Revisiting the Costs of Self-Oriented National Monetary Rules*

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PRELIMINARY AND INCOMPLETE

Abstract

The gains from international monetary policy cooperation are sizeable when the cross-border spillovers of shocks are significant and policymakers face a strong incentive to use monetary policy to insulate their country from these spillovers. We show that financial market arrangements play an integral role in determining these incentives. In a quantitative two-countries, two-goods model with sticky prices and wages, we find large costs of departing from cooperative policies when financial markets are complete and there is sufficient substitutability between the home and the foreign traded goods. By contrast, under incomplete financial markets, large costs arise when the home and the foreign goods are sufficiently complementary.

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* The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of any other person associated with the Federal Reserve System.

1 Introduction

How big are the gains from cooperation for monetary policy across countries? The consensus is that there is little cost of adopting self-oriented national rules.[1] This consensus has influenced the practical conduct of monetary policy, with coordinated action across central banks being the exception rather than the norm. We revisit this consensus through the lens of a workhorse open economy macro model, in the footsteps of Obstfeld and Rogoff (2002), who perhaps most prominently argued that the answer to our question is a resounding no under empirically relevant conditions. On the contrary, we find that the gains from cooperation are sizable, and potentially much larger than the costs of economic fluctuations. Intuitively, competitive dynamics across countries can lead to vicious cycles that have the potential to shift the allocation of resources far from those that obtain under optimal cooperative policies. Previous work on the topic was the product of an economic tradition of aggregate models that did not account for country-specific policy trade-offs and its interplay with financial market arrangements. We show that not only are the gains from cooperation sizable, but that they are pervasive and arise in a wide array of empirically-relevant contexts.

Our analysis relies on a workhorse open economy macro model. Each country specializes in the production of one good that is traded internationally and is an imperfect substitute for the good of the other country. Prices and wages are sticky, creating trade-offs for monetary policy even in the face of efficient shocks. We consider alternative financial market arrangements across countries, including a complete set of Arrow-Debreu securities, only one non-state contingent bond, and autarky.[2] 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 them, we consider cooperative and non-cooperative equilibria that rely on Ramsey optimal strategies.

[1] Canzoneri, Cumby, and Diba (2005) offer a comprehensive review of the attempts to size the gains from cooperation.

[2] 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).

Our model is just a simple example of general conditions for the gains from cooperation to be sizable. The combination of sticky prices and wages is just one of many modeling devices that can generate powerful country-specific policy trade-offs. Furthermore, the pursuit of these trade-offs needs to generate spillover effects abroad. Absent either of these conditions, the gains from cooperation will be small. For instance, we confirmed that sizable mark-up shocks in a model with flexible wages could also generate these trade-offs. Domestically incomplete markets accompanied by financial frictions could also lead to country-specific policy trade-offs, as could the use of nontraded goods for the delivery of final goods.

In the non-cooperative equilibrium, when policymakers in each country face a trade off-between stabilizing output and inflation, attempting to bring about further inflation stabilization, these policymakers disregard the effects of their actions on the foreign utility, producing sizable spillover effects abroad. The foreign policymakers will then face a similar trade-off and their actions will lead to second-round effects in the home country that bolster the competitive dynamics.

We show that financial market arrangements are a key determinant of the strategic interactions between policymakers. When international financial markets are complete, the foreign spillover effects from the conduct of independent monetary policy are heightened by substitutability in the utility function of households between the domestic and foreign goods, leading to large gains from cooperation, possibly an order of magnitude larger than the gains from stabilizing economic fluctuations. Conversely, keeping the inter-temporal elasticity close to one, we confirm that trade elasticities close to one are associated with relatively small spillover effects and, accordingly, trivial gains from cooperation.

Large gains from cooperation also obtain with incomplete financial markets – we focus the standard case in which only one non-state contingent bond is traded across countries. In that case, it is complementarity between the domestic and foreign goods that heightens the spillover effects from the conduct of independent monetary policy and leads to large gains from cooperation. Furthermore, with incomplete markets, the gains from cooperation are time-varying and grow dynamically with the level of net foreign assets. Intuitively, the incentive to chase policy trade-offs is heightened by the effect that policy interventions can have on the value of net foreign assets. Each country will have an incentive to adopt policies that boost its asset position or curb its debt, further amplifying any competitive spiral.

Our model and results are closest to those of Obstfeld and Rogoff (2002) when we exclude the possibility of financial flows across countries, so that volume of trade needs to be balanced in every period. In that case, we confirm that the gains from cooperation remain well below the gains from economic stabilization, regardless of the degree of substitutability between the home and foreign goods. This result obtains because under financial autarky, country specific policy actions affect goods flows in ways that are counteracted by terms of trade movements, leading to spillover effects that remain too modest in size to fuel competitive spirals.

The rest of the paper proceeds as follows. Section 2 presents the model. Section 3 outlines the cooperative and competitive policies. Section 4 outlines the solution method, the parameterization of the model, and the approach to sizing the costs of adopting competitive policies. Section 5 discusses the quantitative results. Section 6 presents conclusions and some directions for future research.

2 The Baseline Two-Country Model

The starting point of the analysis is a two-country New Keynesian model with two traded goods that are imperfect substitutes similar to the models of Obstfeld and Rogoff (2002), Clarida, Gali, and Gertler (2002), Benigno and Benigno (2006), and Corsetti, Dedola, and Leduc (2010). Apart from considering financial arrangements across countries that involve a complete set of state-contingent assets, we also investigate financial autarky and starkly incomplete financial markets that rely on trading only one non-state-contingent bond.

Each country produces a composite good that is composed of a continuum of differentiated varieties. Labor is the sole input into producing the varieties. Prices for the varieties are determined by Calvo contracts (see Calvo 1983). When traded internationally, the composite good is priced in the currency of the producer.

2.1 Model Description

Each country has a continuum of agents of mass 1. As the economic structure of the two countries is analogous, we only describe the economy of country 1 in detail.

