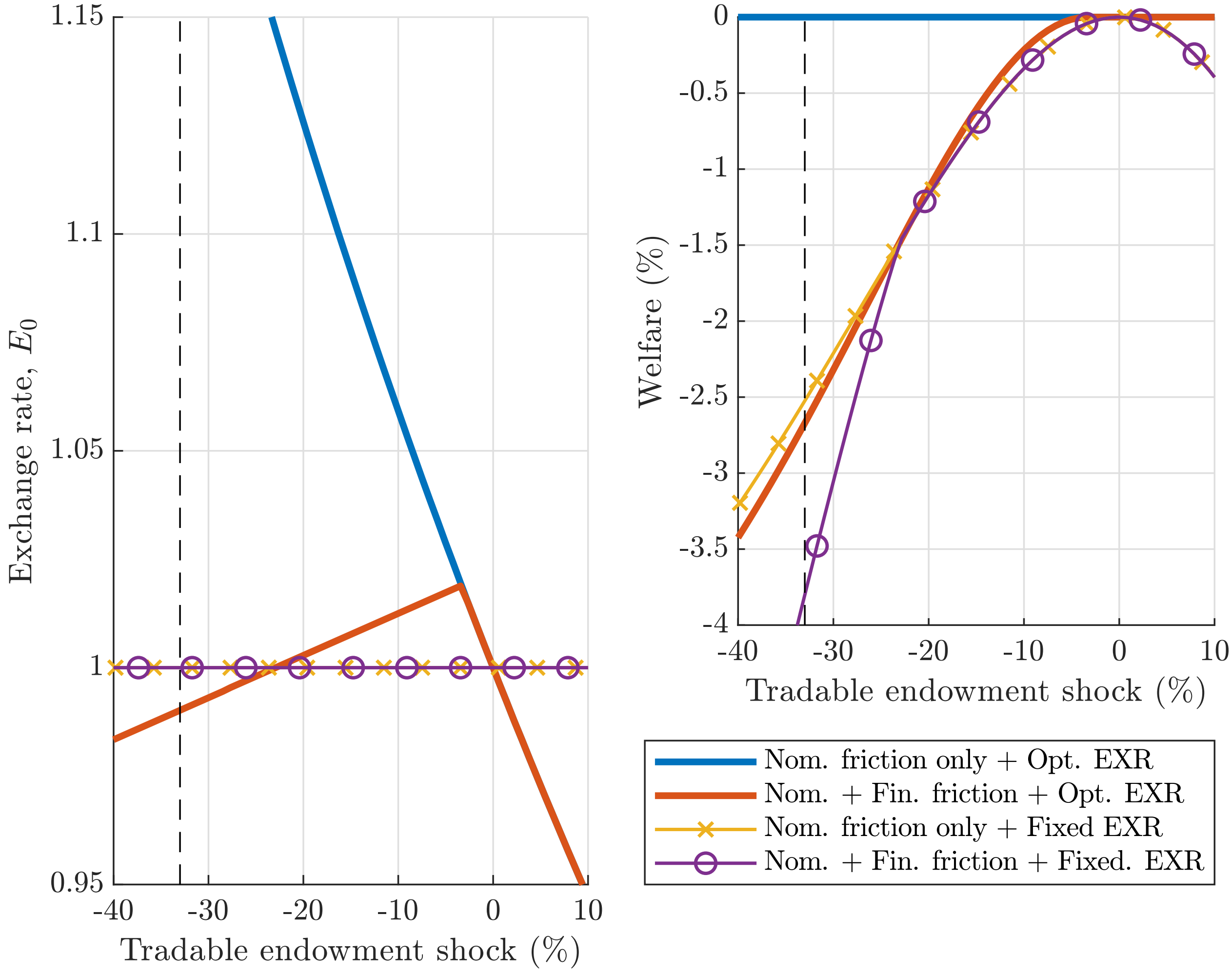
