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The Elusive Gains from Nationally-Oriented Monetary Policy*

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Abstract

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1 Introduction

The consensus view among academic economists and policymakers is that, once monetary authorities have chartered an optimal course to pursue purely domestic objectives, there is little to be gained from explicit coordination of monetary policy at the international level. The international monetary policy compact that follows from this consensus view is encapsulated in the maxim "keep your house in order."[1] Starting in the 1980s, a vast body of research in open economy macro has lent theoretical support to this maxim, suggesting that, from a social welfare point of view, if each country could keep its house in order, the global economy would come arbitrarily close to an equilibrium in which policymakers commit to coordinate their policies optimally.[2] As noted by Taylor (2013) in relation to the Great Moderation period, "[...] policies were executed under a basic understanding that the outcome would be nearly as good as if countries coordinated their policy choices in a cooperative fashion." But the open macro literature that underpins this view draws on a much stronger theoretical result that there is virtually no welfare cost in switching from cooperative to non-cooperative policies. This is to say, the forceful pursuit of nationally-oriented monetary policy beyond current practice—e.g., beyond flexible inflation targeting—should have virtually no consequences on global stabilization and welfare, no matter how aggressively other countries engage in retaliatory measures. Can this theoretical tenet be trusted to provide reliable guidance for policy assessment and design?

We revisit the theory of international monetary cooperation using the same workhorse open economy macro model that has provided the analytical backbone. The key difference between our analysis and the analysis in previous papers is that we assess systematically how the gains from cooperation depend on and evolve dynamically with prevailing economic conditions. Departing from the literature, we show that international spillovers and gains from cooperation are small when global

[1] This view is articulated in detail by Svensson (2003) and Svensson (2010b), which characterize flexible inflation targeting as best practice monetary policy followed by many central banks. At different times, the maxim was reaffirmed by Jerome Powell, the current chair of the Board of Governors of the Federal Reserve, see Federal Reserve Board (2019), as well by his predecessors Janet Yellen, for instance see The Brookings Insitution (2019), and Ben Bernanke, for instance in Bernanke (2017).

[2] For instance, see Sachs and Oudiz (1984), Taylor (1985), Obstfeld and Rogoff (2002), Pappa (2004).

imbalances are modest, whereas policymakers may be tempted to pursue purely national objectives more and more forcefully when imbalances grow, leading to sizable foreign spillovers. With large imbalances, the distance between cooperative and non-cooperative policies widens, as the reaction of foreign policymakers may lead to reverberations that can shift the equilibrium far from the allocations under cooperative policies or under regimes of implicit cooperation, such as flexible inflation targeting. The economic conditions relevant for our argument depend on which financial and real distortions prevail in the economy, but a common thread is that following realistic economic developments, the cost of pursuing purely domestic objectives can rise to multiple times the cost of business cycles.

The model we use has standard features. The world consists of two countries, each specialized in the production of one good that is traded internationally and is an imperfect substitute for the good produced abroad. Both prices and wages are sticky, creating tradeoffs for monetary policy even in the face of technology shocks. We consider alternative financial market arrangements across countries, including incomplete markets with only two non-state contingent bonds alternatively parameterized to include or exclude valuation effects of nominal exchange rate movements, a complete set of Arrow-Debreu securities, and autarky.[3] Apart from the addition of sticky wages and the broader range of financial market arrangements, our model closely follows Benigno and Benigno (2006), and Corsetti, Dedola, and Leduc (2010). Like these authors, we consider cooperative and non-cooperative equilibria with Ramsey optimal strategies for monetary policy. We assume that prices are sticky in the producer's currency, which implies full passthrough of exchange rate movements to export prices. In sensitivity analysis we consider local- and dominant-currency-pricing which limit the passthrough of exchange rate movements to import prices faced by consumers.[4]

Based on this model, we compute the dynamic evolution of the economy under cooperation over a finite but large number of periods, which allows us to characterize

[3] The static model in Obstfeld and Rogoff (2002) featured only sticky wages and either financial autarky or a case in which terms of trade movements render financial market arrangements irrelevant as in Cole and Obstfeld (1991).

[4] Gopinath, Boz, Casas, Diez, Gourinchas, and Plagborg-Moller (2019) document the empirical relevance of dominant-currency-pricing.

the distribution of the variables in the model. Drawing economic conditions from this (dynamically endogenous) distribution, we assess the gains from cooperation relative to non-cooperative behavior. This method allows us to condition our welfare analysis on states of the economy that may be more or less likely, according to the model itself, identifying the key variables and tradeoffs that drive our results.

We show that the relevant variables and tradeoffs crucially vary with the structure of international financial markets. When financial markets across countries are incomplete, we find that the critical state variable is the net-foreign-asset position. Along paths with wider imbalances, the creditor country has a higher consumption profile and correspondingly lower marginal utility of consumption. Accordingly, the cooperative policy enhances overall welfare by compressing the creditor's consumption and expanding the debtor's. Without cooperation, the creditor country can use unanticipated deflation and an exchange rate appreciation to boost its consumption and leisure, something that the creditor will do as long as the perceived gains do not exceed the associated utility loss from changes on price and wage inflation. In turn, as the debtor country leans against the creditor's appreciation with deflation of its own, a competitive cycle arises, which can lead to large efficiency losses.

When international financial markets are complete, however, each country can insure against inflation movements in the other country, and global imbalances no longer motivate strategic monetary measures. Nonetheless, national policymakers may still face significant tradeoffs between stabilizing output and inflation. Just as under incomplete markets the gains from cooperation increase as net-foreign-asset positions grow, under complete markets the gains from cooperation increase with the distance of the real wage in either country from its steady-state value. Intuitively, the real wage maintains an imprint of how the cooperative policy affects relative production, consumption, and inflation levels across countries along the evolution of the global economy: at any point in time, the real wage reflects how cooperative policies have traded-off different objectives in the past. The farther the real wage is from its steady-state level, the greater is the potential mismatch between cooperative and nationally-oriented policies. Drawing transition points from the distribution generated by the model allows us to characterize the distribution of the costs of self-oriented national policies and to show that they can exceed the costs of economic fluctuations.

A distinguishing feature of our analysis is that, for the first time, we offer an assessment of the incentives to deviate unilaterally from cooperation. By contrast, previous papers stopped after characterizing the equilibrium of the competitive game. To analyze the deviation incentives, we set up a two-stage game. In the first stage of the game, each country chooses its preferences to be either exclusively focused on the welfare of its residents, or encompassing the welfare of the residents of the other country. In the second stage, the two countries play an open-loop Nash game that determines the welfare of each country, given the actions selected at the first stage and conditional on the transition point. We find that the gains from unilateral deviations from cooperation at the first stage of the game are influenced by the same prevailing economic conditions that magnify the gains from cooperation. Accordingly, our results indicate that cooperation is more fragile exactly when it is more advantageous.

In our baseline analysis, we follow the literature, contrasting the case of full cooperation with (open-loop) non-cooperative strategies under commitment. As mentioned at the beginning of this text, however, national central banks have the mandate to achieve a small set of nationally-oriented objectives such as domestic price stability and full resource utilization, not to coordinate their policies in support of economic conditions in foreign countries.[5] Much in line with the comment by Taylor (2013), we show that, in the workhorse model we use, a regime of non-cooperative flexible inflation targeting can support an equilibrium that is close to the one under a regime of full cooperation, despite its sole focus on domestic inflation and output. But for this very reason, under the economic conditions discussed above, the incentives to deviate from flexible inflation targeting towards aggressive policies that reflect national objectives are just as strong as the incentives to deviate from full cooperation. In this respect, our analysis moves well beyond Taylor's and the literature characterization of the properties of inward-looking policies.

Our model is related to (and in some cases encompasses) key contributions in the literature which either lend support to, or express criticism of the consensus

[5] See Svensson (2010a) and Reis (2013) for reviews of mandates for central banks.

view.[6] For instance, in specifications of our model in which country-specific monetary policy tradeoffs are small, with financial autarky for example, our results are close to those of Obstfeld and Rogoff (2002). A critical reassessment of the literature is offered by Canzoneri, Cumby, and Diba (2005) who also point out the gains from cooperation can become more sizable than in Obstfeld and Rogoff (2002) in a model with a non-tradeable sector and sector-specific technology shocks. Nonetheless the gains they report remain negligible relative to the cost of business cycles. Rabitsch (2012), stresses the importance of different financial arrangements in shaping the costs of abandoning cooperative policies. Relatedly, Banerjee, Devereux, and Lombardo (2016) consider a model with financial frictions. None of these authors condition the welfare analysis on dynamic economic developments. By focusing on the steady states of their models, these authors only uncover small welfare differences between cooperative and non-cooperative equilibria. By contrast, our results show that, under reasonable and empirically relevant calibrations of the model, the costs of abandoning cooperative policies evolve dynamically and can become quantitatively important, as do the incentives to move towards nationally-oriented policies. A convincing assessment of these costs and incentives can only be conditional on this evolution, emphasizing the need for an approach that moves away from steady-state analysis.

Other closely related papers include Korinek (2017), which presents a First Welfare Theorem for open economies, spelling out conditions on the interactions between policymakers, policy instruments and financial markets that need to be violated to open up any role for cooperation. His work and ours are complementary. A notable paper is by Benigno and Benigno (2006), who emphasize that the conditions under which nationally-oriented policies have no costs are actually quite restrictive—without however highlighting the channels that lead to their dynamic evolution and without pursuing a quantitative analysis.

The rest of the paper proceeds as follows. Section 2 outlines the model, and the cooperative, non-cooperative policies, including flexible inflation targeting. Section 3 showcases the strategic interactions implied by non-cooperative policies and describes

[6] Early contributions include Hamada (1976) and Canzoneri and Henderson (1991).

the analytical framework we use to dissect them. Section 4 presents our results under incomplete markets with a symmetric portfolio of international bonds setup to exclude valuation effects. It sizes the welfare gains from cooperation, the cost of business cycles, the incentives to deviate from cooperative strategies, the Pareto efficiency gains, and the incentives to deviate from policies that are consistent with implicit cooperation. Section 5 looks into valuation effects linked to asymmetric international bond portfolios, into exchange rate passthrough, and into alternative sources of economic fluctuations. Section 6 highlights alternative economic conditions that shape the gains from cooperations under complete financial markets or under financial autarky. Section 7 concludes.

2 Economic Environment

The analysis builds on a standard two-country two-goods New Keynesian model similar to those in Obstfeld and Rogoff (2002), Clarida, Gali, and Gertler (2002), Benigno and Benigno (2006), and Corsetti, Dedola, and Leduc (2010).

2.1 Model Setup

A continuum of agents of mass 1 lives in each of two equal-sized countries. In the baseline model, exports are denominated in the currency of the exporting country (producer-currency-pricing), prices and wages are sticky as in Calvo (1983), international financial markets are incomplete, and shocks to total factor productivity are the only source of uncertainty. In the following brief description of the model, given the symmetry of the setup, we focus on country 1, the home country. Appendix A offers more details on the model and describes the extensions we study as sensitivity analysis, including local-currency-pricing, dominant-currency-pricing, complete international financial markets, and financial autarky.

2.1.1 Households

The intertemporal preferences of the representative household in country 1, the home country, are

$$\mathcal{U}_{1,t} = E_t \sum_{j=0}^{\infty} \beta^j U_{1,t}, \tag{1}$$

$$\text{where } U_{1,t} = \ln\left(C_{1,t+j} - \kappa C_{1,t+j-1}\right) - \frac{\chi_0}{1+\chi} L_{1,t+j}^{1+\chi}. \tag{2}$$

The felicity function $U_{1,t}$ depends on current and lagged consumption $C_{1,t}$ as well as hours worked $L_{1,t}$. In line with the New Keynesian literature, the economy is cashless and abstracts from the utility component of money.

The household maximizes intertemporal utility given the budget constraint

$$P_{1,t}^c C_{1,t} + \frac{1}{\phi_{1,t}^b}\left\{P_{1,t}^b B_{11,t} + e_{1,t} P_{2,t}^b B_{12,t}\right\} + \int_S P_{1,t+1|t}^D D_{1,t+1|t}$$
$$= W_{1,t} L_{1,t} + B_{11,t-1} + e_{1,t} B_{12,t-1} + D_{1,t|t-1} + T_{1,t}. \tag{3}$$

The difference between nominal consumption expenditures, $P_{1,t}^c C_{1,t}$, and nominal wage and non-wage income, $W_{1,t}L_{1,t}$ and $T_{1,t}$ respectively, is accounted for by trade in and holdings of financial assets. In detail, households have access to state-contingent bonds $D_{1,t+1|t}$ that only trade within the country at price $P_{1,t+1|t}^D$. In addition, households trade two non-state-contingent bonds of different currency denomination in the international financial market. The bonds are held/issued in fixed proportions

$$\eta B_{11,t} = (1-\eta) e_{1,t} B_{12,t}. \tag{4}$$

When setting $\eta = 0.5$, half of the net-foreign-asset (NFA) position of country 1 consists of the bond denominated in the currency of country 1, $B_{11,t}$, and the other half denominated in the currency of country 2, $B_{12,t}$. When setting $\eta = 0$, only the bond denoted in the currency of country 1 is traded, yielding an asymmetry when solving our model. Finally, households face a small intermediation cost $\phi_{1,t}^b$ that is a function of the NFA position (relative to the size of the economy). This cost ensures that the distribution of the NFA position is stationary in our simulations.

Perfectly competitive distributors assemble the final consumption basket $C_{1,t}$ from the home and (imported) foreign manufactured goods, $C^d_{1,t}$ and $M_{1,t}$, respectively. The distributors solve the cost minimization problem

$$
\begin{aligned}
&\min_{C^d_{1,t}, M_{1,t}} P^d_{1,t} C^d_{1,t} + P^m_{1,t} M_{1,t} \\
&s.t. \\
&C_{1,t} = \left((\omega^c)^{\frac{\rho^c}{1+\rho^c}} \left(C^d_{1,t}\right)^{\frac{1}{1+\rho^c}} + (1-\omega^c)^{\frac{\rho^c}{1+\rho^c}} \left(M_{1,t}\right)^{\frac{1}{1+\rho^c}} \right)^{1+\rho^c}, \qquad (5)
\end{aligned}
$$

where the price of the imported good, $P^m_{1,t}$, equals its price in the foreign country times the nominal exchange rate, $e_t P^d_{2,t}$.

2.1.2 Price and Wage Phillips Curves

Households supply $L_{1,t}$ units of labor services to labor unions. The unions, indexed by h, introduce distinguishing characteristics to household labor to produce $L_{1,t}(h)$, before selling it to labor bundlers as in Erceg, Henderson, and Levin (2000). These bundlers are perfectly competitive and combine the labor services from the unions into the labor service $L^d_{1,t}$ according to $L^d_{1,t} = \left[\int_0^1 L_{1,t}(h)^{\frac{1}{1+\theta^w}} dh\right]^{1+\theta^w}$. They sell these services at wage $W_{1,t}$ to intermediate goods producers.

The monopolistically competitive unions take the real wage desired by households, $\tilde{W}_{1,t}/P_{1,t}$, as the cost of labor and set nominal wages as in Calvo (1983). Each period, with probability $1-\xi^w$, a union gets to adjust its wage $W_{1,t}(h)$ optimally; otherwise, a union adjusts its wage by the steady-state inflation rate, $\bar{\Pi}$. The union solves

$$
\max_{W_{1,t}(h)} E_t \sum_{j=0}^{\infty} (\xi^w)^j \Lambda_{1,t+j} \left[(1+\tau^w)\bar{\Pi}^j W_{1,t}(h) - \tilde{W}_{1,t+j} \right] L_{1,t+j}(h) \qquad (6)
$$

$$
s.t.
$$

$$
L_{1,t}(h) = \left[\frac{W_{1,t}(h)}{W_{1,t}} \right]^{-\frac{1+\theta^w}{\theta^w}} L^d_{1,t}, \qquad (7)
$$

where the stochastic discount factor, $\Lambda_{1,t+j}$, is such that $\Lambda_{1,t+j} = \beta^j \frac{MU_{1,t+j}}{MU_{1,t}}$ and where $MU_{1,t}$ is the marginal utility of consumption. Equation (7) relates the bundlers' demand for the union's labor to the union's wage $W_{1,t}(h)$. The subsidy τ^w makes the level of the labor supply efficient in the steady state.

We model sticky nominal prices analogously. Monopolistically competitive firms produce differentiated varieties using a linear technology

$$Y_{1,t}(i) = \exp\left(z_{1,t}\right) L_{1,t}^{d}(i), \tag{8}$$

where $z_{1,t}$ is the country-wide technology shock. The term $L_{1,t}^{d}(i)$ is the demand of firm i for the aggregate labor services $L_{1,t}^{d}$ implying marginal production costs of $W_{1,t}/\exp\left(z_{1,t}\right)$. Competitive bundlers combine the varieties into the home manufactured good according to $Y_{1,t}^{d} = \left[\int_0^1 Y_{1,t}\left(i\right)^{\frac{1}{1+\theta^p}} di\right]^{1+\theta^p}$ and sell it at the price $P_{1,t}^{d}$ domestically and at the price $P_{1,t}^{d}/e_t$ abroad.

Variety producers set nominal prices as in Calvo (1983). Each period, a producer adjusts its price $P_{1,t}$(i) with fixed with probability $1-\xi^p$ optimally and with probability ξ^p by the steady-state inflation rate $\bar{\Pi}$. A producer solves

$$\begin{aligned}
&\max_{P_{1,t}(i),\{Y_{1,t+j}(i)\}_{t=0}^{\infty}} E_t \sum_{j=0}^{\infty} (\xi^p)^j \Lambda_{1,t+j} \left(\left(1+\tau^p\right) \bar{\Pi}^j P_{1,t}(i) - \frac{W_{1,t+j}}{\exp\left(z_{1,t+j}\right)} \right) Y_{1,t+j}(i) \\
&s.t. \\
&Y_{1,t+j}(i) = \left[\frac{P_{1,t+j}(i)}{P_{1,t+j}^{d}} \right]^{-\frac{1+\theta^p}{\theta^p}} Y_{1,t+j}^{d}.
\end{aligned} \tag{9}$$

Equation (9) relates the demand by the bundlers for variety i, $Y_{1,t+j}(i)$, to the price of the variety, $P_{1,t}(i)$. The sales subsidy τ^p is set to eliminate the relative price distortions due to monopolistic competition in the deterministic steady state.