2.1.1 Households

The preferences of the representative household are given by:

$$\mathcal{U}_1 = E_t \sum_{j=0}^{\infty} \beta^j \left\{ \frac{1}{1-\sigma} \left(C_{1,t+j} - \kappa C_{1,t+j-1} \right)^{1-\sigma} + \frac{\chi_0 \zeta_{1,t+j}}{1-\chi_1} \left(1 - L_{1,t+j}\right)^{1-\chi_1} \right\}. \tag{1}$$

The variables $C_{1,t}$ and $L_{1,t}$ represent consumption and hours worked, respectively. The parameter κ governs habits. The shock ζ influences the labor supply and hours worked in equilibrium. As customary in the New Keynesian literature, the analysis is conducted in a cashless economy, i.e., the utility component of money is ignored and the monetary policymaker sets a short-term nominal interest rate to achieve its policy goals.

The time t budget constraint of the household depends on the assumptions regarding international risk sharing. We consider complete markets, incomplete markets with one non-state-contingent bond, and financial autarchy.[3] The budget constraint is given by one of the conditions in (2):

1. if international financial markets are complete

$$\begin{aligned} P^c_{1,t} C_{1,t} + \int_S e_t P^b_{2,t+1|t} B_{1,t+1|t} + \int_S P^d_{1,t+1|t} D_{1,t+1|t} \quad &= \quad W_{1,t} L_{1,t} + e_t B_{1,t|t-1} \\ &\quad + D_{1,t|t-1} + \Gamma_{1,t} + T_{1,t}, \end{aligned}$$

2. if the only asset traded internationally is a non-state-contingent bond

$$\begin{aligned} P^c_{1,t} C_{1,t} + \frac{e_{1,t} P^b_{2,t} B_{1,t}}{\phi^b_{1,t}} + \int_S P^d_{1,t+1|t} D_{1,t+1|t} \quad &= \quad W_{1,t} L_{1,t} + e_{1,t} B_{1,t-1} \\ &\quad + D_{1,t|t-1} + \Gamma_{1,t} + T_{1,t}, \end{aligned}$$

[3] Sutherland (2004) analyzes the case of complete markets and financial autarchy. His model allows for two periods only: in the first period make decisions on allocations before the resolution of uncertainty; in the second period these decisions are carried out according to the realised state of world. Incomplete financial market arrangements are not considered in that paper.

3. if there are no international financial markets (financial autarchy)

$$P^c_{1,t}C_{1,t} + \int_S P^d_{1,t+1|t}D_{1,t+1|t} = W_{1,t}L_{1,t} + D_{1,t|t-1} + \Gamma_{1,t} + T_{1,t}. \tag{2}$$

The final consumption $C_{1,t}$ is purchased at the prices $P^c_{1,t}$. The household earns labor income $W_{1,t}L_{1,t}$, receives an aliquot share $\Gamma_{1,t}$ of firm profits, and net transfers of $T_{1,t}$.

Irrespective of the assumptions about international financial markets, households have access to a set of state-contingent domestic bonds, denoted by $D_{1,t+1|t}$, with price $P^d_{1,t+1|t}$. When international financial markets are also complete, an additional set of state-contingent claims is available, $B_{1,t+1|t}$, with the price denoted in foreign currency $P^b_{2,t+1|t}$. If the only asset that trades internationally is a non-state-contingent bond, $B_{1,t}$, households face an intermediation cost $\phi^b_{1,t}$ that raises the price of the bond, $P^b_{2,t}$. These intermediation costs also render the dynamics of $B_{1,t+1}$ stationary under our solution method.

The household maximizes the utility functional (1) with respect to consumption, labor supply, and holdings of domestic and foreign bonds, subject to the relevant budget constraint in (2).

The consumption basket $C_{1,t}$ can be thought of as being produced by perfectly competitive consumption distributors whose production function mirrors the preferences of households over home manufactured good, $C^d_{1,t}$, and the foreign manufactured good, $M_{1,t}$:

$$\begin{aligned}
&\min_{C^d_{1,t}, M_{1,t}} P^d_{1,t}C^d_{1,t} + P^m_{1,t}M_{1,t} \\
&s.t. \\
&C_{1,t} = \left((\omega^c)^{\frac{\rho^c}{1+\rho^c}} \left(C^d_{1,t}\right)^{\frac{1}{1+\rho^c_1}} + (\omega^m)^{\frac{\rho^c}{1+\rho^c}} \left(M_{1,t}\right)^{\frac{1}{1+\rho^c}} \right)^{1+\rho^c_1}
\end{aligned} \tag{3}$$

with $\omega^c = 1 - \omega^m$. The price of the consumption aggregate $P^c_{1,t}$ coincides with the Lagrange multiplier on equation (3) in the cost minimization problem of a distributor.

Under our baseline assumption of producer currency pricing, the price of the imported good, $P^m_{1,t}$, equals its price in the foreign country multiplied by the nominal exchange rate, $e_t P^d_{2,t}$.

2.1.2 Sticky Nominal Wages

Households supply their homogenous labor L_t to intermediate labor unions. The unions differentiate the labor services and sell each type at its own price using Calvo staggered contracts to labor bundlers. In turn, firms purchase the labor aggregate $L^d_{1,t}$ from the labor bundlers.