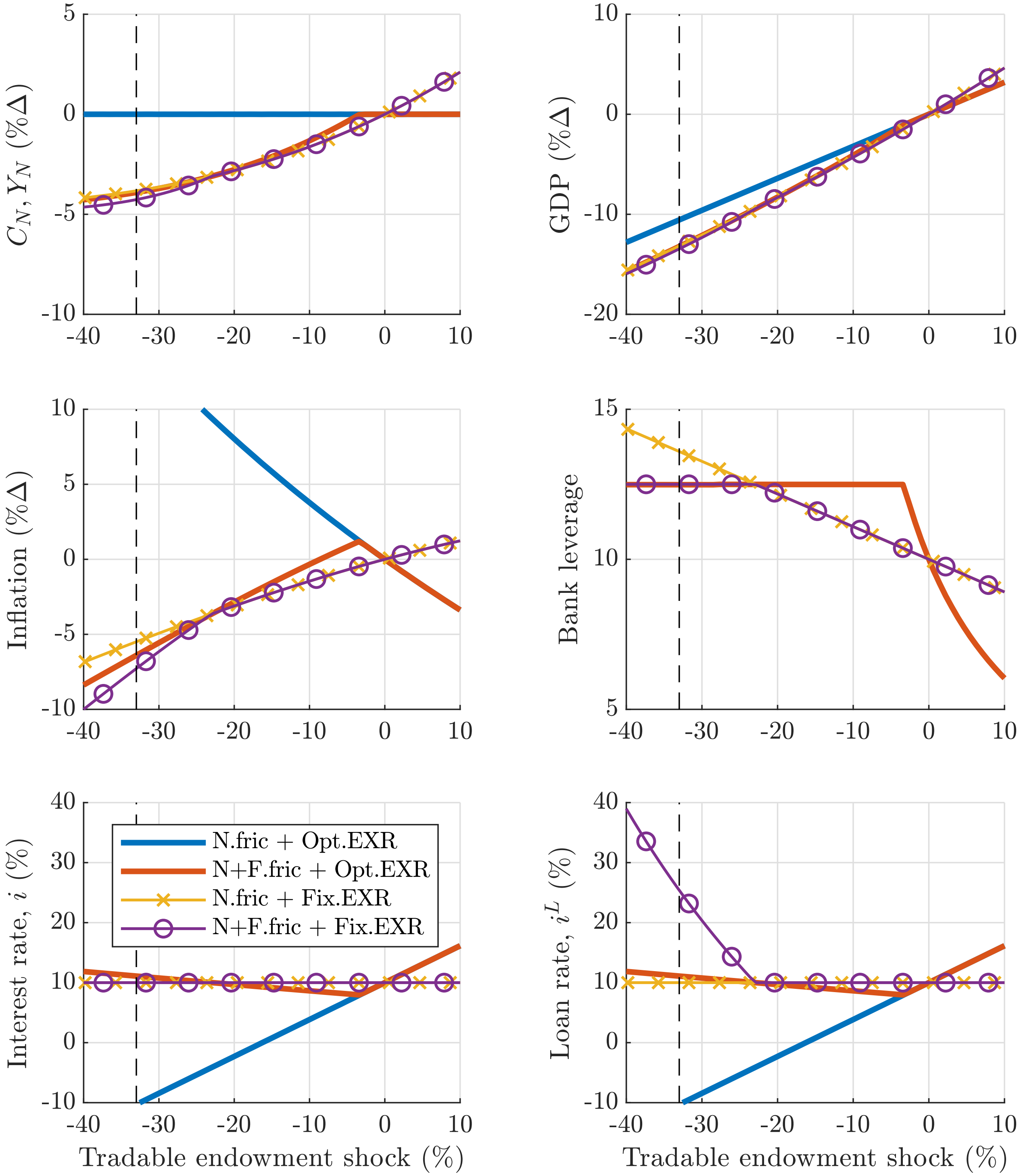