2.1.3 Market Clearing

Market clearing in the factor and goods markets implies

$$L_{1,t} = \int_0^1 L_{1,t}(h) dh \tag{10}$$

and

$$Y_{1,t}^{d} = C_{1,t}^{d} + M_{2,t}, \tag{11}$$

where $M_{2,t}$ denotes the demand of the foreign country for the domestic good.

Finally, domestically traded bonds are in zero net supply, requiring $D_{1,t+1|t} = 0$. For internationally traded bonds, market clearing requires

$$B_{11,t} + B_{21,t} = 0, \tag{12}$$

$$B_{12,t} + B_{22,t} = 0. \tag{13}$$

2.2 Monetary Policy

Monetary policymakers in each country set the path of their respective policy instrument, $i_{1,t}$ and $i_{2,t}$, to optimize their assigned objective function subject to the optimality and market clearing conditions associated with the model as detailed in Appendix A. The optimality and market clearing conditions are summarized by

$$E_t g(\tilde{x}_{t-1}, \tilde{x}_t, \tilde{x}_{t+1}, i_{1,t}, i_{2,t}, \zeta_t) = 0, \tag{14}$$

where $\tilde{x}_t$ are the $(N-2) \times 1$ vector of endogenous variables excluding policy instruments and ζ_t are the exogenous shocks. The objective functions differ between the cooperative and the non-cooperative policy game, as detailed below.

2.2.1 Cooperative Policies

In the cooperative game, the policymakers maximize global welfare defined as the weighted average of the utility of the representative households in the two countries, $\omega \mathcal{U}_{1,t} + (1-\omega)\mathcal{U}_{2,t}$, under full commitment

$$\begin{aligned} &\max_{\{\tilde{x}_t, i_{1,t}, i_{2,t}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \left[\omega U_1(\tilde{x}_{t-1}, \tilde{x}_t, \zeta_t) + (1-\omega) U_2(\tilde{x}_{t-1}, \tilde{x}_t, \zeta_t) \right], \\ &s.t. \\ &E_t g(\tilde{x}_{t-1}, \tilde{x}_t, \tilde{x}_{t+1}, i_{1,t}, i_{2,t}, \zeta_t) = 0. \end{aligned} \tag{15}$$

We refer to the monetary policies associated with the cooperative game as "cooperative policies."

2.2.2 Non-cooperative or Nationally-Oriented Policies

We model the non-cooperative interactions between policymakers in different countries as an open-loop Nash game. Let $\{i_{j,t,-t^*}\}_{t=0}^{\infty}$ denote the sequence of policy choices by player $j = [1,2]$ before and after, but not including period t^*. An open-loop Nash equilibrium is a sequence $\left\{i_{j,t}^*\right\}_{t=0}^{\infty}$ with the property that for all t^*, i_{j,t^*}^* maximizes player $j's$ objective function subject to the structural equations of the economy in Equation (14) for given sequences $\left\{i_{j,t,-t^*}^*\right\}_{t=0}^{\infty}$ and $\left\{i_{-j,t}^*\right\}_{t=0}^{\infty}$, where $\left\{i_{-j,t}^*\right\}_{t=0}^{\infty}$ denotes the sequence of policy moves by the other player. Each player's action is the best response to the other players' best responses.

With policymakers needing to specify a complete contingent plan at time 0 for their respective instrument variable, we can recast each player's optimization problem as an optimal control problem given the policies of the other player

$$\begin{aligned}
&\max_{\{\tilde{x}_t, i_{j,t}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t U_j(\tilde{x}_{t-1}, \tilde{x}_t, \zeta_t), \\
&s.t. \\
&E_t g(\tilde{x}_{t-1}, \tilde{x}_t, \tilde{x}_{t+1}, i_{1,t}, i_{2,t}, \zeta_t) = 0 \\
&\text{for given } \{i_{-j,t}\}_{t=0}^{\infty}.
\end{aligned} \tag{16}$$

We refer to the monetary policies associated with the non-cooperative game as "nationally-oriented policies."

2.2.3 Keep-your-house-in-order Policies

The objective function of the policymakers need not coincide with the utility functions of the representative households. Using the general loss function L_j, we modify the non-cooperative game in Section 2.2.2 to be

$$\begin{aligned}
&\max_{\{\tilde{x}_t, i_{j,t}\}_{t=0}^{\infty}} -E_0 \sum_{t=0}^{\infty} \beta^t L_j(\tilde{x}_{t-1}, \tilde{x}_t, \zeta_t), \\
&s.t. \\
&E_t g(\tilde{x}_{t-1}, \tilde{x}_t, \tilde{x}_{t+1}, i_{1,t}, i_{2,t}, \zeta_t) = 0 \\
&\text{for given } \{i_{-j,t}\}_{t=0}^{\infty}.
\end{aligned} \tag{17}$$

Following Svensson (2003), we capture flexible inflation targeting with the simple loss function

$$L_j = w_\pi(\pi^4_{j,ct} - \bar{\pi}^4)^2 + w_y(y^{gap}_{j,t})^2, \tag{18}$$

where $\pi^4_{j,ct}$ denotes annualized consumption price inflation and $y^{gap}_{j,t}$ the output gap in country j.[7]

2.3 Parameterization and Solution Method

The model parameters are reported in Table 1. While most of the parameters in this table are standard in the literature, it is important to note that there is no general agreement on the appropriate value of the trade elasticity of substitution for aggregate open economy models. Some authors have emphasized elasticities well above one as empirically relevant. For instance, Bernard, Eaton, Jensen, and Kortum (2003) report a trade elasticity of substitution in the range of 4, while Benigno and Thoenissen (2008) and Corsetti, Dedola, and Leduc (2008) stress that values lower than 1 can also be empirically relevant. Accordingly, we explore the whole range of relevant values, $[0.65, 4]$, as measured by $\frac{1+\rho^c}{\rho^c}$, the trade elasticity in our model.

We use second-order perturbation methods to approximate the conditions for an equilibrium implied under cooperative and nationally-oriented policies (see the maximization problems in Equations 15 and 16, respectively). To derive the analytical conditions for an equilibrium under these two policies we apply the symbolic differentiation toolbox of Bodenstein, Guerrieri, and LaBriola (2019). We follow Benigno and Benigno (2006) in using domestic price inflation as the policy instrument.[8]

3 Analytical Framework

Our main interest is to explore the conditions under which cooperative behavior yields significant welfare gains, as well as to characterize the circumstances that may

[7] We defined the output gap as the difference between output in the model with nominal price and wage rigidities and output in the analogous model with flexible prices and wages.

[8] For the second-order perturbation solution we rely on Dynare. See Adjemian, Bastani, Karamé, Juillard, Maih, Mihoubi, Perendia, Pfeifer, Ratto, and Villemot (2011). All the model statistics reported below are computed using a true second-order approximation, using the pruning algorithm described in Kim, Kim, Schaumburg, and Sims (2008).

Table 1: Parameters for the Baseline Two-Country Model

Parameter	Used to Determine	Parameter	Used to Determine
$\beta = 0.995$	discount factor	$\kappa = 0.5$	consumption habits
$\chi = 1/2.84$	labor supply elasticity $= \frac{1}{\chi}$	$\bar{L} = 1/3$	steady-state labor supply to fix χ_0
$\xi^p = 0.75$	price stickiness	$\xi^w = 0.75$	wage stickiness
$\theta_p = 0.1$	price markup (before subsidy)	$\theta_w = 0.1$	wage markup (before subsidy)
$\tau_p = 0.1$	subsidy to producers	$\tau_w = 0.1$	subsidy to unions
$\omega^c = 0.88$	home bias in consumption	$\omega = 0.5$	weight of home country in global welfare
$\phi^b = 10^{-4}$	governs bond intermediation cost	$\eta = 0.5$	share of bonds in home country currency
$\rho^z = 0.95$	persistence of tech. shock	$\sigma^z = 0.015$	std. of tech. shock

Note: This table summarizes the parameterization of the baseline two-country model described in Section at quarterly frequency.

motivate policymakers to switch from cooperative behavior to the aggressive pursuit of national goals. In this section, we first provide an illustration of the difference in macroeconomic dynamics under the two regimes. Then we explain the methods we employ to address our questions of interest.

3.1 From Cooperative Policies to Currency Wars

An intuitive way of gauging the difference between cooperative and non-cooperative policies is to scrutinize the paths of a few key macroeconomic variables under the two regimes, starting from the same initial conditions. We construct an example of transition paths by choosing a set of initial conditions drawn from the ergodic distribution of the model under cooperative policies (characterized in a later section). At the particular conditions, the home country is a creditor.[9]

As a creditor, the inflow of interest payments allows the home country to exert less labor effort and maintain a higher consumption profile, implying a lower marginal utility. Accordingly, the cooperative policy can enhance overall welfare by compressing the creditor's consumption per unit of labor effort, while expanding the debtor's. At these initial conditions, inflation is below its steady-state value at home and abroad; the exchange rate is mildly depreciated.

[9] In this example economy, the trade elasticity is 4 and borrowing and lending is conducted through an equally weighted basket of bonds denominated in each of the two currencies, i.e., $\eta = \frac{1}{2}$.

In this situation, the home country has an incentive to use self-interested monetary measures to reverse the cooperative redistribution. The incentive is to improve the country's terms of trade by a monetary contraction that lowers inflation and leads to an unanticipated appreciation of the real exchange rate. Better terms of trade mean lower labor effort for any given level of consumption. A sharp appreciation of the currency of the home country also reduces its net exports and leads to a drop in its NFA position.

In equilibrium, of course, the foreign debtor will not remain idle. It will have an incentive to lean against the home appreciation, spurring the home country to redouble its efforts to improve its terms of trade—an interaction that is typically dubbed exchange rate war. This war has negative consequences, such as greater price dispersion, below-target inflation and real wage misalignment. These consequences moderate and eventually offset the gains from attempting to improve the consumption-to-labor ratio via monetary policy. The final outcome is a global loss of efficiency and welfare.

The equilibrium paths for key variables are shown in Figure 1. The path for the non-cooperative case is shown in deviation from the case in which the two countries continue to cooperate. The currency war results for both countries in an initial fall in inflation, consumption, and hours worked relative to cooperation. Nonetheless, the home country manages to engineer a real appreciation, hence hours worked drop more than in the foreign country. While this drop in hours worked is beneficial for the home country, both countries end up being worse off under non-cooperation. The exchange rate war produces no winner. Rather, as we show below, the war results in substantial efficiency and welfare losses.

3.2 Assessing the Gains from Cooperation and the Incentive to Deviate from Cooperative Behavior

The preceding example suggests that the macroeconomic and welfare differences between cooperative and non-cooperative arrangements are systematically related to prevailing economic conditions, and so are the incentives to deviate from cooperation.

Below, we detail the methods we deploy to study these relationships. We define the way we size the gains from cooperation, the cost of business cycles, the incentives to deviate from cooperation, Pareto efficiency gains, and the incentives to deviate from implicit cooperative arrangements implied by inflation-targeting policies.

3.2.1 The Gains from Cooperation

To size the gains from cooperation, we rely on a comparison of the *conditional* welfare values attained under the cooperative and the nationally-oriented policies.[10] Specifically, rather than focusing on one arbitrary point, which in the literature is typically the deterministic steady state, we sample transition points from the ergodic distribution of the model under the cooperative equilibrium, and assess welfare conditional on each of these points. To this purpose, we draw random sequences of shocks for 250 periods. The final point in this series provides the transition point for the welfare comparison of the two policies (denoted by $\tilde{x}_{250}$). We compare the conditional welfare implied by non-cooperative policies starting in period 251 with the conditional welfare implied by continued reliance on cooperative policies. We construct a distribution of gains from cooperation (losses from non-cooperative policies) based on a sample of 1000 transition points from the ergodic distribution.

To interpret the units of conditional welfare, we follow the standard metric of consumption equivalent variation. We report the consumption subsidy that would have to be offered in perpetuity to households for them to attain the same level of welfare under the nationally-oriented policies as under the cooperative policies. The subsidy net rate τ equals

$$\tau = \exp\left(\frac{1-\beta}{\omega}\left(Welf_t^{coop} - Welf_t^{nat}\right)\right) - 1.$$

$Welf_t^{coop} = \omega\mathcal{U}_{1,t}^{coop} + (1-\omega)\mathcal{U}_{2,t}^{coop}$ denotes the global welfare level attained under the cooperative equilibrium and, similarly, $Welf_t^{nat}$ is the global welfare level attained under the non-cooperative equilibrium. The derivation of this subsidy is detailed in Appendix B. In the following sections, we report the mean and other characterstics

[10] See Kim and Kim (2018) for a discussion of how optimal policies based on conditional welfare measures can appear suboptimal when ranked with unconditional welfare measures.

of the distribution of this subsidy, such as the fifth and ninety-fifth percentiles.

3.2.2 The Cost of Business Cycles

To interpret the gains from cooperation, τ, we compare them against a measure of the cost of economic fluctuations. Focusing on the cooperative equilibrium, following Lucas (2003), we size the cost of economic fluctuations as the consumption equivalent variation that, starting from the deterministic steady state, with all current and future shocks excluded, would keep households indifferent from having to face shocks.[11]

3.2.3 Incentives to Deviate

Across points of the ergodic distribution, given the different state of the economy at each point, there could be substantial variation in the incentives for policymakers to keep their commitment to cooperation, as opposed to considering a new course of policy strategies, more narrowly focused on national objectives. To assess these incentives, we consider the following two-stage game.

In the first stage, conditional on each transition point $\tilde{x}_{250}$, we let a country choose between *cooperate* or *deviate*. If country j chooses *cooperate*, its objective is the global welfare function $\omega\mathcal{U}_{1,t} + (1-\omega)\mathcal{U}_{2,t}$; if it chooses *deviate*, its objective is the national welfare function $\mathcal{U}_{j,t}$, for $j = 1, 2$. In the second stage, the two countries play an open-loop Nash game (as described in Section 2.2.2) that determines each country's welfare given the actions selected in the first stage and conditional on the transition point $\tilde{x}_{250}$.[12] Note that, if both countries choose *cooperate* in the first stage, the second stage game yields the same outcomes as the cooperative policies defined in Section 2.2.1. Analogously, if both countries choose deviate in the first stage, the second stage game yields the same outcomes as the non-cooperative policies defined in Section 2.2.2.

[11] Mechanically, the two economies have identical second-order perturbation solutions, but for a vector of constants (the stochastic shift factor) that enters the economy with shocks and that drops out of the other economy without shocks. To encompass the effects of current shocks, we draw 1000 random shock vectors, and average the consumption equivalent variation for each shock vector.

[12] The objective functions of the policymakers in Equation (16) are determined by the actions chosen in the first stage of the game.

3.2.4 Efficiency Gains and the Pareto Frontier

Since we model symmetric countries, a natural starting point is to assume a cooperative welfare function that puts equal weights on the utility of each country.[13] However, along the points of the ergodic distribution, countries are no longer symmetric, and one may wonder whether equal weights may cause our results to reflect redistribution under cooperation, rather than only gains in efficiency.

For this reason, in addition to the welfare analysis based on equal weights for the utility of each country, we also consider a Pareto approach. For this approach, we construct the Pareto frontier by varying the welfare weight ω over the range from 0 to 1 at each transition point. We compare the non-cooperative and cooperative allocations by considering the changes in utility consistent with making either country better off without making the other country worse off. Previewing our results, we find that this parsimonious approach still delivers large efficiency gains relative to the cost of business cycles.

4 Fragility of Cooperation with Growing External Imbalances

Under incomplete financial markets, consumption smoothing in the face of economic disturbances typically leads to the accumulation of external imbalances (NFA positions). Once these imbalances widen, the creditor country will have a lower marginal utility of consumption and leisure. As suggested by our example in section 3.1, the cooperative planner will improve global welfare by setting monetary policy to redistribute consumption and leisure from the creditor country to the debtor country. It is this redistribution that creates an incentive to deviate from cooperation, with each country attempting to get a larger share of global resources, at the cost of some misallocation of domestic resources. The inherent tradeoff between external and internal objectives moderates the unbrindled pursuit of non-cooperative policies.

[13] Giving each country the same weight ($\omega = \frac{1}{2}$) in the global welfare function ensures that the cooperative and the non-cooperative game yield the same deterministic steady state in our setup with symmetric, equal-sized countries. Moreover, this deterministic steady state coincides with the steady state for the competitive equilibrium under flexible prices and wages.

Before turning to our results, recall that, our baseline parameterization implies that countries borrow and lend trading an equally-weighted portfolio of domestic-currency and foreign-currency denominated bonds. With this portfolio, monetary policy cannot influence the value of NFA positions by manipulating the exchange rate ex post—ruling out surprise valuation effects.

4.1 Net Foreign Assets and the Gains from Cooperation

Figure 2 provides a striking illustration of the importance of external balance accumulation as a key driver of the gains from cooperation. The results shown in the figure refer to an economy for which technology shocks are the only economic disturbances. The top panel depicts the ergodic probability density functon (PDF) for the NFA position of the home country, measured in percent of annualized output for four values of the trade elasticity $\frac{1+\rho^c}{\rho^c} = \{0.7; 0.8; 2; 4\}$. The bottom panel plots the gains from cooperation against NFA positions for each of the 1000 transition points drawn from the ergodic distribution under the cooperative policies, as detailed in Section 3.2.

In our baseline, we intentionally assume that technology shocks are the only sources of economic fluctuations. Accordingly, the (ergodic) distribution of NFA positions under the cooperative policies varies with the trade elasticity non-monotonically. As is well known from Cole and Obstfeld (1991), technology shocks cause no accumulation of net foreign assets/debts under a unitary trade elasticity and log-utility over consumption (i.e., home and foreign goods are neither substitutes nor complements), since in this limit case terms of trade movements provide efficient risk sharing without the need for trading assets. The distribution of NFA positions in Figure 2, however, becomes more dispersed either as the trade elasticity falls below 1 or as it rises above 1. Extreme NFA positions are more likely under a high trade elasticity, well above 1, than under a low elasticity, well below 1.