The range of differentiated labor services $L_{1,t}(h)$ are combined into its aggregate according to:

$$L^d_{1,t} = \left[\int_0^1 L_{1,t}(h)^{\frac{1}{1+\theta^w_1}} dh\right]^{1+\theta^w_1}. \tag{4}$$

The perfectly competitive labor bundlers buy the labor services $L_{1,t}(h)$ from the unions, combine them to obtain $L^d_{1,t}$, and resell them to the intermediate goods producers at wage $W_{1,t}$, yielding the demand function for $L_{1,t}(h)$:

$$L_{1,t}(h) = \left[\frac{W_{1,t}(h)}{W_{1,t}}\right]^{-\frac{1+\theta^w_{1,t}}{\theta^w_{1,t}}} L^d_{1,t}, \tag{5}$$

and the aggregate producer wage

$$W_{1,t} = \left[\int_0^1 W_{1,t}(h)^{-\frac{1}{\theta^w_1}} dh\right]^{-\theta^w_1}. \tag{6}$$

Labor unions take the real wage desired by the household, $W^f_{1,t+j}/P_{1,t+j}$, as the cost of labor services. In the spirit of Calvo (1983), each union can readjust a wage with probability $1-\xi^w_1$ in each period. For those unions which cannot adjust wages in a given period, wages grow at the steady state wage inflation rate. The problem of union h is given by:

$$\max_{W_{1,t}(h)} E_t \sum_{j=0}^{\infty} (\xi^w_1)^j \Lambda_{1,t+j} \left[(1+\tau^w_1) W_{1,t}(h) L_{1,t+j}(h) - W_{1,t+j} L_{1,t+j}(h)\right] \tag{7}$$

$s.t.$

$$L_{1,t}(h) = \left[\frac{W_{1,t}(h)}{W_{1,t}}\right]^{-\frac{1+\theta^w_1}{\theta^w_1}} L^d_{1,t}, \tag{8}$$

The subsidy τ_1^w is set to induce the efficient level of labor supply in the steady state.

2.1.3 Production of Manufactured Goods

A continuum of representative bundlers combines differentiated intermediate products into the composite home-produced manufactured good $Y_{1,t}$ according to:

$$Y_{1,t}^d = \left[\int_0^1 Y_{1,t}(i)^{\frac{1}{1+\theta_{1,t}^p}} di \right]^{1+\theta_{1,t}^p}, \tag{9}$$

where $Y_{1,t}^d$ is used as the domestic input in producing all final use goods, including exports. One unit of the sectoral output index sells at the price:

$$P_{1,t}^d = \left[\int_0^1 P_{1,t}^d(i)^{\frac{-1}{\theta_{1,t}^p}} di \right]^{-\theta_{1,t}^p}. \tag{10}$$

Under producer currency pricing, the foreign currency price of exports to the foreign country is $P_{2,t}^m = P_{1,t}^d / e_{1,t}$.

Each of the differentiated intermediate products by a single monopolistically competitive firm using labor as the sole input in production:

$$Y_{1,t}(i) = \left(e^{z_{1,t}}\right) L_{1,t}(i). \tag{11}$$

where the country-wide technology shock, $z_{1,t}$, evolves according to $z_{1,t} = \rho_1^z z_{1,t-1} + \sigma_1^z \varepsilon_{1,t}^z$. With an integrated labor market the marginal costs of production are $W_{1,t}/e^{z_{1,t}}$.

Firms are indexed by $i \in [0,1]$ and face the demand function from the bundlers implied by equation (9):

$$Y_{1,t}(i) = \left[\frac{P_{1,t}(i)}{P_{1,t}^d} \right]^{-\frac{1+\theta_{1,t}^p}{\theta_{1,t}^p}} Y_{1,t}^d, \tag{12}$$

where $\theta_{1,t}^p > 0$ is time-varying in order to allow for price mark-up shocks as for example in Smets and Wouters (2007), Gali (2008) or Justiniano, Primiceri, and Tambalotti (2013). The shock follows an AR(1) process with $\theta_{1,t}^p = \rho_1^p \theta_{1,t-1}^p + \sigma_1^p \varepsilon_{1,t-1}^p$.[4]

[4] Our simulations also allow for mark-up shocks as the result of fluctuations in a sales subsidy as an alternative.

The prices of varieties $P_{1,t}(i)$ are determined by Calvo-style staggered contracts with reoptimization probability, $1-\xi^p$, see Calvo (1983). The probabilities are constant and independent across firms, time, and countries. Firms that do not reoptimize their price increase prices with the steady state inflation rate which is set to be zero in this section:

$$\max_{P_{1,t}(i),\{Y_{1,t+j}(i)\}_{t=0}^{\infty}} E_t \sum_{j=0}^{\infty} (\xi^p)^j \Lambda_{1,t+j} \left\{ (1+\tau^p) P_{1,t}(i) - \frac{W_{1,t+j}}{e^{z_{1,t+j}}} \right\} Y_{1,t+j}(i)$$
$$s.t.$$
$$Y_{1,t+j}(i) = \left[\frac{P_{1,t+j}(i)}{P^d_{1,t+j}} \right]^{-\frac{1+\theta^p_{1,t+j}}{\theta^p_{1,t+j}}} Y^d_{1,t+j}. \tag{13}$$

The stochastic discount factor $\Lambda_{1,t+j}$ is given by $\beta^j \left(\frac{C_{1,t+j}}{C_{1,t}} \right)^{-\sigma} \frac{P^c_{1,t}}{P^c_{1,t+1}}$. The parameter τ^p_1 is a sales subsidy that can be set to ameliorate the relative price distortions due to monopolistic competition in the steady state.

2.1.4 Market Clearing

Aggregating over households, clearing the market for the domestic good requires:

$$Y^d_{1,t} = C^d_{1,t} + M_{2,t} \tag{14}$$

where $M_{2,t}$ denotes the foreign country's demand for the domestic good.

As varieties are imperfect substitutes, market clearing in the labor market, i.e., $L_{1,t} = \int_0^1 L_{1,t}(i)di$ implies:

$$\Delta^d_{1,t} Y^d_{1,t} = \left(e^{z_{1,t}}\right) L_{1,t} \tag{15}$$

with the price dispersion measure:

$$\Delta^d_{1,t} = \frac{\int_0^1 Y_{1,t}(i)di}{Y^d_{1,t}} = \int_0^1 \left[\frac{P_{1,t}(i)}{P^d_{1,t}} \right]^{-\frac{1+\theta^p_{1,t}}{\theta^p_{1,t}}} di. \tag{16}$$

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

1. $B_{1,t+1|t} + B_{2,t+1|t} = 0$, if international financial markets are complete,
2. $B_{1,t} + B_{2,t} = 0$, if the only asset traded internationally is a non-state-contingent bond,
3. $B_{1,t} = 0$ and $B_{2,t} = 0$ if there are no international financial markets (financial autarchy).