Figure 7: Response to tradable endowment shock with subsistence consumption

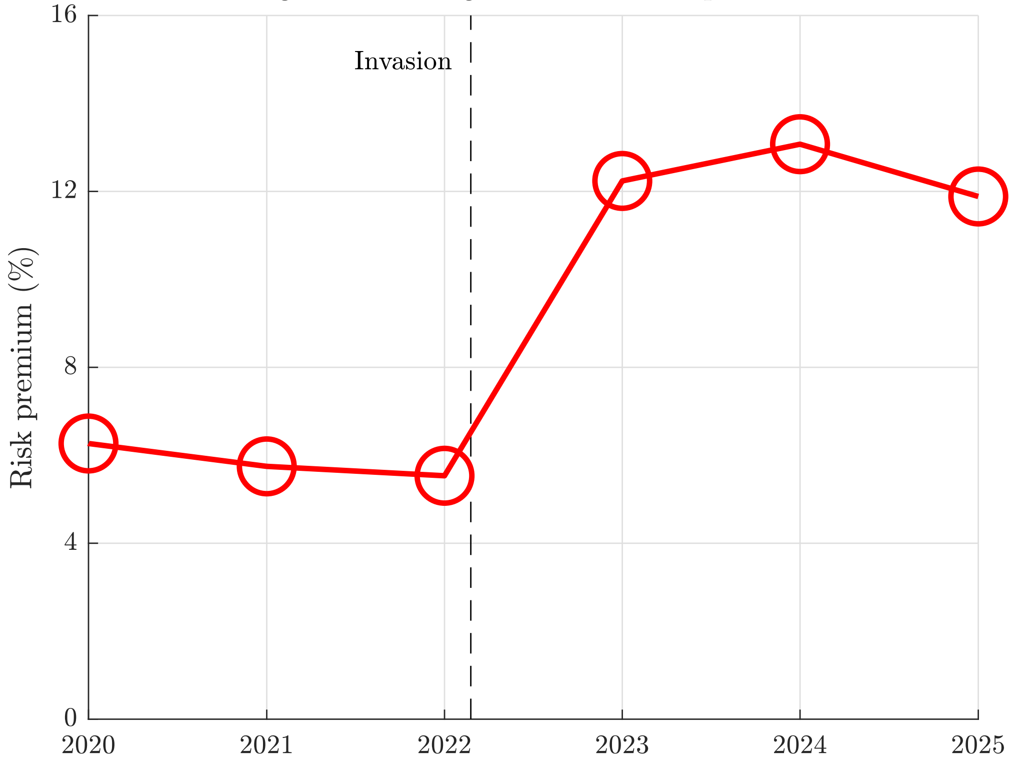


estimated default spread jumped from 5.53% to 12.24%, a rise of 6.70 percentage points. Using an elastic interest rate function of the form

$$i_t^* = i^* + \psi \left(\exp \left(1 - Y_{T,t} \right) - 1 \right), \tag{D.1}$$

plus the change in tradable output and the change in the default spread, we can back out a value for ψ of 0.17. Figures 9 and 10 present the results, which are largely unchanged. The