The gains from cooperation depend on the NFA position at that transition point. As shown in the bottom panel of Figure 2, fixing the value of the trade elasticity, the gains from cooperation increase with the (absolute) value of NFA position. Conversely, fixing the value of NFA position, the gains from cooperation increase as the value of the trade elasticity declines. For NFA positions close to zero, the gains are negligible regardless of the value of the trade elasticity.

The figure suggests that the other endogenous variables, apart from the NFA position, play a negligible role in influencing the size of the gains. To wit, if other variables played a sizable role, the points shown in the bottom panel would not line up in a neat parabola. We confirmed this result with a regression of the gains from cooperation on the NFA positions and their squares. The regression yields an R^2 statistic of 0.99, confirming that the other endogenous variables at the transition point have no meaningful role in influencing the gains from cooperation.

Figure 3 plots the welfare gains from continuing to cooperate rather than adopting nationally-oriented policies, averaging over the 1000 transition points (the dashed-dotted line), against the trade elasticity. The figure shows the mean together with the 5^{th} and 95^{th} percentiles (the dotted lines) of the distribution of gains associated with the 1000 transition points. For comparison, the figure also plots the cost of business cycles, i.e., the gains that would accrue if all fluctuations were to be eliminated, shown by the dashed line.

The figure highlights one of our key results. The gains from cooperation can be much higher than the cost of business cycles—and are large for trade elasticities away from 1. With trade elasticities higher than 1, this result is driven by the higher likelihood of large trade imbalances. Conversely, for trade elasticities lower than 1, gains from cooperation are large even for modest trade imbalances—this is because the equilibrium response of the terms of trade to monetary policy are quite pronounced, causing large monetary spillovers. With the distribution of NFA positions concentrated at zero for trade elasticities near 1, the mean of the gains is 0 and there is no variation. Note that the distance between the percentiles shown in the bottom graph implies that the variation in the gains is higher when the average gains from cooperation are higher.

4.2 Incentives to Deviate from Cooperation and the Distribution of Gains and Losses

The outcomes discussed in the preceding section for each particular transition point incorporate the reaction of the foreign country to the non-cooperative policy switch in the home country. Accordingly, we only captured the final equilibrium. To account for the incentives to deviate from the cooperative behavior, we rely on the two-stage game described in section 3.2.3. At each transition point, in the first stage we let a country choose between *cooperate* or *deviate*; in the second stage, we let them play an open-loop Nash game conditional on the choices in the first stage.

For all combinations of actions in the first stage of the game, Figure 4 plots the payoffs of the second-stage game against the home country's NFA position at each transition point $\tilde{x}_{250}$ for the case of a trade elasticity equal to 4.[14] The payoffs are expressed as country-specific consumption-equivalent variations (τ_1, τ_2). By construction, τ_1 and τ_2 are 0 regardless of the NFA position if both countries choose *cooperate*. For concreteness, we report in Table 2 the payoffs at a particular transition point. In this example, the home country has a debt position of 50 percent of (annualized) output.[15]

Table 2: Payoff Matrix in the Two-Stage Game

		home	
		cooperate	deviate
foreign	cooperate	$(0, 0)$	$(0.45\%, -0.62\%)$
	deviate	$(-0.62\%, 0.45\%)$	$(-0.18\%, -0.18\%)$

The takeaways from Figure 4 and the specific example shown in Table 2 are straightforward. First, when the home country deviates from coopration and the foreign country continues to cooperate, the configuration considered in the upper right panel of the figure, the home country is better off deviating, regardless of

[14] The country-specific consumption-equivalent variation τ_j, $j = 1, 2$, measures the consumption subsidy/tax that would have to be offered in perpetuity to each household in country j to attain the same level of welfare as under the cooperative policies. See Appendix B.

[15] In the Nash equilibrium, the sum $\tau_1 + \tau_2$ is equal, to a first order approximation, to minus the gains from cooperation τ reported earlier. See Appendix B.

whether it is a net creditor or a net debtor. Moreover, the home country is better off deviating also when the foreign country deviates, as can be evinced by comparing the payoffs for the home country across the bottom two panels of the figure. Accordingly, *deviate* is a dominant strategy for the home country for all transition points. By symmetry, *deviate* is also a dominant strategy for the foreign country for all transition points (see the lower left panel of the figure).

Second, since *deviate* is a dominant strategy for both countries in the first stage of the game, the unique Nash equilibrium in the game features both countries opting for their respective nationally-oriented welfare function $\mathcal{U}_{j,t}$, for $j = 1, 2$, in the first stage, followed by the open-loop Nash game in the second stage. As countries borrow and lend by trading a diversified portfolio of bonds denominated in both currencies, exchange rate movements do not change the value of their net positions ex post, limiting the scope for cross-country redistribution via monetary measures. With each country responding to the attempt by the other to tilt the terms of trade in favor of its residents, the Nash equilibrium results in inefficient inflation and output stabilization. As shown in the lower right panel in the figure, national welfare falls with the deterioration in the efficiency of the global allocation.

4.3 Efficiency Gains

We now show that much of the benefits from cooperation discussed so far stem from efficiency gains. For this analysis, when countries continue to cooperate, we do not impose balanced welfare weights ($\omega = 0.5$ for each country), but compute the cooperative allocations for a range of welfare weights, allowing us to trace the Pareto frontier, as discussed in Section 3.2.4.

The top panel of Figure 5 shows the Pareto frontier for one of the randomly drawn 1000 transition points. As an example, we consider the case of a trade elasticity of substitution equal to 4. At that transition point, the home country has a net debt balance of 50% of (annualized) output—recall that the ergodic probability density function for the NFA position of the home country is shown in the top panel of Figure 2 for this case). The X symbol in the top panel of Figure 5 marks the utility levels associated with the non-cooperative outcome. This outcome is inefficient, as indicated by its position inside the Pareto frontier. The broken lines in the chart start from the non-cooperative outcome and reach the frontier to denote alternative outcomes that would leave either country better off without making the other country worse off.

The bottom panel summarizes the Pareto gains for each country for alternative transition points. Again, we expressed the gains as consumption equivalent variation. For comparison, the panel also shows the gains from cooperation from the global welfare function based on symmetric weights.[16] The welfare gains include efficiency gains, but also encompass gains from allocating these efficiency gains to each country optimally, and (possibly) gains from redistribution. The proximity of the global welfare gains to the Pareto gains shown in the figure points to efficiency as being the principal source of gains.

4.4 "Keeping One's House in Order"

In our baseline analysis, we follow the literature by contrasting the case of full cooperation with (open-loop) non-cooperative strategies under commitment. In practice, central banks have the mandate to achieve a small set of nationally-oriented objectives, such as domestic price stability and full resource utilization, which can be modeled as flexible inflation targeting, see Section 2.2.3.

In the model, flexible-inflation-targeting policies that place a sufficiently large weight on the output gap can come close to replicating the cooperative case. For instance, with weights $w_\pi = 1$ and $w_y = 10$ for the loss function in Equation (18), the global welfare loss amounts to a modest 3 basis points of consumption. Accordingly, flexible inflation targeting can be tantamount to implicit cooperation. However, as external imbalances develop, we expect the incentives to deviate from flexible inflation targeting to be just as strong as for the case of explicit cooperation.

We assess the incentives to deviate from flexible inflation targeting towards objectives that consider the full spectrum of each country's welfare (see Equation 2) using

[16] To facilitate the comparison across different cases shown, rather than plotting a dot for consumption variation corresponding to each of the 1000 transition points randomly drawn from the ergodic distribution, we fit a fourth-order polynomial function. Apart from the polynomial interpolation, the blue line shown in the figure matches the results also shown in the bottom panel of Figure 2.

the same two-stage game as in the previous section. In the first stage, each country can choose between *inflation targeting* and *deviate*, given the transition point $\tilde{x}_{250}$. If country j chooses *inflation targeting*, its objective is given by Equation (18); if it chooses *deviate*, its objective is the national welfare function $\mathcal{U}_{j,t}$, for $j = 1, 2$ in Equation (2). In the second stage, the two countries play an open-loop Nash game that determines each country's welfare given the actions selected at the first stage and conditional on the transition point $\tilde{x}_{250}$.

Just like Figure 4, Figure 6 plots the country-specific consumption-equivalent variation of the second stage game against the home country's NFA position for each transition point. The results are strikingly similar to those of Figure 4, but the consumption variation curves are steeper, reflecting the added incentives to move away from sub-optimal, simple objectives towards national welfare functions. Accordingly, inflation targeting is a dominated strategy. In the Nash equilibrium, policymakers in both countries would choose *deviate* in the first stage.

5 How General Are Our Results?

In this section we reconsider our results with a number of popular variants of the workhorse monetary model. To start, we allow for valuation effects of the exchange rate on the ex-post return of external assets.[17] We then consider alternative specifications of nominal rigidities in export pricing, which affect exchange rate passthrough as well as alternative sources of business cycle disturbances.

5.1 Asymmetric International Asset Portfolios and Valuation Effects

We now assume that each country's foreign asset position is denominated solely in the currency of the home country, i.e., we set $\eta = 0$ in Equations (3) and (4). This privilege gives greater power to the home country's monetary policy instrument, which can now reset the real interest rate on foreign debt/assets.

[17] See Gourinchas and Rey (2014) for an overview of the importance of valuation effects for global imbalances.

Figure 7 shows again the gains from cooperation for different values of the trade elasticity of substitution between domestic and foreign goods. The setup is analogous to that of Figure 3, described in Section 4.1. Notice that in this case, monetary policy has additional reverberations. With asymmetric asset portfolios, surprise inflation movements can influence the NFA position. These additional effect boost the gains from cooperation relative to the symmetric case.

Revisiting the two-stage game described in Section 4.2 , Figure 8 shows the payoffs for each country depending on the transition point. The magnitude of the NFA position continues to drive the gains from cooperation—a regression of the gains from cooperation on the NFA position at the transition point yields an R^2 statistic of 0.99.

The home country is now better off by deviating than continuing to cooperate, regardless of the choice of the foreign country. Deviating is also a dominant strategy for the foreign country; accordingly the strategies *deviate*,*deviate* are a Nash equilibrium. We verified that *deviate* is a dominant strategy for each country regardless of the characteristics of the transition point.

Notice that, while both the home and the foreign country can affect the value of their interest payments (ex post) through the real exchange rate, the home country has an additional prerogative. Since nominal debt/asset contracts are written in the home currency, the home country also has the ability to change the ex-post real interest rate. This additional reach of monetary policy makes the home country the winner of the second stage of the game, regardless of whether it is a debtor or a creditor. However, winning the war for global resources is not without consequences. As apparent from the figure, in consumption equivalent terms, the gain of the home country is smaller than the loss of the foreign country. Taken together, the global economy is worse off.[18]

In this case, redistribution plays a non-negligible role in driving the welfare of the two countries apart. The top panel of Figure 9 focuses again on a transition point

[18] These results could be interpreted as one dimension of the privilege enjoyed by countries that can borrow and lend with bonds denominated in their own currency. In this respect, a note of caution is in order. Extrapolating from the preceding results, if a country borrowing and lending in its own currency adopted nationally-oriented policies, that privilege could be expected to come under stress soon.

in which the debt of the home country to the foreign country amounts to 50% of the output of the home country. By engineering a surprise devaluation of the stock of nominal debt, the non-cooperative policy moves the allocation both well inside the Pareto frontier and away from the equal-weight point. Notice that the redistribution is in favor of the home country.

As can be seen in the bottom panel of the figure, which shows again the welfare gains and the Pareto efficiency gains for each country, the Pareto gains for the home country are lower than for the foreign country, as the redistribution shown in the top panel lowers its marginal utility of consumption relative to the home country. While redistribution is more important in this case, efficiency gains continue to play an important role.

5.2 Exchange Rate Passthrough

The baseline model features producer-currency-pricing. Accordingly, exchange rate movements influence import prices one for one; exchange rate passthrough is *full*. We now show that the gains from cooperation are on average larger and more disperse when exchange rate passthrough is less-than-full. In this case, we revert to a symmetric portfolio of international bonds. The top row in Figure 10 shows the gains from cooperation for different values of the trade elasticity of substitution for the case of local-currency-pricing (exports are denominated in the currency of the importing country) and dominant-currency-pricing (exports are denominated in the home country's currency for all countries). The gray-shaded area shows the range of outcomes under the baseline model.

The reason why the gains from cooperation are higher under low exchange rate passthrough lies in the exchange rate sensitivity of the global demand for domestic goods. Under high exchange rate passthrough, a country's attempts to alter its NFA position through monetary policy and the exchange rate strongly affect the country's competitiveness in product markets. The negative welfare consequences of the induced output movements offset the gains from altering the NFA position. If passthrough is low, this offseting mechanism is muted. With the country's incentives to affect the NFA positions not held in check, the use of monetary policy to becomes more aggressive.[19]

Intuitively, these considerations apply more forcefully in the case of local-currency-pricing, when both countries have less-than-full passthrough of exchange rate movements to trade prices, than under dominant-currency-pricing, when the less-than-full passthrough applies to only one country.

The left panel of the middle row of Figure 10 considers the case of dominant-currency-pricing with an asymmetric international bond portfolio for which each country's foreign asset position is denominated only in the home country's currency. Combining these two features further enhances the ability of the home country to compete in products markets and boosts the gains from cooperation.

5.3 Productivity vs. Demand Shocks

Thus far, we have focused on technology shocks as the only source of economic disturbances. The terms of trade movements induced by the technology shock tend to stabilize the global economy, reducing the need for holding and issuing external debt, in particular for trade elasticities near unity. This feature of the model works against finding sizable gains from cooperation.

By contrast, for demand-type shocks, terms of trade movements do not offset the need for trading assets to share risk for any value of the trade elasticity. One shock of this type is a valuation shock; this shock alters the effective time preference of households, capturing households' time-varying preferences for consuming or saving. In an open economy setting, valuation shocks induce international borrowing and lending and may give rise to large external imbalances. Following Albuquerque, Eichenbaum, Luo, and Rebelo (2016), we implement the valuation shock in the

[19] Devereux and Engel (2003) also consider how local-currency-pricing affects cooperative and non-cooperative policies. In a model with complete markets, they focus on the special case in which the trade elasticity of substitution and the intertemporal elasticity of substitution are the inverse of each other, see Cole and Obstfeld (1991), which lends analytical tractability but masks the differences between cooperative and non-cooperative equilibria. Relatedly, Fujiwara and Wang (2017) show that the welfare gains from cooperation are larger under local-currency-pricing than producer-currcency-pricing in a model similar to ours but with complete markets. However, given their choices of parameters and initial conditions, the welfare gains from cooperation remain negligible regardless of the assumptions about the currency of invoicing.

home country $\iota_{1,t}$ as follows

$$\mathcal{U}_{1,t} = E_t \sum_{j=0}^{\infty} \iota_{1,t+j} \beta^j \left\{ \ln \left(C_{1,t+j} - \kappa C_{1,t+j-1} \right) - \frac{\chi_0}{1+\chi} L_{1,t+j}^{1+\chi} \right\} \tag{19}$$

with the growth rate of $\iota_{1,t}$ following an auto-regressive process of order 1

$$\ln \left(\frac{\iota_{1,t}}{\iota_{1,t-1}} \right) = \rho^\iota \ln \left(\frac{\iota_{1,t-1}}{\iota_{1,t-2}} \right) + \sigma^\iota \varepsilon_{1,t}^\iota. \tag{20}$$

Here, $\varepsilon_{1,t}^\iota$ is an i.i.d. standard-normal random variable. We set the persistence of the shock process $\rho^\iota = 0.95$ and its standard deviation $\sigma^\iota = 0.00089$. The unconditional variance of the growth rate of $\iota_{1,t}$ is the same as in Albuquerque, Eichenbaum, Luo, and Rebelo (2016).[20] The valuation shock in the foreign country is implemented analogously.

The right-hand panel in the middle row of Figure 10 compares the gains from cooperation for a model that includes valuation shocks as well as technology shocks with the gains for a model with only technology shocks. The notable difference is that the gains from cooperation do not drop to 0 for trade elasticities near unity. This feature is easily understood by noticing that valuation shocks profoundly alter the ergodic distribution of NFA positions. With trade elasticities near unity, the support of the distribution of NFA positions will be broad in the face of valuation shocks; by contrast, in the face of technology shocks the support will be narrowly concentrated around 0.

6 Financial markets

We have seen that, under incomplete markets the key tradeoffs that may motivate policymakers to deviate from cooperative practices arise from the accumulation of foreign debt—the temptation to monetary policy is to manipulate the interest payments on foreign assets, at the cost of inefficient price and wage stabilization. Shutting down the accumulation of non-state-contingent debt by assuming, in turn,

[20] Albuquerque, Eichenbaum, Luo, and Rebelo (2016) specify the shock to be more persist, but to be of smaller standard deviation.

complete markets or financial autarky allows us to highlight alternative economic conditions that shape the gains from cooperation.

6.1 Fragility of Cooperation with Growing Real Wage Misalignment under Complete Financial Markets

Under complete markets, since agents have access to a full set of state-contingent claims, monetary policy loses the ability to influence asset positions through inflation. Nonetheless, in the presence of nominal rigidities, monetary policy can still influence real allocations, and the real wage, in particular. To the extent that national trade-offs will be judged differently by national policymakers that do not internalize the spillover effects of their actions on foreign welfare, there will still be large gains from cooperation.

In line with this insight, we now show that under complete financial markets, the temptation to deviate from cooperation is increasing in the tradeoffs between inflation and unemployment, as is the case when price and wage rigidities translate into large and divergent real wage distortions. For ease of comparison with the literature and our previous analysis, we again focus again on a model that includes only technology shocks, and plot the gains from cooperation for different values of the trade elasticity. The bottom left panel of Figure 10 shows that, for our benchmark parameters, the gains from cooperation under complete markets rise monotonically with the trade elasticity. In other words, the spillover effects of country-specific monetary policy rise with the trade elasticity, leading to stronger strategic interactions. In the highest range of the trade elasticities we consider, from about 2.5 to 4, the gains rise to multiple times the cost of business cycles.