2.1.5 Stochastic Processes

The model includes three sources of stochastic variation in each country: a labor supply shock $\zeta_{i,t}$ (where i is 1 or two, see equation); a technology shock $Z_{i,t}$ (see equation); and a markup shock $\theta^p_{1,t}$ (see equation). The shocks follow auto-regressive processes of order 1. Focusing on country 1:

$$\zeta_{1,t} = \rho^{\zeta}\zeta_{1,t-1} + \epsilon^{\zeta}_{1,t}, \tag{17}$$

$$z_{1,t} = \rho^{z} z_{1,t-1} + \epsilon^{z}_{1,t}, \tag{18}$$

$$\theta^p_{1,t} = \rho^{\zeta}\theta^p_{1,t-1} + \epsilon^{\theta}_{1,t}. \tag{19}$$

The innovations $\epsilon^{\zeta}_{1,t}$, $\epsilon^{z}_{1,t}$, and $\epsilon^{\theta}_{1,t}$ are normally and independently distributed with standard deviation σ^{ζ}, σ^{z}, and σ^{θ}, respectively.

2.1.6 Private Sector Equilibrium

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 private sector equilibrium.

Let $\tilde{x}_t$ be the $(N-2)\times 1$ vector of endogenous variables excluding 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 private sector equilibrium is generically given by

$$E_t g(\tilde{x}_{t-1}, \tilde{x}_t, \tilde{x}_{t+1}, i_{1,t}, i_{2,t}, \zeta_t) = 0 \tag{20}$$

where g collects the $N-2$ first-order and market clearing conditions of the model.

3 Optimal Monetary Policy

In each country the monetary policymakers sets the respective policy instrument in order to optimise an assigned objective function. Following the literature, the objective function of the central bank in a given country, $\mathcal{U}_j$ for $j=[1,2]$, coincides with the utility function of the representative household in that country as in equation (1).

We distinguish two policy regimes. Under cooperation, the two central banks maximise the joint welfare function $\omega\mathcal{U}_1+(1-\omega)\mathcal{U}_2$ for a given weight ω. We impose that welfare weight satisfy $\omega \leq 1$. Absent cooperation, each policymaker considers his own preferences only.

3.1 Policy under Cooperation

The welfare-maximizing Ramsey policy with full commitment is derived from the maximization program

$$\begin{aligned}
&\max_{\{\tilde{x}_t, i_{1,t}, i_{2,t}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \left[\omega U_1(\tilde{x}_{t-1}, \tilde{x}_t, \zeta_t) + (1-\omega) U_2(\tilde{x}_{t-1}, \tilde{x}_t, \zeta_t)\right] \\
&s.t. \\
&E_t g(\tilde{x}_{t-1}, \tilde{x}_t, \tilde{x}_{t+1}, i_{1,t}, i_{2,t}, \zeta_t) = 0. \qquad (21)
\end{aligned}$$

The $(N-2)\times 1$ Lagrange multipliers associated with the private sector equilibrium conditions in (20) are denoted by λ_t for any $t \geq 0$. Taking derivatives of the Lagrangian associated with the program (21) with respect to the N endogenous variables in $(\tilde{x}_t, i_{1,t}, i_{2,t})$ delivers N first order conditions. Additionally, taking derivatives with respect to λ_t delivers again the $N-2$ private sector conditions. In total, there are $2N-2$ conditions for each period and $2N-2$ sequences endogenous variables $\{\tilde{x}_t, i_{1,t}, i_{2,t}, \lambda_t\}_{t=0}^{\infty}$.

3.2 Policy without Cooperation

We restrict attention to the case of open-loop Nash equilibria. 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^*} maximises player $j's$ objective function subject to the structural equations of the economy in equation (20) 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:

$$
\begin{aligned}
&\max_{\{\tilde{x}_t, i_{j,t}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t U_j(\tilde{x}_{t-1}, \tilde{x}_t, \zeta_t) \\
&s.t. \\
&E_t g(\tilde{x}_{t-1}, \tilde{x}_t, \tilde{x}_{t+1}, i_{1,t}, i_{2,t}, \zeta_t) = 0 \\
&\text{for given } \{i_{-j,t}\}_{t=0}^{\infty}.
\end{aligned}
\tag{22}
$$

Taking derivates of the Lagrangian associated with the maximization program (22) with respect to the $N-1$ choice variables $(\tilde{x}_t, i_{j,t})$ and the $N-2$ Lagrange multipliers $\lambda_{j,t}$, attached to the $N-2$ structural relationships, delivers $2N-3$ conditions for each player.

As the full set of $4N-6$ first-order conditions includes the $N-2$ structural equations twice, the total number of equilibrium conditions reduces to $3N-4$ for the $3N-4$ variables $\{\tilde{x}^*_t, i^*_{1,t}, i^*_{2,t}, \lambda^*_{1,t}, \lambda^*_{2,t}\}_{t=0}^{\infty}$ for an interior Nash equilibrium in open-loop strategies.

4 Solution Method and Parameterization

We approximate the conditions for an equilibrium implied by the optimal policy problems under cooperation (equation 21) and under competition (equation 22) by second order-perturbation methods.[5] 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).

Most of the model's parameter values are standard. They are reported in Table 1. We determine the relative sizes of the shocks with the simulated method of moments using a closed-economy analog of our open economy model. For this empirical model, we assume that monetary policy follows a simple Taylor-type rule that responds to lagged interest rates and inflation. We use quarterly U.S. data for four series:

1. Hours worked per capita, constructed as total hours worked in the non-farm business sector divided by total employment in the non-farm business sector. Both series are from the Bureau of Labor Statistics.