Figure 8: Ratings-based default spread



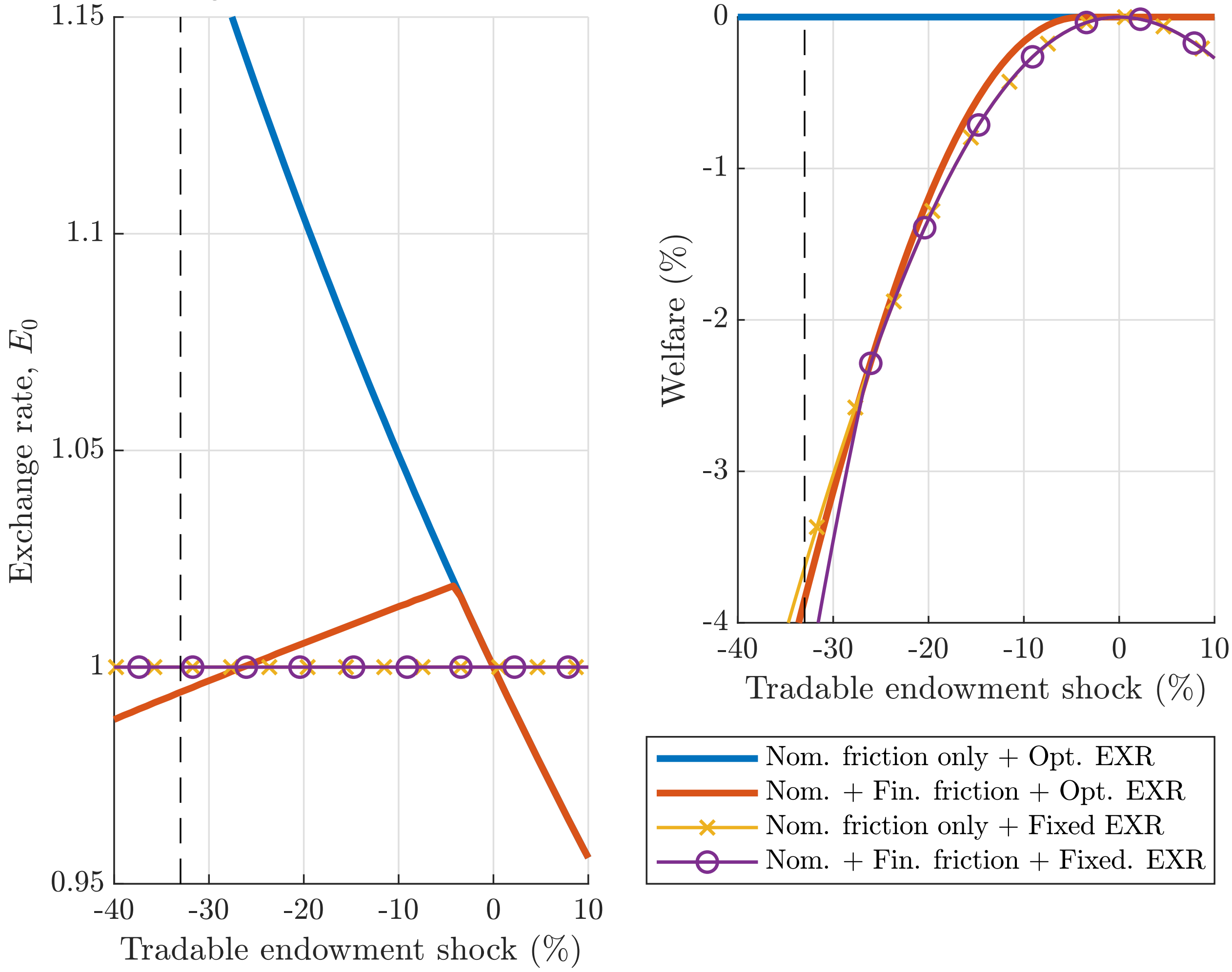
Source: Aswath Damodaran (`https://pages.stern.nyu.edu/~adamodar/`)

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 percent.