As for the incomplete market economies studied in the previous sections, the gains from cooperation continue to depend on the characteristics of the transition point between cooperation and non-cooperation under complete markets, and the welfare cost of a switch to non-cooperation can be tracked closely by a subset of the state variables. Recall that, under incomplete markets, the R^2 statistic for a regression of the gains from cooperation on the NFA imbalances and its square is 0.99. When markets are complete, we attain an R^2 of 0.99 regressing the gains from cooperation on domestic and foreign real wages (and their squares). The intuition for this finding is that the real wage at home and abroad maintain an imprint of how the cooperative policies have allocated consumption and hours worked in each country, a role similar to the role of the NFA position under incomplete markets.

Intuitively, gains from cooperation stem from the fact that, relative to cooperation, countries with higher real wages (possibly because of positive technology shocks) would like to pursue nominal and real exchange rate appreciation to benefit from higher leisure. Under complete markets, conditional on real wages and productivity being high, the gains in terms of leisure from extra monetary contraction cum appreciation (relative to cooperation) are larger than the cost of reducing consumption (which is high to start with) and producing some wage inflation dispersion. Accounting for retaliation, the non-cooperative equilibrium implies an allocation with too much inflation and suboptimal stabilization.

6.2 Financial Autarky

Under financial autarky, the determinants of the gains from cooperation can be expected to be similar to those under complete markets. We confirmed this insight by regressing the gains from cooperation on the real wage at home and abroad (and their squares) for each transition point. The R^2 statistic is again 0.99 (irrespective of the trade elasticity chosen).

However, without trade in assets, the gains from cooperation are much diminished. As shown in the bottom left panel of Figure 10, they are non negligible (but quite modest) only for low trade elasticities, below 0.7. Unlike under complete markets, non-cooperative policies result in non-negligible spillover effects abroad only as the trade elasticity shrinks. Absent risk sharing via financial markets, agents are no longer able to insure their consumption from undesired effects of non-cooperative policies. At high real wages, the perceived gains from attempting to improve leisure by improving a country terms of trade are moderated by the costs in terms of consumption.

7 Conclusion

The idea that international monetary cooperation can yield substantial benefits has traditionally been met with deep skepticism. Over the past five decades, one can identify at least three waves of criticisms. In the 1970s, when calls for cooperation were motivated by the need for joint management of large global shocks, such as the oil shocks, critics pointed out that negotiating the appropriate joint response took too long, and agreement was typically reached too late, after the worst effects of the shock had already abated. Moreover, throughout the 1970s, some countries systematically failed to deliver on the agreed action plan, reinforcing the view that cooperative agreements were unavoidably plagued by free riding and incentive-compatibility issues. A fundamental objection was formalized by Rogoff (1985), in the context of the disinflation policies during the 1980s. Rogoff warned that, while cooperation may be effective in internalizing cross-border demand spillovers, it may also reduce the credibility of central banks vis-à-vis the private sector, frustrating disinflation efforts. While these criticisms point to extant problems, a third and overarching criticism to cooperative monetary arrangements was leveled more recently by Obstfeld and Rogoff (2002), when these authors claimed that in modern monetary models, gains from cooperation are negligible, relative to *both* best-practice monetary policy *and* full-fledged Nash equilibrium policy strategies. While these authors focused on a special version of the workhorse monetary model, the subsequent literature did not overturn their findings.[21]

Our results are in line with this recent literature, in that they strengthen the theoretical support for the view that the gains of full cooperation may be small relative to best practice flexible inflation targeting. But our analysis also shows that the range of theoretical results from open economy macro theory is broader than previously acknowledged, and that policies consistent with a non-cooperative Nash equilibrium can be consequential for global welfare. Our contributions to the literature can be summarized in six points.

[21] The baseline model of Obstfeld and Rogoff (2002) assumes that technology shocks are the only source of economic fluctuations and that the trade elasticity and the intertemporal elasticity of substitution are the inverse of each other, the case discussed by Cole and Obstfeld (1991), for which we have shown that the gains from cooperation are minimized.

First and foremost, using the same model that has lent support to the claim by Obstfeld and Rogoff (2002), we have shown that there are empirically plausible conditions that make the gains from cooperation several times larger than the cost of economic fluctuations. Our second point is methodological: welfare gains from cooperation are to be assessed conditional on economic conditions. Our third point concerns the nature of these gains. While non-cooperative strategies are essentially redistributive (aiming to improve the terms of trade of a country), welfare gains from cooperation are largely driven by Pareto efficiency gains—the efficiency cost of non-cooperative policies can be large. This is so even when foreign (nominal) assets and liabilities are denominated in one currency, giving one country the ability to manipulate real rates of return ex post in its own favor, by means of unexpected movements in the exchange rate.

The fourth and fifth points raise economic policy concerns. The same economic conditions that magnify the gains from cooperation also magnify the incentives to deviate from cooperation unilaterally, thus making cooperation more fragile exactly when it is more beneficial. In addition, monetary policy regimes that deliver de facto cooperation, such as flexible inflation targeting, are subject to the same incentives to reoptimize towards fully national objectives as formal cooperative arrangements.

Our sixth and last point stresses that financial frictions are not a necessary condition for monetary policy to have large cross-border spillovers. The economic conditions that magnify the gains from cooperation arise under both incomplete and complete financial markets arrangements. Financial arrangements that govern risk-sharing and influence trade flows across countries do not determine whether there are gains from cooperation, but which economic conditions matter the most. We have shown that, with incomplete markets, the gains from cooperation grow quadratically with the net-foreign-asset position—internal imbalances have little or no weight independently of their role in driving foreign debt/wealth accumulation. With complete markets, the gains depend on real wages at home and abroad, which bear an imprint of how production and consumption respond to shocks.

During the last decades, the world has witnessed substantial and persistent accumulation of external debt, accompanied by remarkable changes in relative incomes and wages. Especially in the aftermath of the Global Financial Crisis, macroeconomic stabilization has been challenged by complex tradeoffs. With persistent external and internal imbalances, domestic policymakers may become less tolerant of the requirements of good behavior from a global perspective. Holding foreign policies constant, the perceived tradeoffs may tilt in favor of nationally-oriented policies, which, breaking away from the post-Bretton Woods equilibrium, may be pursued in an antagonistic way. The risk is that strong policy actions may end up magnifying external spillovers, especially if they trigger a spiral of retaliatory actions.

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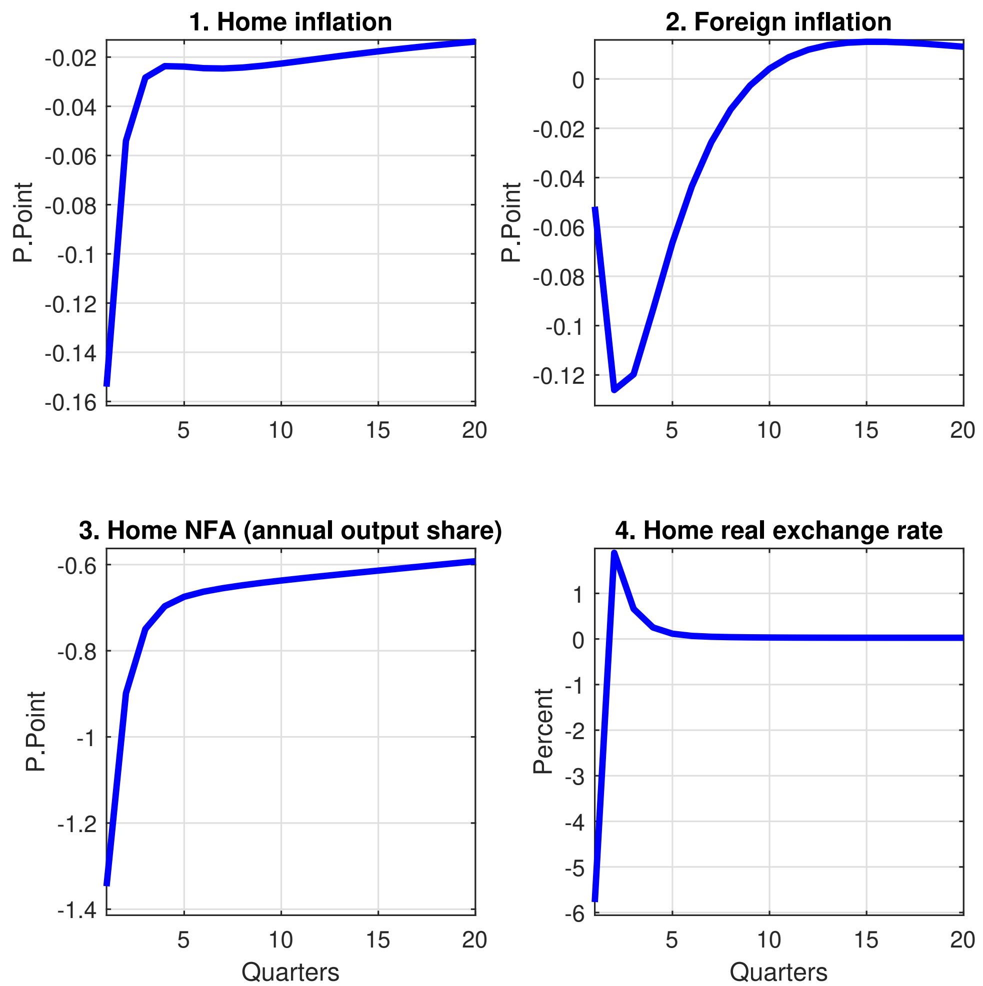
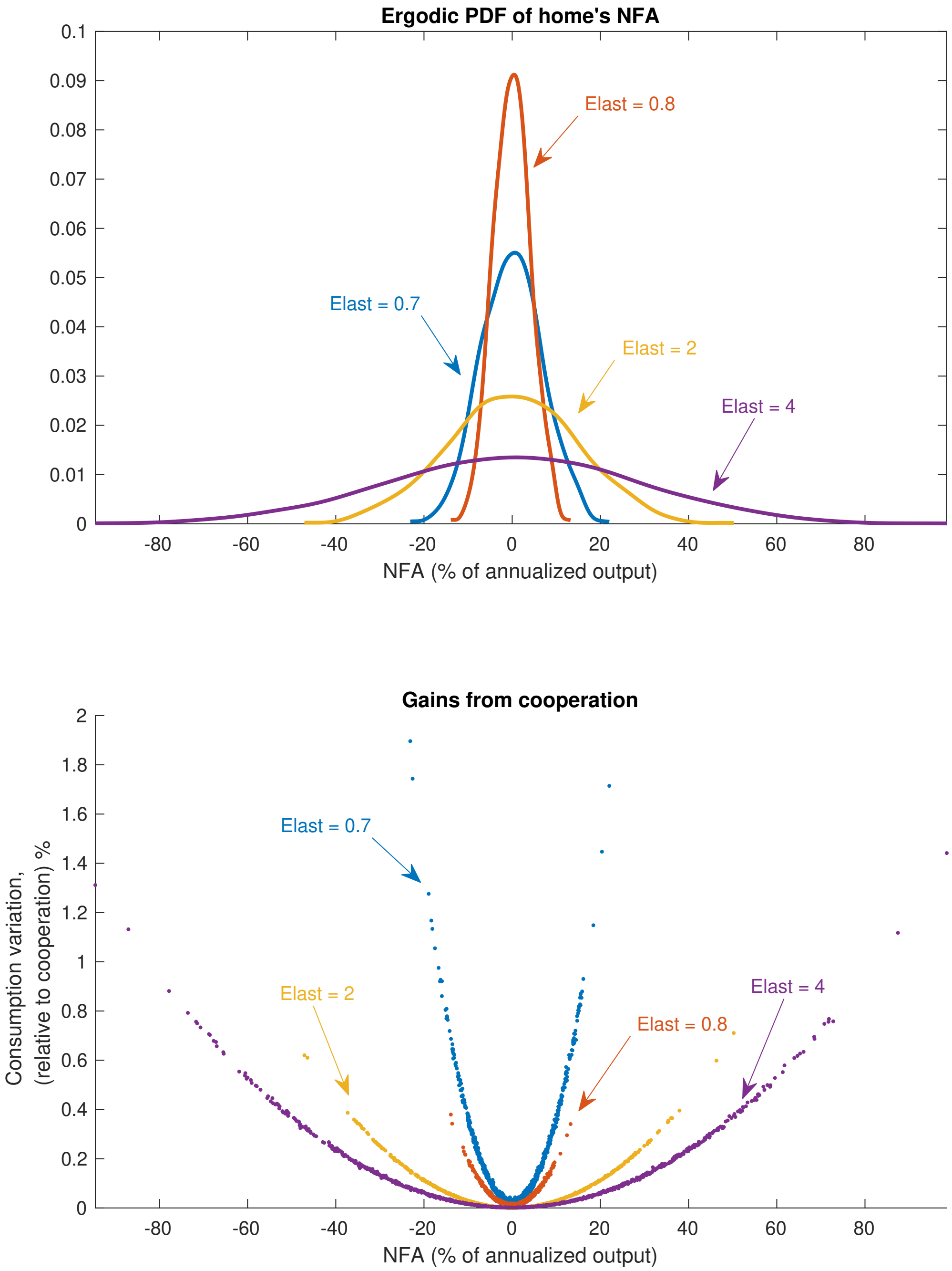
Figure 1: Transition paths from cooperation to non-cooperation—Symmetric Portfolio and Trade Elasticity = 4



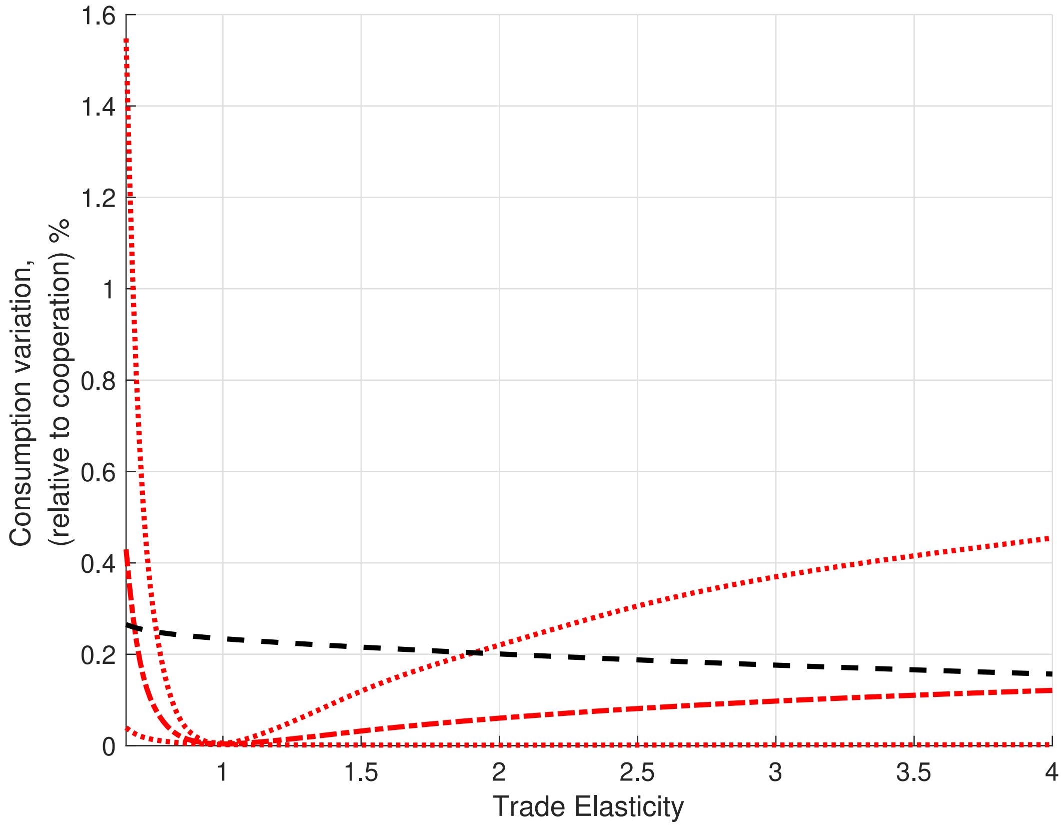
Note: The figure shows the equilibrium transition paths for key variables when deviating from cooperation. The non-cooperative paths are shown in deviation from the paths that obtain, abstracting from additional shocks, if the two countries continue to cooperate. At the transition point, the home country is a creditor. The trade elasticity is 4 and borrowing and lending is conducted through an equally weighted basket of bonds denominated in each of the two currencies.