2. Output per capita, using data on real output per person in the non-farm business sector from the Bureau of Labor Statistics.

3. Policy interest rate, using the Effective Federal Funds rate from the Federal Reserve Board.

4. Inflation, using the quarterly change in the deflator for personal consumption expenditures from National Income and Product Accounts from the Department of Commerce.

For the simulated method of moments, we match the variance and the autocorrelation of the observed series with their model counterparts to obtain estimates of the autocorrelation coefficient and standard deviation of the innovation for the shocks to technology, to price markups and to the marginal disutility of labor. We also estimate the coefficient that governs the response to lagged interest rates the monetary policy rule and the standard deviation of a monetary policy shock.[6]

Table 2 reports the target observed moments used for the moment matching ex-

[5] In practice, we avoid the pitfalls of the analytical derivation of the conditions for an equilibrium under equation (21) under equation (22) by symbolic differentiation, as implemented in Bodenstein, Guerrieri, and LaBriola (2014). For the second-order perturbation solution we rely on Dynare, a popular modelling platform. See Adjemian, Bastani, Karam, Juillard, Maih, Mihoubi, Perendia, Pfeifer, Ratto, and Villemot (2011).

[6] The simple monetary policy rule used in the moment matching exercise is irrelevant for our subsequent results but helps us pin down some of the other parameters of interest. The rule is fixed to respond to quarterly inflation with a coefficient equal to 1 and a smoothing parameter estimated at 0.19. The standard deviation of the monetary policy shock is estimated at 0.007.

ercise and their model counterparts. Target and model moments are close. We confirmed that while each model shock principally affects variance and autocorrelation of one of the target variables, it also influences the other moments of interest. For instance, the table reports the model moments without labor supply shocks. In that case, as expected, the variance of hours worked is markedly lower than its observed counterpart, but all other moments are affected, too. Intuitively, these cross effects account for why we cannot obtain a perfect match to the data, even though we are controlling as many parameters as target moments.

4.1 Sizing the Gains from Cooperation

To size the gains from cooperation, we rely on a comparison of the conditional welfare values attained under cooperation and Nash competition. Our focus on conditional (as opposed to unconditional measures) is dictated by the set up of our model. After all, in the model we consider, households maximize *conditional* utility and optimal policies maximize *conditional* welfare measures.

Rather than limiting our analysis to comparisons at a given, arbitrary point, we sample points from the ergodic distribution of the model under the cooperative equilibrium. To this purpose, we draw random sequences of shocks for 250 periods (a number of periods sufficiently high to reach, in the absence of shocks, the non-stochastic fixed point for the second-order solution). In period 250, unexpectedly, we switch to the competitive equilibrium and compare the conditional welfare under that equilibrium with the conditional welfare that would have been attained under the cooperative equilibrium. Using this procedure, we construct a distribution of gains from cooperation (losses due to competition) based on 1000 points.

The competitive equilibrium has double the number of Lagrange multipliers associated witht the constraints imposed by the conditions for a decentralized equilibrium (summarized in equation 21). Since some of these multipliers are included in the state vector for the second-order perturbation solution, we set their values in period 249 to match the corresponding multipliers under the cooperative equilibrium that applied in that period. The interpretation of this choice is that competing policymakers are still bound by past promises.[7]

We interpret the units of conditional welfare by focusing on the concept of consumption equivalent variation. We report the consumption subsidy that would have to be offered in perpetuity to households in the home country to attain, under the competitive equilibrium, the same level of welfare as under the cooperative equilibrium. The subsidy net rate τ is defined as:

$$\tau = \left(\frac{Welf_t^{coop} - Welf_t^{Nash}}{\omega Welf_{1,t}^{C}} + 1 \right)^{1-\sigma} - 1, \tag{23}$$

where $Welf_t^{coop}$ denotes the welfare level attained under the cooperative equilibrium, $Welf_t^{Nash}$ is the welfare level attained under the competitive equilibrium and $Welf_{1,t}^{C}$ is the component of welfare stemming from consumption in country 1. The derivation of this subsidy is detailed in Appendix A. In the following sections, we report the mean and other characterstics of the distrubution of this consumption subsidy, such as the fifth and the ninety-fifth percentiles.

4.2 The Cost of Economic Fluctuations

To facilitate the interpretation of the size of the consumption equivalent variation associated with departing from a cooperative equilibrium, we use the familar cost of economic fluctuations as a yardstick. Focusing on the cooperative equilibrium, we size the cost of economic fluctuations as the consumption equivalent variation that, starting from a non-stochastic steady-state with all current and future shocks excluded would keep households indifferent from having to face shocks.

Mechanically, the two economies will have identical second-order perturbation solutions, but for a vector of constants (the stochastic shift factor) that will enter the economy with shocks and that will drop out of the other economy with shocks excluded. We size the consumption tax that would make the agents in the economy without shocks indifferent from facing current and future shocks. To encompass the effects of current shocks, we draw 1000 random shock vectors, and average the

[7] When we experimented with resetting the multipliers to 0, a choice which can be interpreted as policymakers repudiating past promises, our results were little changed.

consumption equivalent variation for each shock vector.

5 Results

The top panel of Figure 1 shows the gains from cooperation for different values of the trade elasticity of substitution between the home and the foreign traded goods. The figure shows gains under complete and incomplete international financial markets. The figure showcases that gains from cooperation are pervasive, as they occur under drastically different financial market arrangements. Ceteris paribus, in the case of complete markets, large gains occur for high values of the trade elasticity of substitution, whereas under incomplete markets, they occur for relatively low values of the trade elasticity of substitution. These observations are easily reconciled since for gains to occur, country-specific policy choices or shocks need to generate spillover effects abroad. As is well understood, under incomplete markets, the spillover effects of country-specific shocks are larger the lower the trade elasticity of substitution. Conversely, under complete markets, the opposite configuration obtains, and spillover effects are larger the higher the trade elasticity of substitution.