D.2 Use of data from an alternative emerging market economy

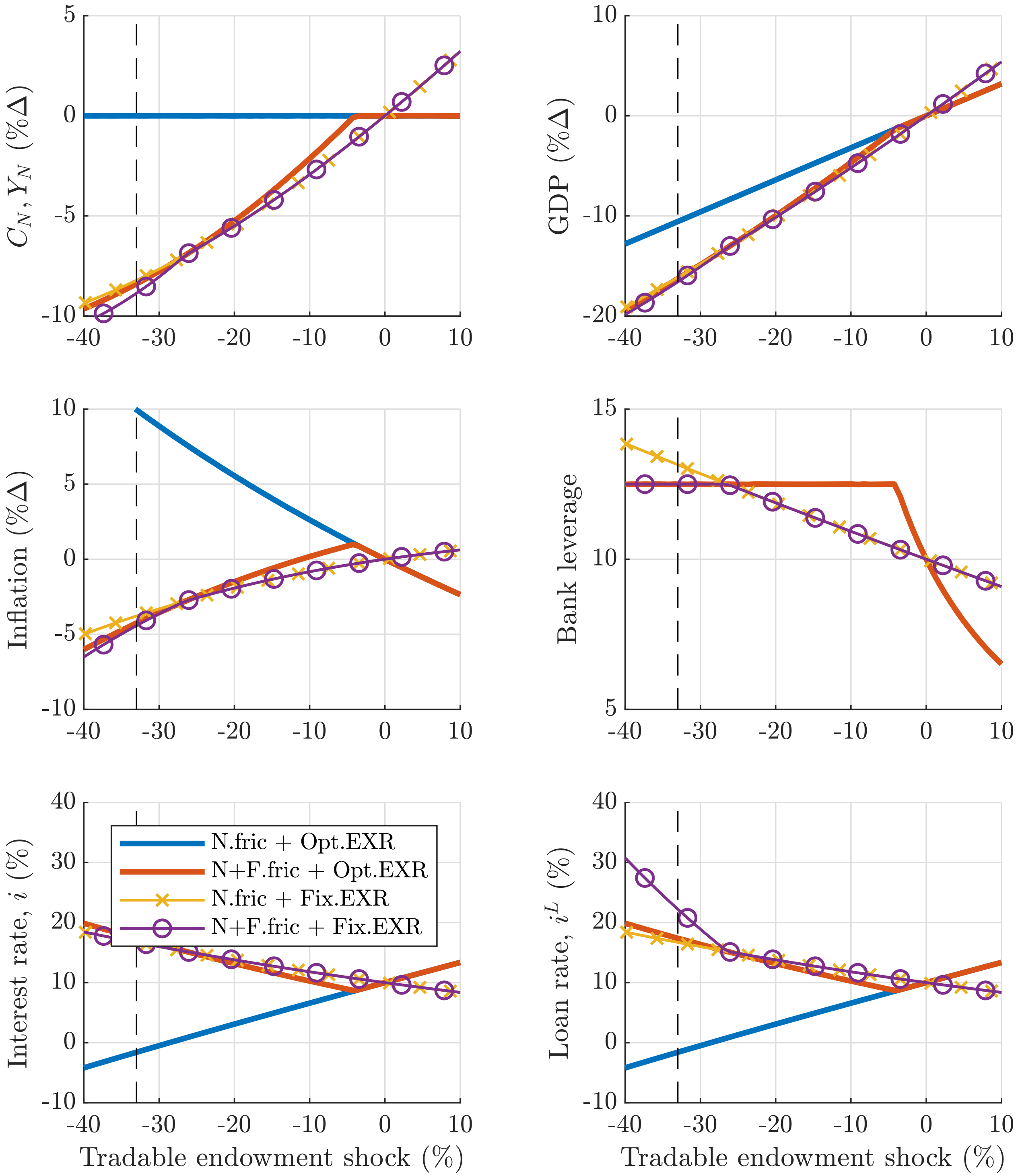
Since the previous approach was based on just two data points, 12 months apart, in this subsection, we instead use time-series evidence from an alternative emergin market economy—Argentina. In Uribe and Schmitt-Grohé (2017) Chapter 9, the estimated impact of a tradable

Figure 9: Response to tradable endowment & risk-premium shock



Note: Based on the elastic-interest rate function.

Figure 10: Response to a tradable endowment & risk-premium shock: More variables



Note: Based on the elastic-interest rate function.

output shock is given as

$$\begin{bmatrix} \ln Y_{T,t} \\ \ln \frac{1+i_t^*}{1+i^*} \end{bmatrix} = \begin{bmatrix} 1.23 \\ -0.08 \end{bmatrix} \varepsilon_t. \tag{D.2}$$

Rearranging, this gives the relation

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

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). Figures 11 and 12 present 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.

E 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 (2.12), while allowing for time variation in ε, we obtain