Figure 2: The Distribution of the Net Foreign Assets and Gains from Cooperation for Alternative Values of the Elasticity of Substitution between Traded Goods



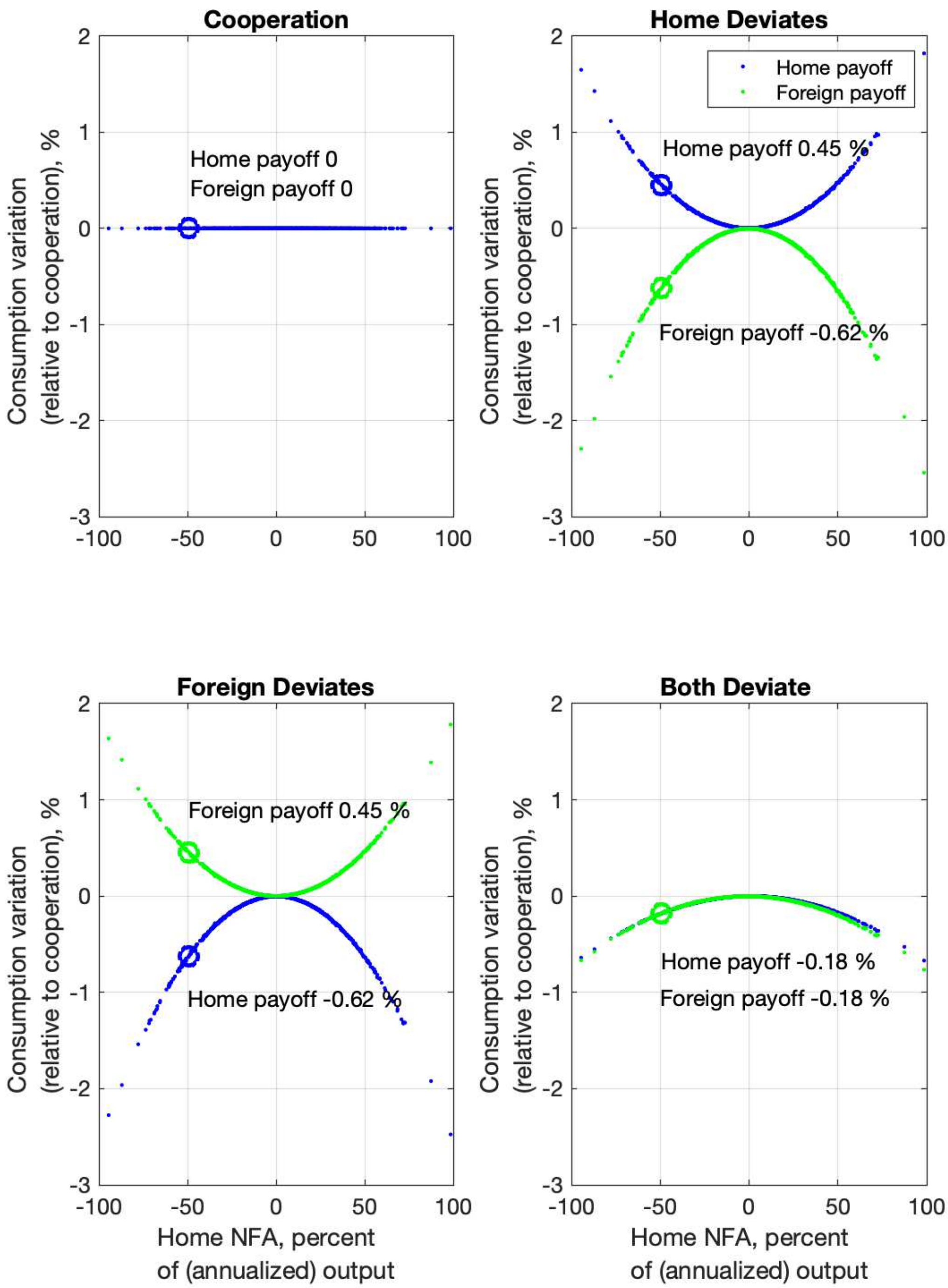
Note: The top panel shows the ergodic probability density function of the NFA position for the home country for alternative values of the trade elasticity of substitution. For the same trade elasticities, the bottom panel shows the expected gain from continuing to cooperate relative to adopting nationally-oriented policies. The gains are evaluated at 1000 points randomly drawn from the ergodic distribution under cooperative policies. The welfare difference between the two policy arrangements is translated into a consumption equivalent variation as described in Section 3.2.1.

Figure 3: The Gains from Cooperation as a Function of the Elasticity of Substitution between Traded Goods—Symmetric Portfolio



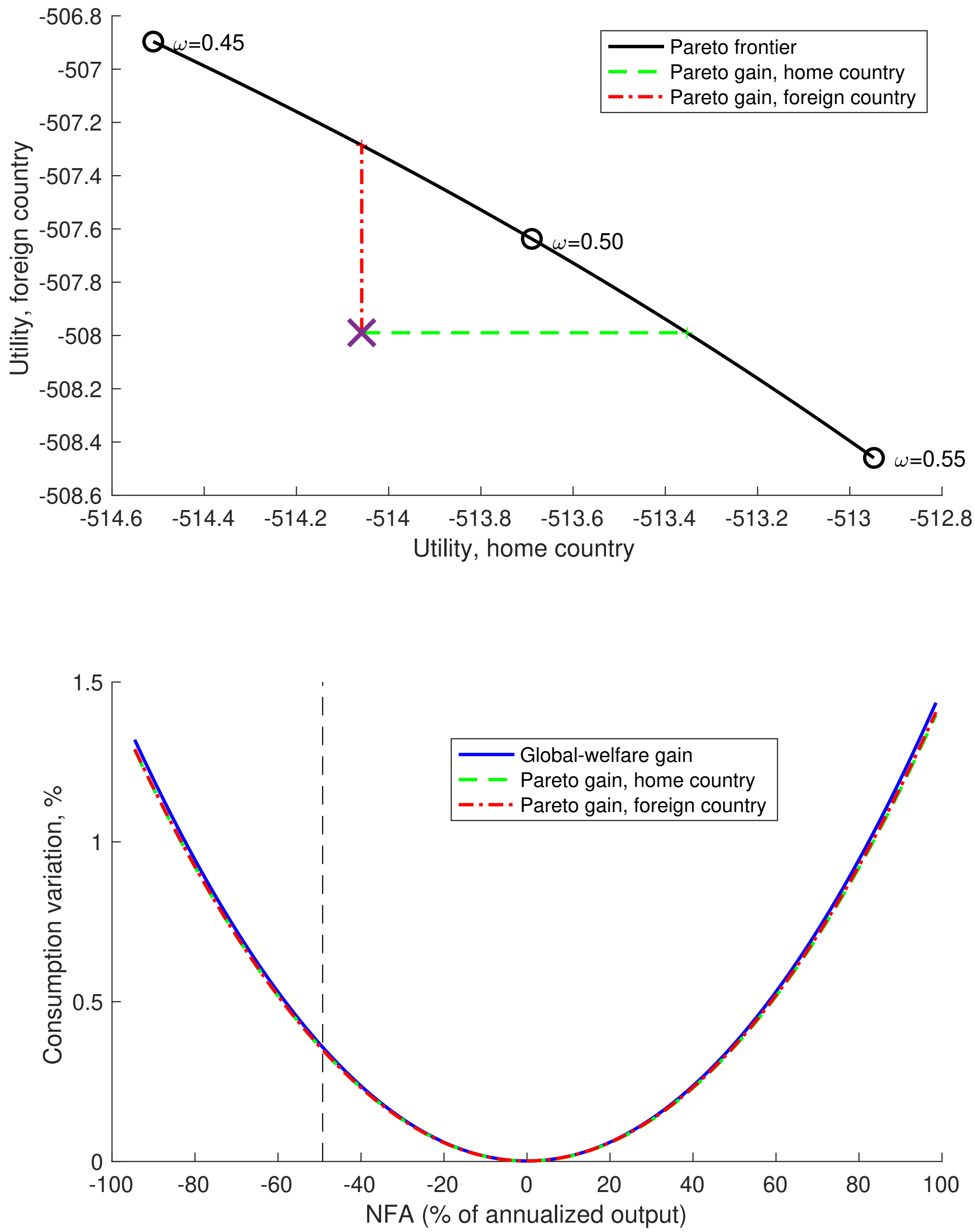
Note: The figure shows the mean gain from continuing to cooperate relative to adopting nationally-oriented policies based on 1000 points randomly drawn from the ergodic distribution under cooperative policies (the dashed-dotted line). The welfare difference between the two policy arrangements is translated into a consumption equivalent variation as described in Section 3.2.1. The 5th and 95th percentiles (the dotted lines) refer to the realized distribution of gains for the different transition points. For comparison, the figure also shows the cost of business cycles (the dashed line), computed as described in Section 3.2.2.

Figure 4: Two-Stage Game—Symmetric Portfolio and Trade Elasticity = 4



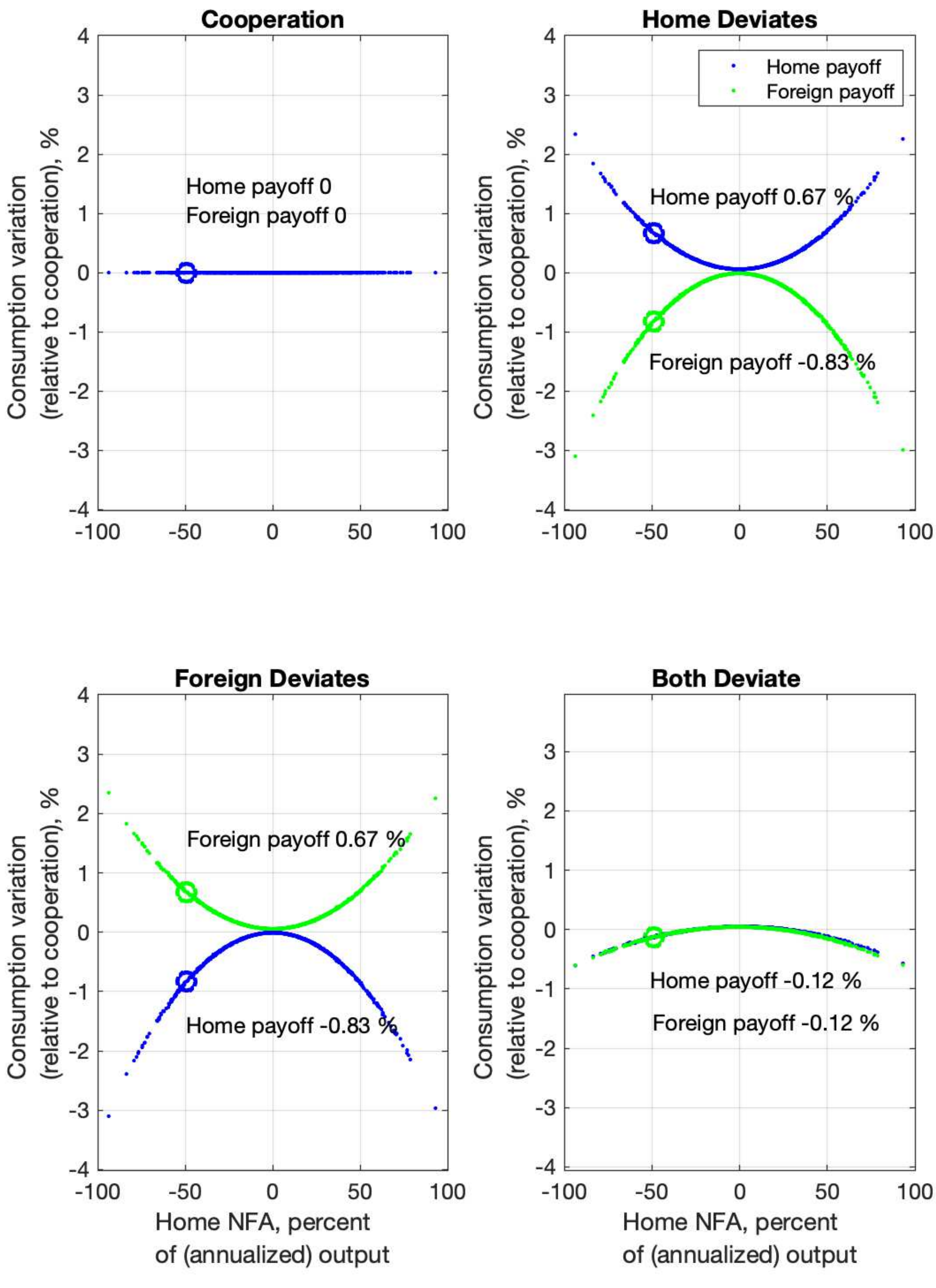
Note: To account for the incentives to deviate from the cooperative behavior, we rely on the two-stage game described in section 3.2.3. At each transition point, in the first stage we let each country choose between *cooperate* or *deviate*; in the second stage, we let the countries play an open-loop Nash game conditional on their preference choices in the first stage. For all combinations of actions in the first stage of the game, the figure plots the payoff of the second-stage game against the home country's NFA position at each transition point. The payoffs are expressed as country-specific consumption-equivalent variations (τ_1, τ_2). By construction, τ_1 and τ_2 are 0 regardless of the NFA position if both countries choose *cooperate*.

Figure 5: Pareto Frontier and Efficiency Gains—Symmetric Portfolio and Trade Elasticity = 4



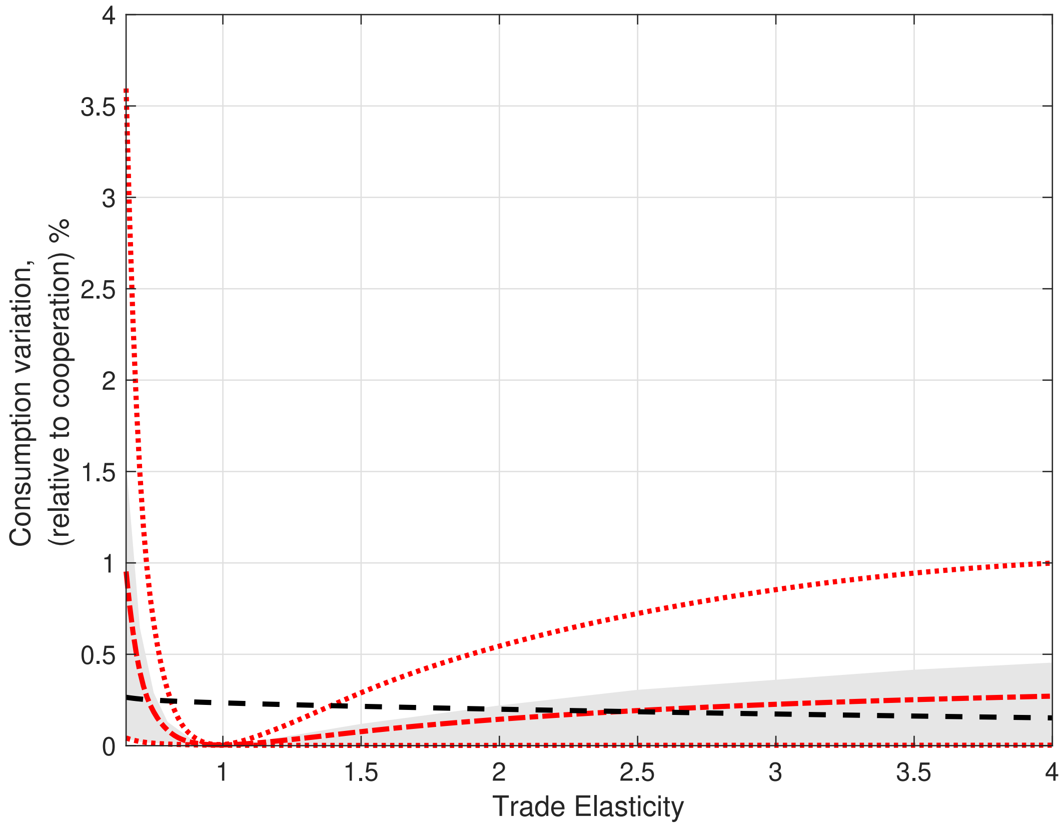
Note: The top panel shows the Pareto frontier (the solid black line) for one of the randomly drawn 1000 transition points. At that transition point, the home country has a net debt balance of 50% of (annualized) output. The X symbol in the top panel marks the utility associated with the non-cooperative allocation. The bottom panel summarizes the Pareto gains for each country for alternative transition points. The vertical dashed line denotes the NFA position for the transition point used for the Pareto frontier shown in the top panel. The bottom panel also shows the gains from cooperation from the global welfare function based on symmetric weights.

Figure 6: Two-Stage Game, Inflation Targeting—Symmetric Portfolio and Trade Elasticity = 4



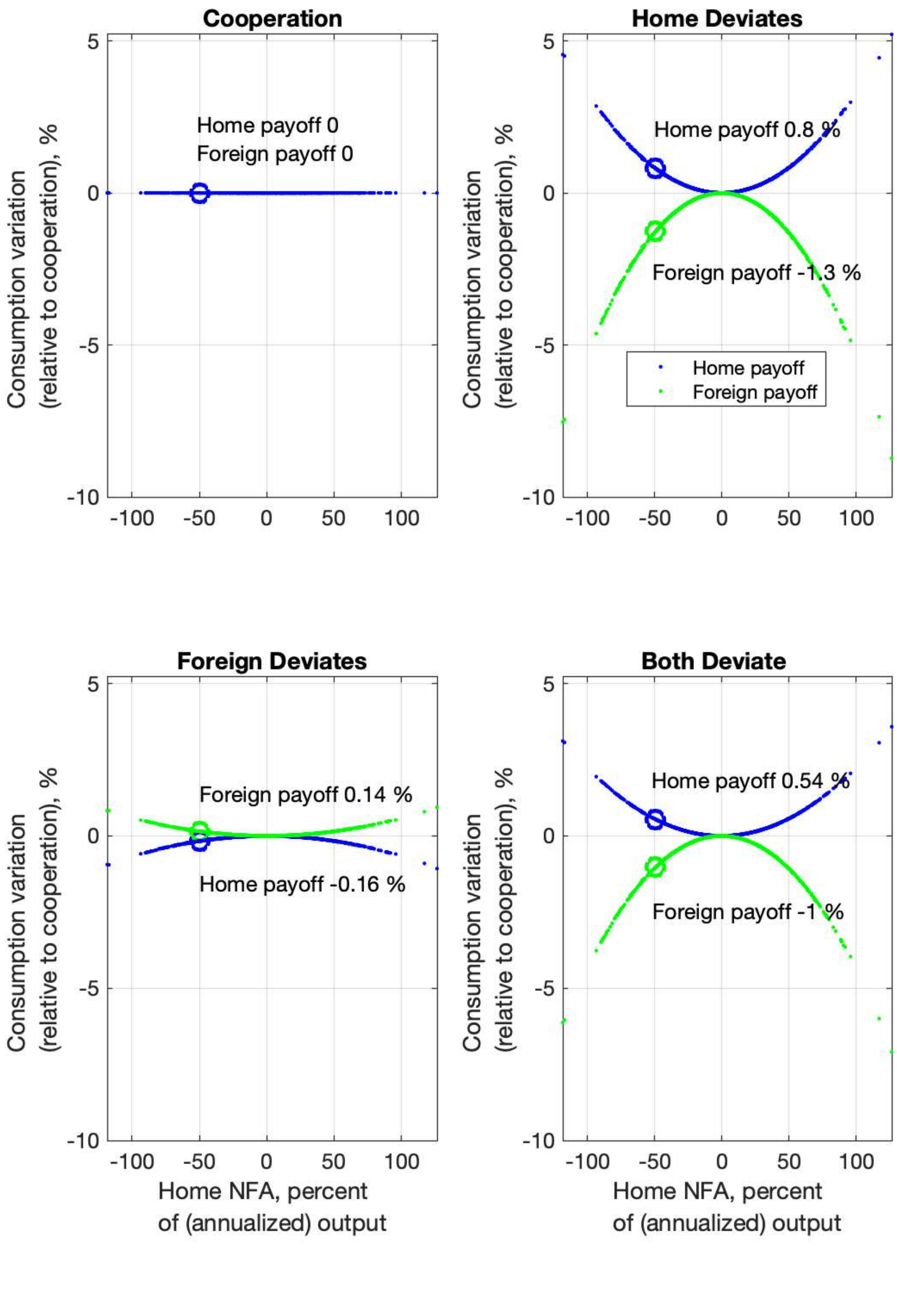
Noe: To account for the incentives to deviate from the cooperative behavior, we rely on the two-stage game described in subsection 3.2.3. At each transition point, in the first stage we let each country choose between *inflation targeting* or *deviate towards national policies*; in the second stage, we let the countries play an open-loop Nash game conditional on their preference choices in the first stage. For all combinations of actions in the first stage of the game, the figure plots the payoff of the second-stage game against the home country's NFA position at each transition point. The payoffs are expressed as country-specific consumption-equivalent variations (τ_1, τ_2). By construction, τ_1 and τ_2 are 0 regardless of the net- foreign-asset position if both countries choose *cooperate*.