It is also 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) emphasize a trade elasticity of substitution in the range of four as empirically relevant, while Benigno and Thoenissen (2008) and Corsetti, Dedola, and Leduc (2008) stress values lower than one can also be empirically relevant. Notice that, in sizing the gains from cooperation, Obstfeld and Rogoff (2002) focus on a case in which the trade elasticity coincides with the inverse of the intertemporal elasticity of substitution, a very special case in which financial market arrangements are irrelevant for the allocations. In our case with habits, that point of coincidence is slightly below one, where we observe the lowest gains.

We proceed to highlight the specific channels by which gains from cooperation occur, in turn, for each type of financial market arrangements. We start with the complete markets case since it is also the focus of the bulk of the literature on the gains from cooperation.

5.1 The Gains from Cooperation under Complete Markets

Figure 2 illustrates the role of some model features in determining the magnitude of the gains from cooperation. For ease of comparison, the top panel replicates the benchmark case shown in Figure 1.[8] The top panel confirms that the cost of abandoning cooperative policies can be an order of magnitude higher than the cost of economic fluctuations (sized as explained in Section 4.2).

The benchmark specification includes multiple sources of shocks – technology, labor supply, and markup shocks. The second panel of Figure 2 confirms that the gain from cooperation remain sizable even when supply shocks and markup shocks are excluded (with technology remaining as the only source of variation). This is perhaps not too surprising. The work of Erceg, Henderson, and Levin (2000) for a closed economy shows that sticky prices and wages introduce trade-offs for the conduct of monetary policy even when technology shocks are the only source of exogenous variation. These trade-offs continue to apply at the level of each country in an open economy setting. Accordingly, exploiting country-specific trade-offs, each policymaker will have an incentive to re-optimize away from the cooperative solution that internalizes the spillover effects of exploiting these trade-offs. Strikingly, in this case, the cost of business cycles go down proportionately more than the cost of departing from cooperative policies.

Our benchmark calibration includes some degree of consumption habits – the parameter κ in Equation 1 is set to 0.5. As an alternative the dashed line, labeled "no habits," sets the habits parameter to 0. In this case, the gains from cooperation are somewhat reduced, but the difference relative to the benchmark case is quantitative rather than qualitative. Even excluding consumption habits, the gains from cooperation remain sizable for the higher range of the trade elasticities shown in Panel (b). For instance, with a trade elasticity equal to 4, the consumption variation equivalent

[8] Since for complete markets the gains from cooperation are relatively independent of the configuration of the state variables, Figure 2 focus on the mean gain across the ergodic distribution for the model.

to switching away from cooperation is about $\frac{1}{4}$ percent, as opposed to $\frac{4}{10}$ percent under the benchmark calibration.

The last panel of the figure clarifies that sticky wages are important for obtaining sizable gains from cooperation in our simple model. The panel shows that excluding sticky wages, the cost of economic fluctuations is uniformly greater than the cost of departing from cooperative policies for the range of trade elasticities shown.

Of course, with sticky prices and markup shocks, even in the absence of sticky wages, policymakers in each country still face country-specific trade-offs for monetary policy. Nonetheless, without sticky wages, these tradeoffs are not sizable enough for meaningful departures from the cooperative allocations to occur. We confirmed that, without sticky wages, markup shocks could indeed provide country-specific trade-offs that lead to match the gains from cooperation of our benchmark specification, but the variance of these shocks would have to be thirty times as large as under our benchmark specification. In turn, these larger shocks would render the volatility of inflation counter-factually high by an order of magnitude. We also confirmed that the gains from cooperation vary smoothly with the degree of wage stickiness (increasing as the wage stickiness rises). Taken together, these results confirm that rather than a particular model ingredient, the broader condition for obtaining larger gains from cooperation under complete markets is that the policymaker in each country face country-specific trade-offs.

5.2 The Effects of a Technology Shock

The effects of a technology shock help to understand the strategic interactions between policymakers. Specifically Figure 3 considers a negative (one-standard-deviation) shock to technology in the home country under cooperative and Nash equilibria. The trade elasticity is set at three. Under cooperation, domestic output falls and the exchange rate appreciates as the technology level declines. Foreign output rises to compensate for the domestic output loss. Foreign prices and wages rise modestly.

The foreign spillover effects of the domestic technology contraction play a key role in shaping the Nash strategies. Under a Nash equilibrium, the foreign country has an incentive to tighten monetary policy to curb the inflation spike induced by the increased import prices. Intended to moderate the foreign exchange depreciation and rising import prices, this policy can, in turn, trigger further tightening of monetary policy in the home country.

When the trade elasticity is high the competitive policy tightening spiral is particularly pronounced. The responses in Figure 3 are for a trade elasticity of substitution equal to three. When the home and foreign traded goods are sufficiently substitutable, each policymaker believes that further monetary policy tightening can move the relative prices in an advantageous way so that decreased production does not have to result in decreased consumption if a relatively higher share of imports can be secured. Accordingly, the two policymakers essentially compete for a larger share of a shrinking pie and fail to internalize how their actions shrink the pie even further. The figure shows how under competition, both home and foreign output are lower, and consistent with the inferior outcomes of the Nash equilibrium, inflation does not appear any closer to being stabilized.

When the trade elasticity is low, the policy tightening spiral is not as pernicious. With lower elasticities, it becomes more difficult to compensate the domestic production loss induced by a further tightening of monetary policy through a sufficiently higher quantity of imports. This consideration reduces the incentive to use monetary policy towards a relative exchange rate appreciation aimed at securing a larger share of world production.