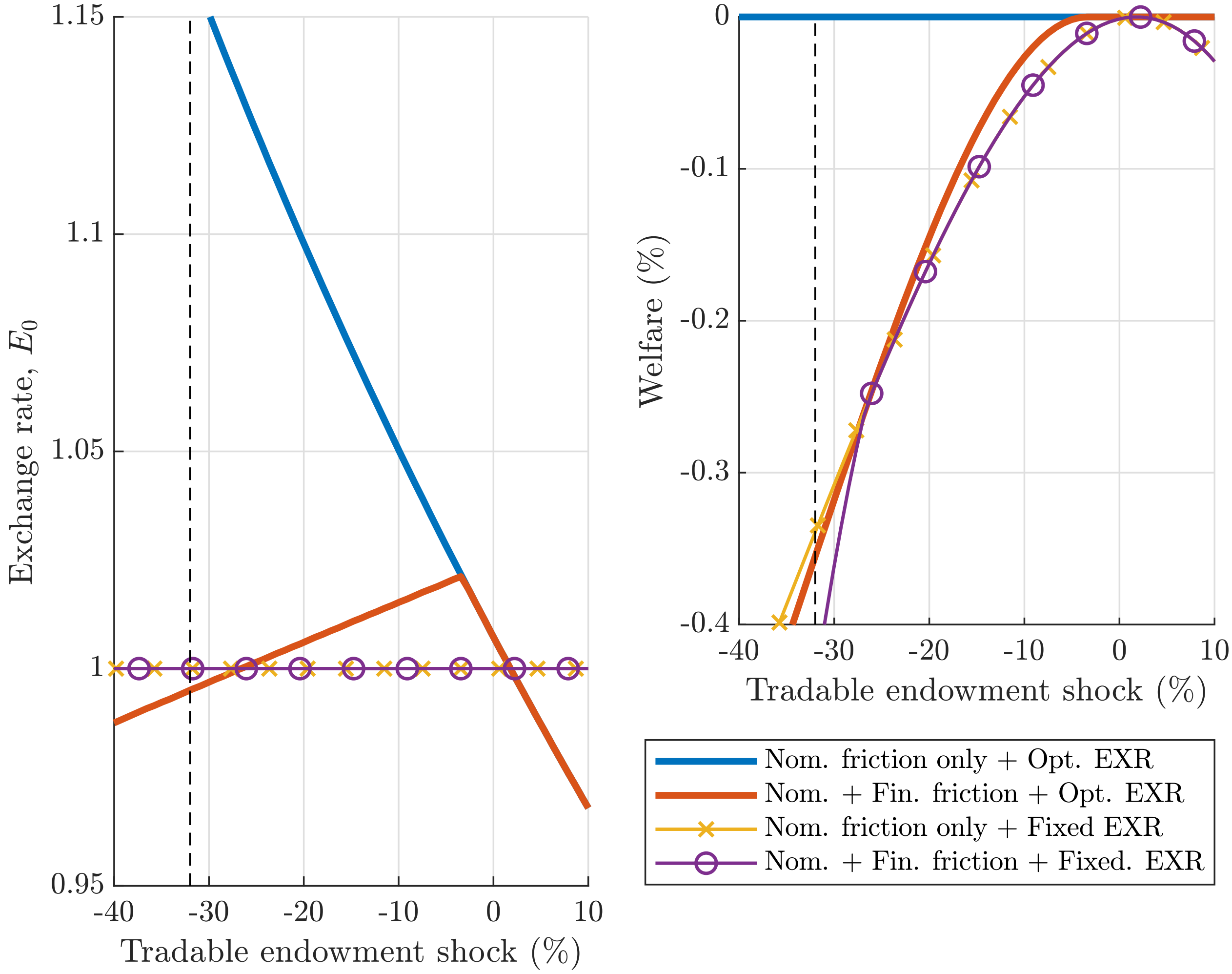
$$P_{N,t}(j) = (1-\phi) \frac{\varepsilon_t}{\varepsilon_t - 1} \frac{W_t}{A_t F'(N_t)}. \tag{E.1}$$