Figure 7: The Gains from Cooperation as a Function of the Elasticity of Substitution between Traded goods—Asymmetric Portfolio



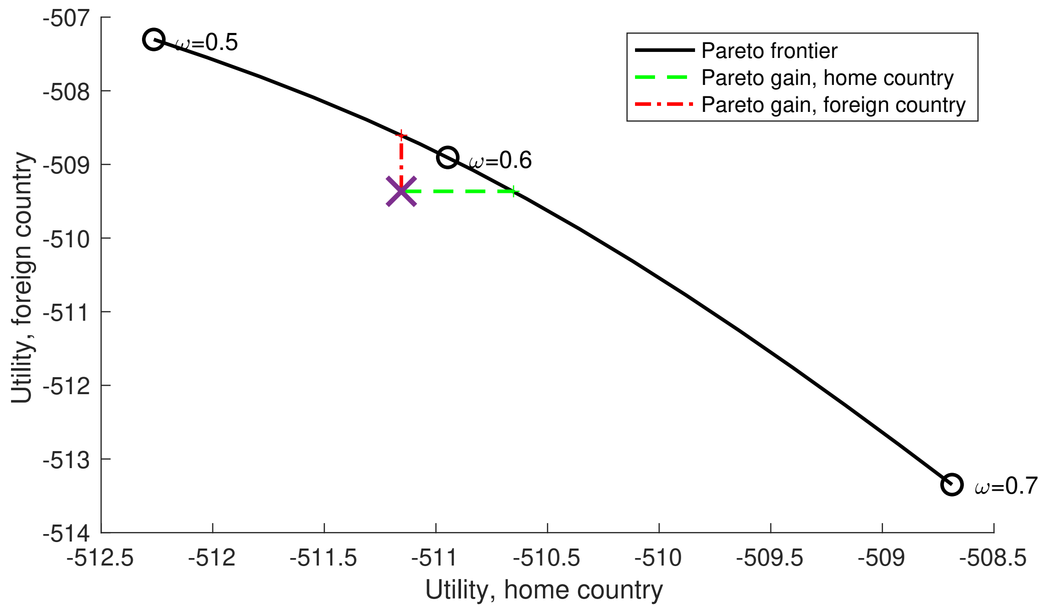
Note: The figure shows the mean gain from continuing to cooperate relative to adopting nationally-oriented policies based on 1000 points randomly drawn from the ergodic distribution under cooperative policies (the dashed-dotted line). The welfare difference between the two policy arrangements is then translated into a consumption equivalent variation as described in Section 3.2.1. The 5th and 95th percentiles (the dotted lines) refer to the realized distribution of gains for the different transition points. For comparison, the figure also shows the cost of business cycles (the dashed line), computed as described in Section 3.2.2.

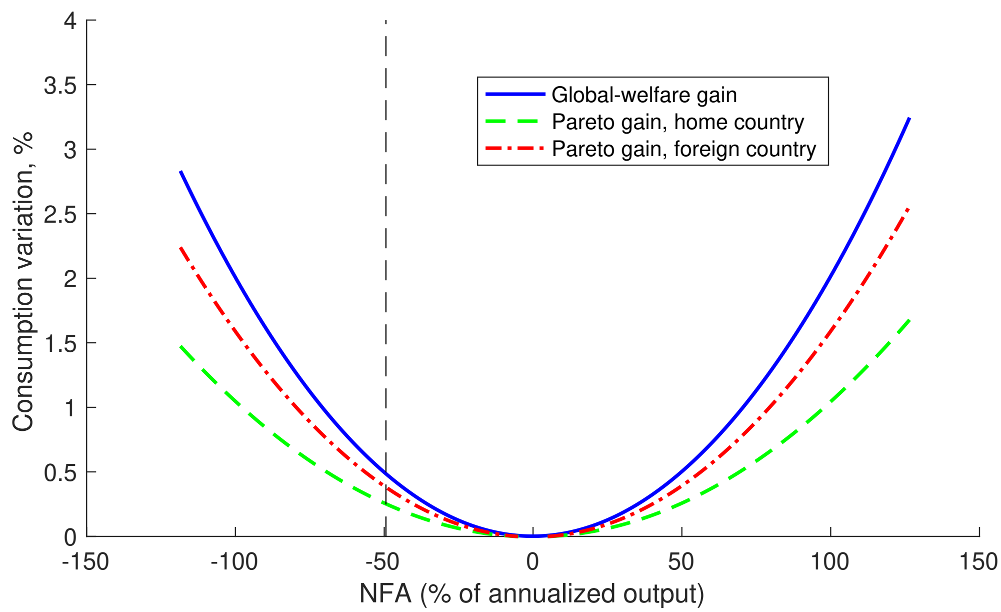
Figure 8: Two-Stage Game with Valuation Effects—Asymmetric Portfolio and Trade Elasticity = 4



Note: To account for the incentives to deviate from the cooperative behavior, we rely on the two-stage game described in section 3.2.3. At each transition point, in the first stage we let each country choose between *cooperate* or *deviate*; in the second stage, we let the countries play an open-loop Nash game conditional on their preference choices in the first stage. For all combinations of actions in the first stage of the game, the figure plots the payoff of the second-stage game against the home country's NFA position at each transition point. The payoffs are expressed as country-specific consumption-equivalent variations (τ_1, τ_2). By construction, τ_1 and τ_2 are 0 regardless of the NFA position if both countries choose *cooperate*.

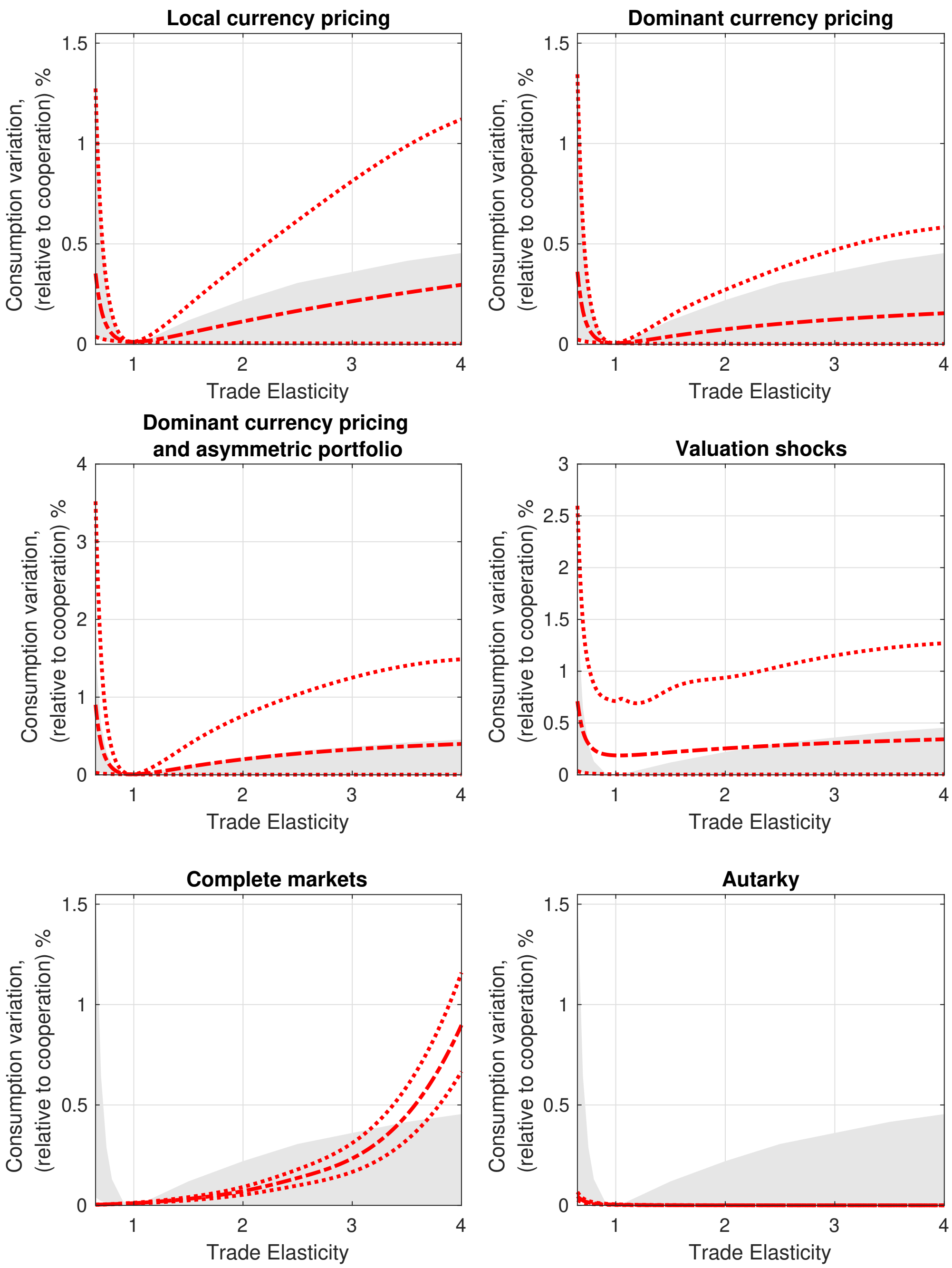
Figure 9: Pareto Frontier and Efficiency Gains with Valuation Effects—Asymmetric Portfolio and Trade Elasticity = 4





Note: The top panel shows the Pareto frontier (the solid black line) for one of the randomly drawn 1000 transition points. At that transition point, the home country has a net debt balance of 50% of (annualized) output. The X symbol in the top panel marks the utility associated with the non-cooperative allocation. The bottom panel summarizes the Pareto gains for each country for alternative transition points. The vertical dashed line denotes the NFA position for the transition point used for the Pareto frontier shown in the top panel. The bottom panel also shows the gains from cooperation from the global welfare function based on symmetric weights.

Figure 10: The Importance of Exchange Rate Passthrough, Shock Sources, and Financial Arrangements for the Gains from Cooperation



Note: The figure shows the mean gain from continuing to cooperate relative to adopting nationally-oriented policies based on 1000 points randomly drawn from the ergodic distribution under cooperative policies (the dashed-dotted line). The welfare difference between the two policy arrangements is then translated into a consumption equivalent variation as described in Section 3.2.1. The 5th and 95th percentiles (the dotted lines) refer to the realized distribution of gains for the different transition points. Each panel focuses on an alternative model as discussed in Section 5. For comparison, the shaded area in each panel shows the 5th-95th interval for the gains from cooperation for the baseline model with incomplete markets and a symmetric portfolio of international bonds.

A Appendix: Model description

We provide a detailed description of the model sketched in the main text. Notation and mathematical expressions are lined up with the Dynare codes used in the numerical implementation of our analysis.

A.1 Relative Prices

We define

$$\nu_{j,t} = \frac{P^m_{j,t}}{P^d_{j,t}} \tag{A.1}$$

for $j = [1, 2]$ to be the relative price of the imported good in local currency $P^m_{j,t}$ and the exported good in local currency $P^d_{j,t}$ of country j. We denote by

$$\delta_{1,t} = \frac{P^m_{1,t}}{e_{1,t}P^m_{2,t}} = \frac{\nu_{1,t}P^d_{1,t}}{\nu_{2,t}e_{1,t}P^d_{2,t}}. \tag{A.2}$$

the ratio of import prices expressed in common currency. $e_{1,t}$ is the nominal exchange rate.

Given the assumptions spelled out below, the relative prices $\frac{P^c_{1,t}}{P^d_{1,t}}$ and $\frac{P^c_{2,t}}{P^d_{2,t}}$ can then be expressed as

$$\frac{P^c_{1,t}}{P^d_{1,t}} = \left[\omega^c_1 + (1-\omega^c_1)\nu_{1,t}^{-\frac{1}{\rho^c}}\right]^{-\rho^c} = F_{1,t}^{-\rho^c}, \tag{A.3}$$

$$\frac{P^c_{2,t}}{P^d_{2,t}} = \left[\omega^c_2 + (1-\omega^c_2)\nu_{2,t}^{-\frac{1}{\rho^c}}\right]^{-\rho^c} = F_{2,t}^{-\rho^c}. \tag{A.4}$$

$P^c_{j,t}$ is the price of the final consumption good in country j.

A.2 Households

Households solve the maximization problem

$$\max_{\substack{C_{1,t+j},B_{11,t+j},\\ B_{12,t+j},D_{1,t+1+j|t+j}}} E_t \sum_{j=0}^{\infty} \beta^j \left\{ \ln\left(C_{1,t+j} - \kappa C_{1,t+j-1}\right) - \frac{\chi_0}{1+\chi} L_{1,t+j}^{1+\chi} \right\}$$

s.t.

$$P^c_{1,t+j}C_{1,t+j} + \frac{P^b_{1,t+j}B_{11,t+j} + e_{1,t+j}P^b_{2,t+j}B_{12,t+j}}{\phi^b_{1,t+j}} + \int_S P^D_{1,t+1+j|t+j}D_{1,t+1+j|t+j} =$$

$$W_{1,t+j}L_{1,t+j} + B_{11,t-1+j} + e_{1,t+j}B_{12,t-1+j} + D_{1,t+j|t-1+j} + T_{1,t+j}$$

$$\eta B_{11,t+j} = (1-\eta)e_{1,t+j}B_{12,t+j}.$$

The first order conditions associated with this problem can be written as

$$MU_{1,t} = \left(\frac{1}{1-\kappa \frac{C_{1,t-1}}{C_{1,t}}} - \frac{\beta\kappa}{\frac{C_{1,t+1}}{C_{1,t}} - \kappa} \right) \frac{1}{C_{1,t}}, \tag{A.5}$$

$$\frac{\tilde{W}_{1,t}}{P^d_{1,t}} = \chi_{0,1} \frac{L_{1,t}^{\chi_1}}{MU_{1,t}} \frac{1}{F_{1,t}^{\rho^c}}, \tag{A.6}$$

$$\frac{1}{1+R_{1,t}} = \beta E_t \left\{ \frac{MU_{1,t+1}}{MU_{1,t}} \frac{P^d_{1,t}}{P^d_{1,t+1}} \left(\frac{F_{1,t+1}}{F_{1,t}} \right)^{\rho^c} \right\}, \tag{A.7}$$

$$\begin{aligned} \tilde{P}^b_{1,t} &\equiv (1-\eta) P^b_{1,t} + \eta P^b_{2,t}, \\ &= \phi^b_{1,t} \beta E_t \left\{ \frac{MU_{1,t+1}}{MU_{1,t}} \frac{\delta_{1,t+1}}{\delta_{1,t}} \frac{\nu_{1,t+1}}{\nu_{1,t}} \frac{\nu_{2,t}}{\nu_{2,t+1}} \left(\frac{F_{1,t+1}}{F_{1,t}} \right)^{\rho^c} \frac{P^d_{2,t}}{P^d_{2,t+1}} \left((1-\eta) \frac{e_{1,t}}{e_{1,t+1}} + \eta \right) \right\}. \end{aligned} \tag{A.8}$$

The term $MU_{1,t}$ denotes the marginal utility of consumption. The term $\tilde{W}_{1,t}$ is the wage desired by households as opposed to the wage $W_{1,t}$ received by households. The intermediation cost $\phi^b_{1,t}$ is given by

$$\phi^b_{1,t} = \exp \left(\phi^b \frac{B^A_{11,t} + e_{1,t} B^A_{12,t}}{P^d_{1,t} C^{d,A}_{1,t} + e_{1,t} P^m_{2,t} M^A_{2,t}} \right). \tag{A.9}$$

This cost depends on the aggregate bond holdings at the country level and aggregate output. Thus an individual household does not take into account the effects of its choices on the intermediation costs. In equilibrium, it is of course that case that $B^A_{11,t} = B_{11,t}$, $B^A_{12,t} = B_{12,t}$, $C^{d,A}_{1,t} = C^d_{1,t}$, and $M^A_{2,t} = M_{2,t}$.

Our analysis tracks the NFA position of the two countries. As we solve the model to second order accuracy, restricting the set of international assets to a single bond, with the bond denominated in the currency of one country, introduces an asymmetry between the two countries even if the two countries are otherwise mirroring each other. With two bonds that are denominated in the two countries' respective currencies we can eliminate this asymmetry by requiring the two countries to hold the bonds in equal proportion, i.e., $\eta = 0.5$.