5.3 The Gains from Cooperation under Incomplete Markets

For the case of incomplete financial markets, we focus on two canonical cases: 1) a case in which only one non-state-contingent bond can be traded across countries, and 2) the case of autarky, in which no financial assets are available and trade flows need to balance in every period.

Returning to the top panel of Figure 1, with incomplete financial markets, the relationship between the size of the gains and the trade elasticity of substitution is reversed relative to the case with complete markets. As emphasized above, lower values of the trade elasticity are associated with larger gains from cooperation because, under incomplete markets, these lower elasticities allow larger foreign spillover effects of country-specific shocks. For the case in which one bond can be traded across countries (labeled "Incomplete markets" in the figure), the relationship between the gains from cooperation and the trade elasticity is non-monotonic. For low values of the trade elasticity (but still empirically plausible) the gains of cooperation are high, on average. As the trade elasticity declines, the gains fall and reach their minimum when the trade elasticity is just shy of a value equal to one. When the elasticity rises further, the gains from cooperation increase moderately.

The non-monotonicity of the relationship between the trade elasticity and the average gains from cooperation stems from the multiple channels that link the two under incomplete markets. Not only can monetary policy influence trade allocations as under complete markets, but it can also influence the relative asset position of each country.[9] Intuitively, the policymaker of a debtor country will also have an incentive to use monetary policy to reduce the relative debt burden through a real exchange rate appreciation. And the policymaker of a lender country will have the same incentive, leading, in turn, to a competitive spiral.

Figure 4 showcases the importance of the asset valuation channel for strategic interactions and the gains from cooperation. We focus here on the case in which the two countries can trade one non-state-contingent asset. For various values of the trade elasticity, we explore different points in the support of the endogenous variables for the model by drawing a long sequence of shocks before switching from the cooperative to the competitive equilibrium.[10] While for the complete markets case, the switch point from the cooperative equilibrium to the Nash equilibrium is essentially irrelevant, under complete markets it can be very important.

The top panel plots the mean, the fifth percentile, and the ninety-fifth percentile of the gains from cooperation for different values of the trade elasticity. The figure also confirms that the gains from cooperation can be much larger (or smaller) than the mean value shown. Notice that, as can be evinced from the figure by the distance

[9] Intuitively, under complete markets, the rich asset structure can be used to also insure against monetary policy actions that would otherwise reduce the overall relative value of foreign assets, making policy actions geared to revalue foreign asset positions futile.

[10] This sampling procedure is described si Section 4.1.

between the percentiles shown, the variation in the gains is higher when the average gains from cooperation are also higher, displaying analogous non-monotonicity for the outer percentiles as for the mean. The figure also shows that the gains from cooperation, depending on the trade elasticity of stubsitution, can be much higher than then the gains that would accrue if all fluctuations were to be eliminated.

Panel (b) of Figure 4 highlights the connection between the net foreign asset position in the period when monetary policy switches from the cooperative equilibrium to the Nash equilibrium and the gains from cooperation. In panel (b), we plot the absolute value of the net foreign asset position normalized by each country's output (in the period of the switch from the cooeperative to the Nash equilibrium) against the associated gains from cooperation.[11] We use different colors to denote results for different values of the trade elasticity of substitution. As panel shows, for each value of the trade elasticity, the gains from cooperation are an increasing function of the absolute value of the net foreign asset position. Moreover, increasing the value of the trade elasticity while keeping the absolute value of the net foreign asset position unchanged results in lower gains from cooperation.

Yet, the trade elasticity not only influences the gains from cooperation for a given absolute value of the net foreign asset position, but it also affects the distribution of net foreign assets given random sequences of shocks. Starting from a trade elasticity equal to 0.65, the support of the foreign asset position in our simulations remains modest in size, with few realizations of the ratio of net foreign assets to output above 0.4. For slightly higher values of the trade elasticity, 0.7, 0.8, and 0.9, shown in the figure, the distribution of the net foreign asset position becomes even less disperse. With an elasticity of 0.9 we we did not encounter any ratio of net foreign assets to output above 0.2. However, further increases in the trade elasticity result again in a more disperse distribution the net foreign asset position. Although a high trade elasticity reduces the gains from cooperation for a given value of the net foreign asset position, higher values of the net foreign asset position are considerably more likely and thus the mean of the gains from cooperation increases again.

[11] Each point shown in Panel (b) of Figure 4 was sampled by drawing a random sequence of shocks. This procedure allows us to select points from the ergodic distribution of the model.

But how does the net foreign asset position affect the strategic interaction between the players in the Nash equilibrium and thus the gains from cooperation, in the first place? Cooperative monetary policy under incomplete financial markets facilitates risk-sharing; in doing so, monetary policy restrains consumption in the country with a positive net foreign asset position (the lender country) while preventing the labor supply and production from dropping. Thus, the lender country has pent-up demand for leisure and consumption. Upon switching to the Nash policies, the lender country seizes the opportunity to satisfy this demand by tightening the policy rate (without internalizing the effects of this action on foreign payoffs). This tightening leads to an appreciation of the lender's currency (and a corresponding depreciation of the currency of the debtor country), which makes debt repayments for the debtor country more expensive. To curb the depreciation of its currency, the debtor country also has an incentive to tighten monetary policy. Thus, monetary policy in the Nash equilibrium is tighter than under the cooperative equilibrium.[12]

When the trade elasticity is high, i.e., the home and foreign traded goods are substitutes in the utility functions of the households, the policy tightening cycle has modest proportions. The debtor country ends up earning greater export revenues which curb its debt—the net foreign asset positions shrink. When the trade elasticity is low, i.e., the home and foreign traded goods are complements in the utility functions of the households, the policy tightening spiral is much more pronounced. In that case, the debtor country does not earn greater net export revenues and its debt expands. Accordingly, the consumption paths deviate in a more pronounced fashion from those under cooperation. Notice that when the elasticity is around 0.9, the strategic interactions are muted because the increase in import volumes is closely offset by the lower unit price, so that the net foreign asset positions remain roughly unchanged. Finally, more extreme net foreign asset positions amplify the incentive to tighten monetary policy. Consequently, the strategic interactions and the gains from cooperation are also boosted.