Hence, the aggregate price level becomes

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

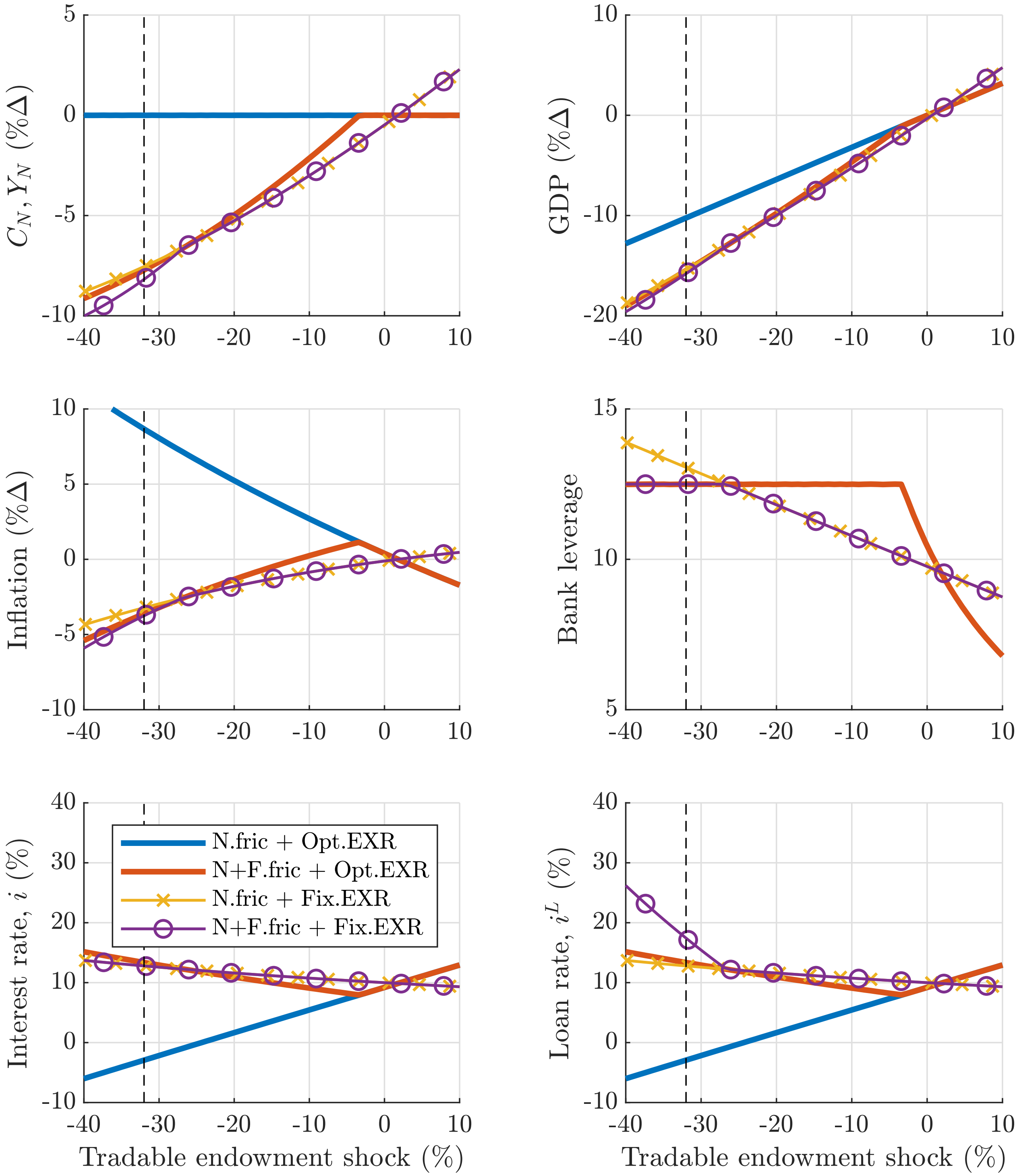
In the flexible-price equilibrium (which is no-longer efficient), the equilibrium condition be-

Figure 11: Response to tradable endowment and risk-premium shock



Note: Based on the correlation of tradable output and interest rates for Argentina.