The final consumption good combines the home good (priced at $P^d_{1,t}$) and the foreign good (priced at $P^m_{1,t}$) according to

$$C_{1,t} = \left((\omega^c_1)^{\frac{\rho^c}{1+\rho^c}} \left(C^d_{1,t} \right)^{\frac{1}{1+\rho^c}} + (\omega^m_1)^{\frac{\rho^c}{1+\rho^c}} \left(M_{1,t} \right)^{\frac{1}{1+\rho^c}} \right)^{1+\rho^c}, \tag{A.10}$$

with the first order conditions of cost minimization given by

$$C^d_{1,t} = \omega^c_1 \left(\frac{P^c_{1,t}}{P^d_{1,t}} \right)^{\frac{1+\rho^c}{\rho^c}} C_{1,t} = \omega^c_1 F_{1,t}^{-(1+\rho^c)} C_{1,t}, \tag{A.11}$$

$$M_{1,t} = (1-\omega_1^c)\left(\frac{P_{1,t}^c}{P_{1,t}^m}\right)^{\frac{1+\rho^c}{\rho^c}} C_{1,t} = (1-\omega_1^c)F_{1,t}^{-(1+\rho^c)}\nu_{1,t}^{-\frac{1+\rho^c}{\rho^c}} C_{1,t}. \quad \text{(A.12)}$$

A.3 Sticky Nominal Wages

Unions introduce distinguishing characteristics to the homogenous labor $L_{1,t}$ supplied by the households and resell these services to bundlers. The bundlers sell the aggregate labor services $L_{1,t}^d$ to the producers of good. It is

$$L_{1,t}^d = \left[\int_0^1 L_{1,t}(h)^{\frac{1}{1+\theta^w}} dh\right]^{1+\theta^w}. \quad \text{(A.13)}$$

Given the distribution of wages, profit maximization of a bundler implies the demand function for each labor variety to satisfy

$$L_{1,t}(h) = \left[\frac{W_{1,t}(h)}{W_{1,t}}\right]^{-\frac{1+\theta^w}{\theta^w}} L_{1,t}^d. \quad \text{(A.14)}$$

The zero-profit condition yields that the wage (paid for one unit of the aggregate labor services) is

$$W_{1,t} = \left[\int_0^1 W_{1,t}(h)^{-\frac{1}{\theta^w}} dh\right]^{-\theta^w}. \quad \text{(A.15)}$$

The labor unions price their labor service $L_{1,t}(h)$ using contracts as in Calvo (1983) to maximize profits

$$\max_{W_{1,t}(h)} E_t \sum_{j=0}^{\infty} (\xi^w)^j \Lambda_{1,t+j}\left[(1+\tau^w)\bar{\Pi}^j W_{1,t}(h) - \tilde{W}_{1,t+j}\right] L_{1,t+j}(h)$$

$s.t.$

$$L_{1,t}(h) = \left[\frac{W_{1,t}(h)}{W_{1,t}}\right]^{-\frac{1+\theta^w}{\theta^w}} L_{1,t}^d.$$

The stochastic discount factor satisfies $\Lambda_{1,t+j} = \beta^j \frac{MU_{1,t+j}}{MU_{1,t}}$. The first order conditions associated with the union's maximization problem imply that the wage $W_{1,t}^*$ set in the current period by all reoptimizing unions satisfies

$$\frac{W_{1,t}^*}{P_{1,t}^d} = \frac{H_{1,t}^w}{G_{1,t}^w}, \quad \text{(A.16)}$$

with the definitions

$$H_{1,t}^w = \frac{\frac{P_{1,t}^c}{P_{1,t}^d}}{MU_{1,t}} E_t\left\{\sum_{j=0}^{\infty} (\xi^w\beta)^j \frac{MU_{1,t+j}}{\frac{P_{1,t+j}^c}{P_{1,t+j}^d}} \frac{1+\theta^w}{\theta^w} \frac{\tilde{W}_{1,t+j}}{P_{1,t+j}^d}\left[\frac{(\bar{\Pi})^j W_{1,t}}{W_{1,t+j}}\right]^{-\frac{1+\theta^w}{\theta^w}} L_{1,t+j}^d\right\}$$

$$= \frac{1+\theta^w}{\theta^w}\frac{\tilde{W}_{1,t}}{P^d_{1,t}}\left(\frac{1}{\Delta^w_{1,t}}L_{1,t}\right) + \xi^w \beta E_t\left\{\frac{MU_{1,t+1}}{MU_{1,t}}\frac{\frac{P^c_{1,t}}{P^d_{1,t}}}{\frac{P^c_{1,t+1}}{P^d_{1,t+1}}}\left(\frac{\bar{\Pi}W_{1,t}}{W_{1,t+1}}\right)^{-\frac{1+\theta^w}{\theta^w}} H^w_{1,t+1}\right\} \tag{A.17}$$

and

$$\begin{aligned} G^w_{1,t} &= \frac{\frac{P^c_{1,t}}{P^d_{1,t}}}{MU_{1,t}}E_t\left\{\sum_{j=0}^{\infty}(\xi^w\beta)^j\frac{MU_{1,t+j}}{\frac{P^c_{1,t+j}}{P^d_{1,t+j}}}\frac{1+\tau^w}{\theta^w}\frac{\left(\bar{\Pi}\right)^j P^d_{1,t}}{P^d_{1,t+j}}\left[\frac{\left(\bar{\Pi}\right)^j W_{1,t}}{W_{1,t+j}}\right]^{-\frac{1+\theta^w}{\theta^w}} L^d_{1,t+j}\right\} \\ &= \frac{1+\tau^w}{\theta^w}\left(\frac{1}{\Delta^w_{1,t}}L_{1,t}\right) + \xi^w\beta E_t\left\{\frac{MU_{1,t+1}}{MU_{1,t}}\frac{\frac{P^c_{1,t}}{P^d_{1,t}}}{\frac{P^c_{1,t+1}}{P^d_{1,t+1}}}\frac{\bar{\Pi}P^d_{1,t}}{P^d_{1,t+1}}\left(\frac{\bar{\Pi}W_{1,t}}{W_{1,t+1}}\right)^{-\frac{1+\theta^w}{\theta^w}} G^w_{1,t+1}\right\} \end{aligned} \tag{A.18}$$

Wage inflation is defined as

$$\frac{W_{1,t}}{W_{1,t-1}} = \frac{W_{1,t}}{P^d_{1,t}}\frac{P^d_{1,t}}{P^d_{1,t-1}}\frac{P^d_{1,t-1}}{W_{1,t-1}}. \tag{A.19}$$

The definition of the wage index, the optimal wage, and the definition of wage inflation implies

$$(1-\xi^w)\left(\frac{W^*_{1,t}}{P^d_{1,t}}\frac{P^d_{1,t}}{W_{1,t}}\right)^{-\frac{1}{\theta^w}} + \xi^w\left(\bar{\Pi}\frac{W_{1,t-1}}{W_{1,t}}\right)^{-\frac{1}{\theta^w}} = 1. \tag{A.20}$$

The fact that household labor supply and aggregate labor services are related via $L_{1,t} = \int_0^1 L_{1,t}(h)dh = \Delta^w_{1,t}L^d_{1,t}$ implies the dispersion in wages to satisfy

$$\Delta^w_{1,t} = (1-\xi^w)\left[\frac{W^*_{1,t}}{P^d_{1,t}}\frac{P^d_{1,t}}{W_{1,t}}\right]^{-\frac{1+\theta^w}{\theta^w}} + \xi^w\left[\bar{\Pi}\frac{W_{1,t-1}}{W_{1,t}}\right]^{-\frac{1+\theta^w}{\theta^w}}\Delta^w_{1,t-1}. \tag{A.21}$$

A.4 Production of Manufactured Goods

Intermediate variety producers introduce distinguishing characteristics into their output. Competitive bundlers sell the manufactured good $Y^d_{1,t}$ to households. It is

$$Y^d_{1,t} = \left[\int_0^1 Y_{1,t}(i)^{\frac{1}{1+\theta^p}}\,di\right]^{1+\theta^p}. \tag{A.22}$$

Given the distribution of prices, profit maximization of a bundler implies the demand function for each intermediate variety to satisfy

$$Y_{1,t}(i) = \left[\frac{P_{1,t}(i)}{P^d_{1,t}}\right]^{-\frac{1+\theta^p}{\theta^p}} Y^d_{1,t}. \tag{A.23}$$

The zero-profit condition yields that the price index is

$$P^d_{1,t} = \left[\int_0^1 P^d_{1,t}(i)^{-\frac{1}{\theta^p}}\, di\right]^{-\theta^p}. \tag{A.24}$$

Under our baseline assumptions, the foreign currency price of exports is $P^m_{2,t} = P^d_{1,t}/e_{1,t}$. Intermediate variety producers price their variety $Y_{1,t}(i)$ using contracts as in Calvo (1983). Firms experience country-specific technology shocks $z_{1,t}$

$$z_{1,t} = \rho^z z_{1,t-1} + \sigma^z \varepsilon^z_{1,t}. \tag{A.25}$$

With linear technology,

$$Y_{1,t}(i) = \exp(z_{1,t})\, L^d_{1,t}(i), \tag{A.26}$$

real marginal production costs, which are identical across firms, are given by

$$\frac{MC_{1,t}}{P^d_{1,t}} = \frac{1}{\exp(z_{1,t})}\frac{W_{1,t}}{P^d_{1,t}} \tag{A.27}$$

and the profit maximization problem is

$$\max_{P_{1,t}(i),\{Y_{1,t+j}(i)\}_{t=0}^{\infty}} E_t \sum_{j=0}^{\infty} (\xi^p)^j \Lambda_{1,t+j}\left((1+\tau^p)\,\bar{\Pi}^j P_{1,t}(i) - \frac{W_{1,t+j}}{\exp(z_{1,t+j})}\right) Y_{1,t+j}(i)$$

$s.t.$

$$Y_{1,t+j}(i) = \left[\frac{P_{1,t+j}(i)}{P^d_{1,t+j}}\right]^{-\frac{1+\theta^p}{\theta^p}} Y^d_{1,t+j}. \tag{A.28}$$

The first order conditions from the intermediate producer's maximization problem imply that the price $P^{d*}_{1,t}$ set in the current period by all reoptimizing producers satisfies

$$\frac{P^{d*}_{1,t}}{P^d_{1,t}} = \frac{H^p_{1,t}}{G^p_{1,t}}, \tag{A.29}$$

with the definitions

$$H^p_{1,t} = \frac{\frac{P^c_{1,t}}{P^d_{1,t}}}{MU_{1,t}} E_t\left\{\sum_{j=0}^{\infty}(\xi^p\beta)^j \frac{MU_{1,t+j}}{\frac{P^c_{1,t+j}}{P^d_{1,t+j}}}\frac{1+\theta^p}{\theta^p}\frac{MC_{1,t+j}}{P^d_{1,t+j}}\left[\frac{(\bar{\Pi})^j P^d_{1,t}}{P^d_{1,t+j}}\right]^{-\frac{1+\theta^p}{\theta^p}} Y^d_{1,t+j}\right\}$$

$$= \frac{1+\theta^p}{\theta^p}\frac{MC_{1,t}}{P^d_{1,t}}Y^d_{1,t} + \xi^p\beta E_t\left\{\frac{MU_{1,t+1}}{MU_{1,t}}\frac{\frac{P^c_{1,t}}{P^d_{1,t}}}{\frac{P^c_{1,t+1}}{P^d_{1,t+1}}}\left(\frac{\bar{\Pi}P^d_{1,t}}{P^d_{1,t+1}}\right)^{-\frac{1+\theta^p}{\theta^p}}H^p_{1,t+1}\right\}, \quad (A.30)$$

where $\Lambda_{1,t+j} = \beta\frac{MU_{1,t+1}}{MU_{1,t}}\frac{P^c_{1,t}}{P^c_{1,t+j}}$ and

$$G^p_{1,t} = \frac{\frac{P^c_{1,t}}{P^d_{1,t}}}{MU_{1,t}}E_t\left\{\sum_{j=0}^{\infty}(\xi^p\beta)^j\frac{MU_{1,t+j}}{\frac{P^c_{1,t+j}}{P^d_{1,t+j}}}\frac{1+\tau^p}{\theta^p}\left[\frac{\left(\bar{\Pi}\right)^j P^d_{1,t}}{P^d_{1,t+j}}\right]^{1-\frac{1+\theta^p}{\theta^p}}Y^d_{1,t+j}\right\}$$

$$= \frac{1+\tau^p}{\theta^p}Y^d_{1,t} + \xi^p\beta E_t\left\{\frac{MU_{1,t+1}}{MU_{1,t}}\frac{\frac{P^c_{1,t}}{P^d_{1,t}}}{\frac{P^c_{1,t+1}}{P^d_{1,t+1}}}\left(\frac{\bar{\Pi}P^d_{1,t}}{P^d_{1,t+1}}\right)^{1-\frac{1+\theta^p}{\theta^p}}G^p_{1,t+1}\right\}. \quad (A.31)$$

The definition of the price index implies that

$$(1-\xi^p)\left(\frac{P^{d*}_{1,t}}{P^d_{1,t}}\right)^{\frac{-1}{\theta^p}} + \xi^p\left(\bar{\Pi}\frac{P^d_{1,t-1}}{P^d_{1,t}}\right)^{\frac{-1}{\theta^p}} = 1. \quad (A.32)$$

The fact that output and labor are related via $\int_0^1 \frac{Y_{1,t}(h)}{e^{z_{1,t}}}dh = \int_0^1 L^d_{1,t}(h)dh = L^d_{1,t}$ implies for the price dispersion measure $\Delta^p_{1,t}$ that

$$\Delta^p_{1,t} = (1-\xi^p)\left(\frac{P^{d*}_{1,t}}{P^d_{1,t}}\right)^{-\frac{1+\theta^p}{\theta^p}} + \xi^p\left(\bar{\Pi}\frac{P^d_{1,t-1}}{P^d_{1,t}}\right)^{-\frac{1+\theta^p}{\theta^p}}\Delta^p_{1,t-1}. \quad (A.33)$$

A.5 Market Clearing

Aggregating over households, market clearing for the domestic good requires

$$Y^d_{1,t} = C^d_{1,t} + M_{2,t} \quad (A.34)$$

where $M_{2,t}$ denotes the demand of the foreign country for the domestic good. Labor and product market differentiation imply that the labor supplied by household members is related to the output of the domestically produced good via

$$L_{1,t} = \Delta^w_{1,t}\Delta^p_{1,t}\frac{Y^d_t}{\exp\left(z_{1,t}\right)}. \quad (A.35)$$

Combining the two conditions yields

$$\exp\left(z_{1,t}\right)L_{1,t} = \Delta^w_{1,t}\Delta^p_{1,t}\left(C^d_{1,t} + M_{2,t}\right). \quad (A.36)$$

Domestically traded bonds are in zero net supply, requiring $D_{1,t+1|t} = 0$. For internationally traded bonds, market clearing requires

$$B_{11,t} + B_{21,t} = 0, \quad (A.37)$$

$$B_{12,t} + B_{22,t} = 0. \tag{A.38}$$

A.6 Useful Definitions and Simplifications

Under producer-currency-pricing, theory implies

$$\delta_{1,t} = \nu_{1,t} \tag{A.39}$$

$$\nu_{1,t} = \frac{1}{\nu_{2,t}}. \tag{A.40}$$

Defining the trade balance as

$$T_{1,t} \equiv e_t P^m_{2,t} M_{2,t} - P^m_{1,t} M_{1,t}, \tag{A.41}$$

we obtain the trade balance normalized by the value of exports as

$$\tilde{T}_{1,t} = \frac{T_{1,t}}{e_t P^m_{2,t} M_{2,t}} = 1 - \frac{1-\omega^c_1}{1-\omega^c_2} \left[\frac{\omega^c_1 \nu_{1,t}^{\frac{1}{\rho^c}} + (1-\omega^c_1)}{\omega^c_2 \nu_{2,t}^{\frac{1}{\rho^c}} + (1-\omega^c_2)} \right]^{-(1+\rho^c)} \delta_{1,t} \frac{C_{1,t}}{C_{2,t}}. \tag{A.42}$$

The optimal choices of the two bonds imply for country 1

$$\tilde{P}^b_{1,t} \equiv (1-\eta) P^b_{1,t} + \eta P^b_{2,t} = \phi^b_{1,t} \beta E_t \frac{\lambda_{1,t+1}}{\lambda_{1,t}} \frac{e_{1,t+1}}{e_{1,t}} \left\{ (1-\eta) \frac{e_{1,t}}{e_{1,t+1}} + \eta \right\} \tag{A.43}$$

and for country 2

$$\tilde{P}^b_{2,t} \equiv (1-\eta) P^b_{1,t} + \eta P^b_{2,t} = \phi^b_{2,t} \beta E_t \frac{\lambda_{2,t+1}}{\lambda_{2,t}} \left\{ (1-\eta) \frac{e_{1,t}}{e_{1,t+1}} + \eta \right\}, \tag{A.44}$$

where by construction

$$\tilde{P}^b_{1,t} = \tilde{P}^b_{2,t}. \tag{A.45}$$

The budget constraint of the household can be rewritten to record the evolution of the country's NFA position

$$\frac{1}{\phi^b_{1,t}} \tilde{P}^b_{2,t} \tilde{B}_{1,t} = \frac{\nu_{2,t-1}}{\nu_{2,t}} \frac{P^d_{2,t-1} M_{2,t-1}}{P^d_{2,t} M_{2,t}} \left\{ (1-\eta) \frac{e_{1,t-1}}{e_{1,t}} + \eta \right\} \tilde{B}_{1,t-1} + \tilde{T}_{1,t} \tag{A.46}$$

where we defined

$$\tilde{B}_{1,t} = \frac{\frac{e_{1,t} B_{12,t}}{\eta}}{e_{1,t} P^m_{2,t} M_{2,t}}.$$

The cost $\phi^b_{1,t}$ is given by

$$\phi^b_{1,t} = \exp\left(\phi^b_1 \tilde{B}_{1,t} \frac{\frac{\nu_{1,t}}{\delta_{1,t}} M_{2,t}}{C^d_{1,t} + \frac{\nu_{1,t}}{\delta_{1,t}} M_{2,t}}\right). \tag{A.47}$$

We define the consumption-price based real exchange rate as

$$rer_{1,t} = \left(\frac{F_{1,t}}{F_{2,t}}\right)^{\rho^c} \frac{\nu_{1,t}}{\delta_{1,t}\nu_{2,t}}. \tag{A.48}$$

A.7 Equilibrium Conditions for the Private Sector

For given sequences of the policy instruments set by the two policymakers, the endogenous variables have to satisfy the first order and market clearing conditions associated with the model laid out above. The full set of conditions describing the equilibrium conditions of the private sector (compare also to Dynare codes) consists of Equations (A.3), (A.5), (A.6), (A.7), (A.11), (A.12), (A.16), (A.17), (A.18), (A.19), (A.20), (A.21), (A.27), (A.29), (A.30), (A.31), (A.32), (A.33), (A.36), (A.43), (A.46), (A.47), for country 1 and their counterparts in the foreign country (not displayed) plus Equations (A.39), (A.40), (A.42), (A.45), (A.48). The exogenous shock process for technology in country 1 is given by Equation (A.25). A similar equation applies in country 2.

Let $\tilde{x}_t$ be the $(N-2) \times 1$ vector of endogenous variables excluding the policy instruments. The exogenous shocks are summarized in the vector ζ_t. Then, assuming that each country's central bank uses one instrument only, denoted $i_{1,t}$ and $i_{2,t}$ respectively, the $N-2$ first order and market clearing conditions of the model are summarized by

$$E_t g(\tilde{x}_{t-1}, \tilde{x}_t, \tilde{x}_{t+1}, i_{1,t}, i_{2,t}, \zeta_t) = 0. \tag{A.49}$$

A.8 Model Variants

This section of the appendix describes the model variants that allow us to consider less-than-full passthrough of exchange rate movements to export prices, demand shocks, and alternative arrangements for international financial markets.

A.8.1 Local- and Dominant-Currency-Pricing

Under local-currency-pricing, we have to split the pricing problem of the firm by destination. The local-currency prices of the varieties are denoted by $P^d_{1,t}(i)$ and $P^m_{1,t}(i)$, respectively. The price indices

$$P^d_{1,t} = \left[\int_0^1 P^d_{1,t}(i)^{\frac{-1}{\theta^p}}\, di\right]^{-\theta^p}, \tag{A.50}$$

$$P^m_{1,t} = \left[\int_0^1 P^m_{1,t}(i)^{\frac{-1}{\theta^p}}\, di\right]^{-\theta^p} \tag{A.51}$$

evolve according to

$$(1-\xi^p)\left(\frac{P^{d*}_{1,t}}{P^d_{1,t}}\right)^{\frac{-1}{\theta^p}}+\xi^p\left(\bar{\Pi}\frac{P^d_{1,t-1}}{P^d_{1,t}}\right)^{\frac{-1}{\theta^p}}=1, \tag{A.52}$$

$$(1-\xi^p)\left(\frac{P^{m*}_{1,t}}{P^m_{1,t}}\right)^{\frac{-1}{\theta^p}}+\xi^p\left(\bar{\Pi}\frac{\nu_{1,t-1}P^d_{1,t-1}}{\nu_{1,t}P^d_{1,t}}\right)^{\frac{-1}{\theta^p}}=1 \tag{A.53}$$

in country 1 and similarly in country 2. Prices of firms that do not adjust optimally in the current period rise at the steady-state inflation rate of the country in which the goods are sold.

In addition, we define the dispersion measures

$$\begin{aligned}\Delta^d_{1,t} &= \int_0^1\left[\frac{P^d_{1,t}(i)}{P^d_{1,t}}\right]^{-\frac{1+\theta^p}{\theta^p}}di\\ &= (1-\xi^p)\left(\frac{P^{d*}_{1,t}}{P^d_{1,t}}\right)^{-\frac{1+\theta^p}{\theta^p}}+\xi^p\left(\bar{\Pi}\frac{P^d_{1,t-1}}{P^d_{1,t}}\right)^{-\frac{1+\theta^p}{\theta^p}}\Delta^d_{1,t-1} \qquad \text{(A.54)}\end{aligned}$$

and

$$\begin{aligned}\Delta^m_{1,t} &= \int_0^1\left[\frac{P^m_{1,t}(i)}{P^m_{1,t}}\right]^{-\frac{1+\theta^p}{\theta^p}}di\\ &= (1-\xi^p)\left(\frac{P^{m*}_{1,t}}{P^m_{1,t}}\right)^{-\frac{1+\theta^p}{\theta^p}}+\xi^p\left(\bar{\Pi}\frac{P^m_{1,t-1}}{P^m_{1,t}}\right)^{-\frac{1+\theta^p}{\theta^p}}\Delta^m_{1,t-1}. \qquad \text{(A.55)}\end{aligned}$$

We continue to assume that the producers of the differentiated intermediate varieties purchase homogeneous input goods and differentiate them. The producers of the homogeneous input good use labor only as before

$$Y_{1,t}(h)=e^{z_{1,t}}L^d_{1,t}(h). \tag{A.56}$$

Aggregation implies

$$\int\frac{Y_{1,t}(h)}{e^{z_{1,t}}}dh=\int L^d_{1,t}(h)dh=L^d_{1,t}. \tag{A.57}$$

Market clearing for the intermediate varieties requires

$$\int Y_{1,t}(h)dh=\int C^d_{1,t}(i)di+\frac{1}{\zeta_1}\int M_{2,t}(i)di. \tag{A.58}$$

or

$$\frac{e^{z_{1,t}}}{\Delta^w_{1,t}}L_{1,t}=\Delta^d_{1,t}C^d_{1,t}+\frac{1}{\zeta_1}\Delta^m_{2,t}M_{2,t}. \tag{A.59}$$

The value of total sales for firm i in period $t+j$ is

$$S_{1,t+j}(i) = \left(\bar{\Pi}\right)^j P^d_{1,t}(i) C^d_{1,t}(i) + \frac{1}{\zeta_1} e_t \left(\bar{\Pi}\right)^j P^m_{2,t}(i) M_{2,t}(i).$$

Expected discounted profits over the life-time of the given prices $P^d_{1,t}(i)$ and $P^m_{2,t}(i)$ are

$$E_t \sum_{j=0}^{\infty} \left(\xi^p\right)^j \Lambda_{1,t+j} \left\{ \left(1+\tau^p\right) S_{1,t+j}(i) - MC_{1,t+j} \left(C^d_{1,t+j}(i) + \frac{1}{\zeta_1} M_{2,t+j}(i) \right). \right\}$$

The conditions for the pricing of the domestically sold goods are unchanged subject to modifying the relevant demand driver from $Y^d_{1,t}$ to $C^d_{1,t}$. Hence, it is

$$\frac{P^{d*}_{1,t}}{P^d_{1,t}} = \frac{H^p_{1,t}}{G^p_{1,t}} \tag{A.60}$$

with the definitions

$$H^p_{1,t} = \frac{1+\theta^p}{\theta^p} \frac{MC_{1,t}}{P^d_{1,t}} C^d_{1,t} + \xi^p \beta E_t \left\{ \frac{MU_{1,t+1}}{MU_{1,t}} \frac{\frac{P^c_{1,t}}{P^d_{1,t}}}{\frac{P^c_{1,t+1}}{P^d_{1,t+1}}} \left(\frac{\bar{\Pi} P^d_{1,t}}{P^d_{1,t+1}} \right)^{-\frac{1+\theta^p}{\theta^p}} H^p_{1,t+1} \right\}, \tag{A.61}$$

where $\Lambda_{1,t+j} = \beta \frac{MU_{1,t+1}}{MU_{1,t}} \frac{P^c_{1,t}}{P^c_{1,t+j}}$

$$G^p_{1,t} = \frac{1+\tau^p}{\theta^p} C^d_{1,t} + \xi^p \beta E_t \left\{ \frac{MU_{1,t+1}}{MU_{1,t}} \frac{\frac{P^c_{1,t}}{P^d_{1,t}}}{\frac{P^c_{1,t+1}}{P^d_{1,t+1}}} \left(\frac{\bar{\Pi} P^d_{1,t}}{P^d_{1,t+1}} \right)^{1-\frac{1+\theta^p}{\theta^p}} G^p_{1,t+1} \right\}. \tag{A.62}$$

The conditions for export pricing imply

$$\frac{P^{m*}_{2,t}}{P^m_{2,t}} = \frac{MH^p_{1,t}}{MG^p_{1,t}} \tag{A.63}$$

with

$$\begin{aligned} MH^p_{1,t} &= \frac{\frac{P^c_{1,t}}{P^d_{1,t}}}{MU_{1,t}} E_t \left\{ \sum_{j=0}^{\infty} \left(\xi^p \beta\right)^j \frac{MU_{1,t+j}}{\frac{P^c_{1,t+j}}{P^d_{1,t+j}}} \frac{1+\theta^p}{\theta^p} \frac{MC_{1,t+j}}{P^d_{1,t+j}} \left[\frac{\bar{\Pi}^j P^m_{2,t}}{P^m_{2,t+j}} \right]^{-\frac{1+\theta^p}{\theta^p}} M_{2,t+j} \right\} \\ &= \frac{1+\theta^p}{\theta^p} \frac{MC_{1,t}}{P^d_{1,t}} M_{2,t} + \xi^p \beta E_t \left\{ \frac{MU_{1,t+1}}{MU_{1,t}} \frac{\frac{P^c_{1,t}}{P^d_{1,t}}}{\frac{P^c_{1,t+1}}{P^d_{1,t+1}}} \left(\frac{\bar{\Pi} P^d_{2,t}}{P^d_{2,t+1}} \right)^{-\frac{1+\theta^p}{\theta^p}} MH^p_{1,t+1} \right\} \end{aligned} \tag{A.64}$$

$$
\begin{aligned}
MG^p_{1,t} &= \frac{\frac{P^c_{1,t}}{P^d_{1,t}}}{MU_{1,t}} E_t \left\{ \sum_{j=0}^{\infty} (\xi^p \beta)^j \frac{MU_{1,t+1}}{\frac{P^c_{1,t+j}}{P^d_{1,t+j}}} \frac{1+\tau^p}{\theta^p} \frac{\nu_{1,t+j}}{\delta_{1,t+j}} \left[\frac{\bar{\Pi}^j P^m_{2,t}}{P^m_{2,t+j}} \right]^{1-\frac{1+\theta^p}{\theta^p}} M_{2,t+j} \right\} \\
&= \frac{1+\tau^p}{\theta^p} \frac{\nu_{1,t}}{\delta_{1,t}} M_{2,t} + \xi^p \beta E_t \left\{ \frac{MU_{1,t+1}}{MU_{1,t}} \frac{\frac{P^c_{1,t}}{P^d_{1,t}}}{\frac{P^c_{1,t+1}}{P^d_{1,t+1}}} \left(\frac{\bar{\Pi} P^d_{2,t}}{P^d_{2,t+1}} \right)^{1-\frac{1+\theta^p}{\theta^p}} MG^p_{1,t+1} \right\}.
\end{aligned}
\tag{A.65}
$$

Relative to the model with producer-currency-pricing, we newly introduce Equations (A.53), (A.55), (A.63), (A.64), (A.65), replace Equations (A.36), (A.30), (A.31) with Equations (A.59), (A.61), (A.62), and remove Equations (A.39), (A.40). We proceed analogously for country 2. Under dominant-currency-pricing, we make the above adjustments for only one country.

A.8.2 Valuation Shocks

We model valuation shocks as in Albuquerque, Eichenbaum, Luo, and Rebelo (2016). We implement the valuation shock in the home country $\iota_{1,t}$ as follows

$$
\mathcal{U}_{1,t} = E_t \sum_{j=0}^{\infty} \iota_{1,t+j} \beta^j \left\{ \ln \left(C_{1,t+j} - \kappa C_{1,t+j-1} \right) - \frac{\chi_0}{1+\chi} L^{1+\chi}_{1,t+j} \right\}, \tag{A.66}
$$

with the growth of $\iota_{1,t}$ following an auto-regressive process of order 1

$$
\ln \left(\frac{\iota_{1,t}}{\iota_{1,t-1}} \right) = \rho^\iota \ln \left(\frac{\iota_{1,t-1}}{\iota_{1,t-2}} \right) + \sigma^\iota \varepsilon^\iota_{1,t}. \tag{A.67}
$$

Consequently, the first order conditions of the household with respect to consumption and labor in Equations (A.5) and (A.6) need to be augmented as follows

$$
MU_{1,t} = \left(\frac{\iota_{1,t}}{1 - \kappa \frac{C_{1,t-1}}{C_{1,t}}} - \frac{\beta \kappa \iota_{1,t+1}}{\frac{C_{1,t+1}}{C_{1,t}} - \kappa} \right) \frac{1}{C_{1,t}}, \tag{A.68}
$$

$$
\frac{\tilde{W}_{1,t}}{P^d_{1,t}} = \iota_{1,t} \chi_{0,1} \frac{L^{\chi_1}_{1,t}}{MU_{1,t}} \frac{1}{F^{\rho^c}_{1,t}}. \tag{A.69}
$$

A.8.3 Complete Markets and Financial Autarchy

Under complete markets, we remove Equations (A.43), (A.46), (A.47), and their equivalent expressions for the foreign country, as well as Equations (A.42), (A.45) and newly introduce

$$
\frac{MU_{1,t}}{MU_{2,t}} = e_0 \frac{\lambda_{1,0}}{\lambda_{2,0}} \frac{\frac{P^c_{1,t}}{P^d_{1,t}}}{\frac{P^c_{2,t}}{P^d_{2,t}}} \frac{\nu_{2,t}}{\nu_{1,t}} \delta_{1,t} = \frac{1-\omega^c_1}{1-\omega^c_2} \left[\frac{\omega^c_1 \nu^{\frac{1}{\rho^c}}_{1,t} + (1-\omega^c_1)}{\omega^c_2 \nu^{\frac{1}{\rho^c}}_{2,t} + (1-\omega^c_2)} \right]^{-\rho^c} \delta_{1,t}, \tag{A.70}
$$

where $e_0 \frac{\lambda_{1,0}}{\lambda_{2,0}} = \frac{C_{2,0}}{C_{1,0}} = \frac{1-\omega^c_1}{1-\omega^c_2}$.

Under financial autarchy, we remove Equations (A.43), (A.46), (A.47), and their equivalent expressions for the foreign country, as well as Equations (A.42), (A.45) and newly introduce

$$\frac{C_{2,t}}{C_{1,t}} = \frac{1-\omega_1^c}{1-\omega_2^c}\left[\frac{\omega_1^c \nu_{1,t}^{\frac{1}{\rho^c}} + (1-\omega_1^c)}{\omega_2^c \nu_{2,t}^{\frac{1}{\rho^c}} + (1-\omega_2^c)}\right]^{-(1+\rho^c)} \delta_{1,t}. \tag{A.71}$$

This condition is derived from the fact that trade is balanced at every point in time under financial autarchy, i.e., $\delta_{1,t}M_{1,t} = M_{2,t}$.

B Appendix: Consumption Equivalent Variation

Consider the utility functions of the two countries $i = 1, 2$, repeated for convenience

$$\mathcal{U}_{i,t} = E_t \sum_{j=0}^{\infty} \beta^j \left\{ \ln \left(C_{i,t+j} - \kappa C_{i,t+j-1} \right) - \frac{\chi_0}{1+\chi} L_{i,t+j}^{1+\chi} \right\}.$$

Define global conditional welfare to be $Welf_t = \omega \mathcal{U}_{1,t} + (1-\omega)\mathcal{U}_{2,t}$. We denote by $Welf_t^{coop}$ the global welfare level attained under the cooperative equilibrium, and by $Welf_t^{nat}$ the global welfare level attained under the non-cooperative equilibrium. For given paths of consumption and labor in the two countries, we are interested in sizing a permanent subsidy τ applied to the consumption utility stream of country 1 such that the level of global welfare under the non-cooperative policies is equal to the level of global welfare under the cooperative policies. Thus,

$$\begin{aligned} & \omega E_t \sum_{j=0}^{\infty} \beta^j \left\{ \ln \left((1+\tau) \left(C_{1,t+j}^{nat} - \kappa C_{1,t+j-1}^{nat} \right) \right) - \frac{\chi_0}{1+\chi_1} \left(L_{1,t+j}^{nat} \right)^{1+\chi} \right\} \\ + \quad & (1-\omega) E_t \sum_{j=0}^{\infty} \beta^j \left\{ \ln \left(C_{2,t+j}^{nat} - \kappa C_{2,t+j-1}^{nat} \right) - \frac{\chi_0}{1+\chi} \left(L_{2,t+j}^{nat} \right)^{1+\chi} \right\} = Welf_t^{coop}, \end{aligned}$$

which can be rewritten as

$$\frac{\omega}{1-\beta} \log (1+\tau) + \omega Welf_{1,t}^{nat} + (1-\omega) Welf_{2,t}^{nat} = Welf_t^{coop}.$$

Rearranging terms, we obtain

$$\tau = \exp \left(\frac{1-\beta}{\omega} \left(Welf_t^{coop} - Welf_t^{nat} \right) \right) - 1.$$

Similarly, when considering country-specific outcomes, we compute country-specific gains for choosing nationally-oriented policies over cooperation as

$$\begin{aligned} \tau_1 &= \exp \left((1-\beta) \left(Welf_{1,t}^{nat} - Welf_{1,t}^{coop} \right) \right) - 1 \\ \tau_2 &= \exp \left((1-\beta) \left(Welf_{2,t}^{nat} - Welf_{2,t}^{coop} \right) \right) - 1. \end{aligned}$$

Using a first order approximation, the following relationship holds

$$-\tau = \tau_1 + \frac{1-\omega}{\omega} \tau_2,$$

between the global gains from cooperation τ and the country-specific gains from nationally-oriented policies τ_1, τ_2.