Figure 12: Response to a tradable endowment and risk-premium shock: More variables



Note: Based on the correlation of tradable output and interest rates for Argentina.

comes

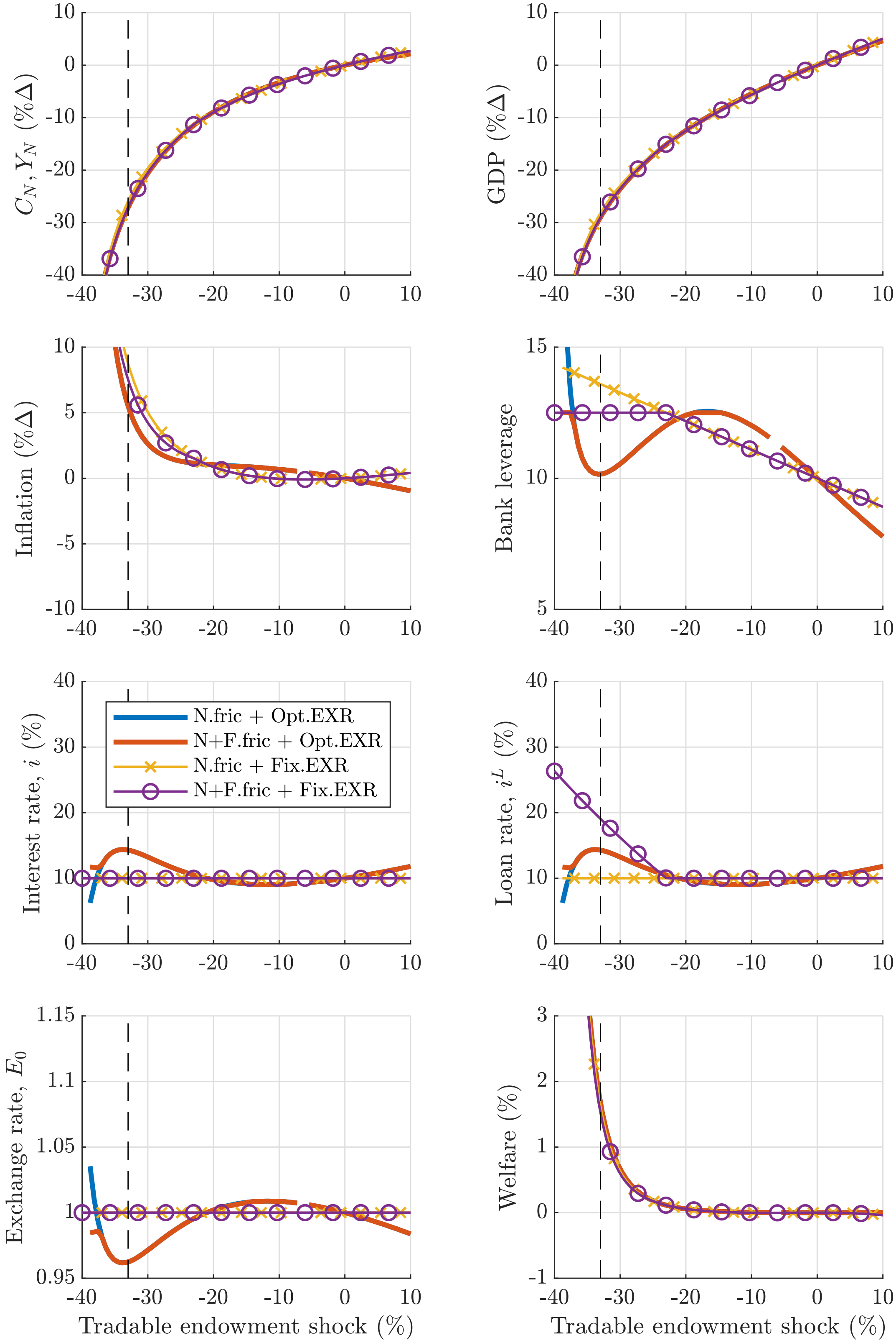
$$\chi C_{N,0}/\left(1-\alpha\right)=\frac{1}{1-\phi}\frac{\varepsilon_t-1}{\varepsilon_t}A_0. \tag{E.3}$$

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

$$\varepsilon=9+\chi\left(Y_{T,0}-1\right) \tag{E.4}$$

we obtain $\chi=19.8$. The results are reported in Figure 13. 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) prescribes a very modest depreciation for small negative shocks and an appreciation of 4% when tradable output declines by 33%. 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.

Figure 13: Response to tradable endowment and non-tradable supply shock



Note: Any gaps in the lines reflect occasional numerical converge problems.