[12] Benigno (2009) also considered how asymmetric positions for net foreign assets affect the gains of departing from a policy that fully stabilizes prices. Benigno (2009), however, does not consider optimal cooperative or competitive policies, as we do here.

5.4 The Transition from Cooperation to Competition

Figure 5 focuses on the transition from cooperation to competition for a particular realization of the state variables of the model with incomplete markets. The figure considers a trade elasticity equal to 0.8 and a particular realization of the state variables that correspond to sizable but not extreme gains from cooperation, at the 60th percentile of the distribution of gains. Both lines shown in the figure abstract from the realization of further shocks and show paths converging towards the non-stochastic fixed point for the second-order solution. Under the case labeled cooperation, the two countries were and remain in a cooperative equilibrium. Under the case labeled "Nash Policy" the two countries cooperated until the period prior to the first shown in the figure, but in that first period, unexpectedly, they switch to a Nash competitive equilibrium. This is the same kind of thought experiment that we use to size the gains from cooperation.

For this particular realization of the state variables, the home country is a debtor. The figure's top left panel shows debt in deviation from the non-stochastic fixed point for the model. In this case, the home country's debt with the foreign country is sized just over four percent of the home country's quarterly output. As the figure shows, the reaction to the switch to a Nash equilibrium can be dramatic. In this case, both countries lower inflation relative to the cooperative case, and raise policy rates in an attempt to change the real value of the home country's debt. In equlibrium, the response of the foreign country is more pronounced, consistent with a depreciation of the home country's exchange rate (shown as an upward movement in the figure). Notice that under the competitive equilibrium, consumption contracts further in both countries but hours worked drop dramatically only in the foreign country. In this case, the strategic interactions surrounding the net foreign assets are further boosted by country-specific policy tradeoffs. For instance, the exchange rate depreciation in the home country, also spurs that country to redouble its efforts at containing the resulting inflation spike and to engineer domestic goods price deflation. This reaction, in turn, through its effects on the real exchange rate, further inflames the competition surrounding the value of the net foreign assets.

5.5 Sensitivity Analysis: Incomplete Markets

Figure 6 offers some sensitivity analysis regarding the size of the gains from cooperation for the case of incomplete markets. For ease of comparison, the first panel replicates the benchmark case. The second panel considers the effects of dropping some of the sources of stochastic variation, namely, the labor supply shocks and the markup shocks (only technology shocks remain). As under complete markets, the sources of the shocks turn out to be relatively unimportant, as can be evinced by noticing that the gains shown in the second panel are little changed relative to the first.

The third panel considers the effects of excluding sticky wages on top of excluding non-technology shocks. This panel confirms the importance of country-specific policy trade-offs for boosting the gains from cooperation, since, when the trade-offs are removed by turning off the sticky wages (and, less importantly, the non-technology shocks), the gains from cooperation appear much diminished. This lower profile applies to the average as well as to the realizations closer to the tails of the distribution of gains.

Finally, the last panel, shows the case of financial autarky. In this case, we stripped away the non-state-contingent bond traded across countries and forced trade flows to balance in every period. Under autarky, the gains from cooperation are much diminished. This case allows us to confirm that the combination of incentives to manipulate the value of net foreign assets and to exploit country specific trade-offs are essential for the large gains that obtain under our benchmark case. Stripping away either channel results in lower gains from cooperation. Notably, Obstfeld and Rogoff (2002) also considered this type of financial market arrangement and similarly found small gains from cooperation under autarky.

6 Conclusion

There are sound practical reasons to think that cooperative equilibria may be fragile. Deviating from cooperation may look attractive as long as partner countries do not retaliate, incentivating the collapse of cooperative agreements. Making this problem worse, the deviations from cooperation may be difficult to detect. Furthermore, countries may agree to cooperate only after events whose repercussions could have been mitigated by cooperative policies have already occurred, in turn, leaving fertile grounds for the collapse of these agreements. However, these practical concerns pale in comparison with the criticism leveled by Obstfeld and Rogoff (2002), who argued that the gains from cooperating on the setting of monetary policy across countries are so insignificant as to render cooperation entirely irrelevant.

We have shown that the financial arrangements that govern risk-sharing and influence trade flows across countries play an important role in determining the conditions under which the gains from cooperation can be sizable, well above the typical gains from economic stabilization. Under complete financial markets, we find relatively larger gains when the goods traded across countries are relatively substitutable, as this subsitititutability boosts the spillover effects of country-specific policy actions or shocks. At the higher range of trade elasticities that we consider, the gains from cooperation are an order of magnitude larger than the gains from eliminating economic fluctuations.

With incomplete financial markets, we find larger gains when the goods traded across countries are relatively complementary, as this complementarity also boosts the spillover effects of country-specific policy actions or shocks. With incomplete markets, the gains from cooperation evolve dynamically and are related importantly to the net foreign asset position. Intuitively, competitive policy spirals can become more vicious when policy intervention can affect the real size of net-foreign-asset positions, an effect excluded under complete markets.

More generally, we have shown that the temptation to exploit country-specific policy trade-offs, coupled with their foreign spillover effects, are essential in boosting strategic incentives and the gains from cooperation. It is perhaps not surprising that Obstfeld and Rogoff (2002) used a model that did not encompass this kind of trade-offs and that precluded the possibility of important foreign spillover effects. After all, their model was well suited to capture the essence of the Great Moderation that seemed to have conquered inflation and output fluctuations, and during which the possibility of important foreign spillover effects seemed remote. By contrast, our model that emphasizes policy trade-offs and financial market arrangements is better suited to capture the policy dilemmas and turbulent international repercussions of the more recent Financial Crisis.

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Table 1: Parameters for the Baseline Two-Country Model

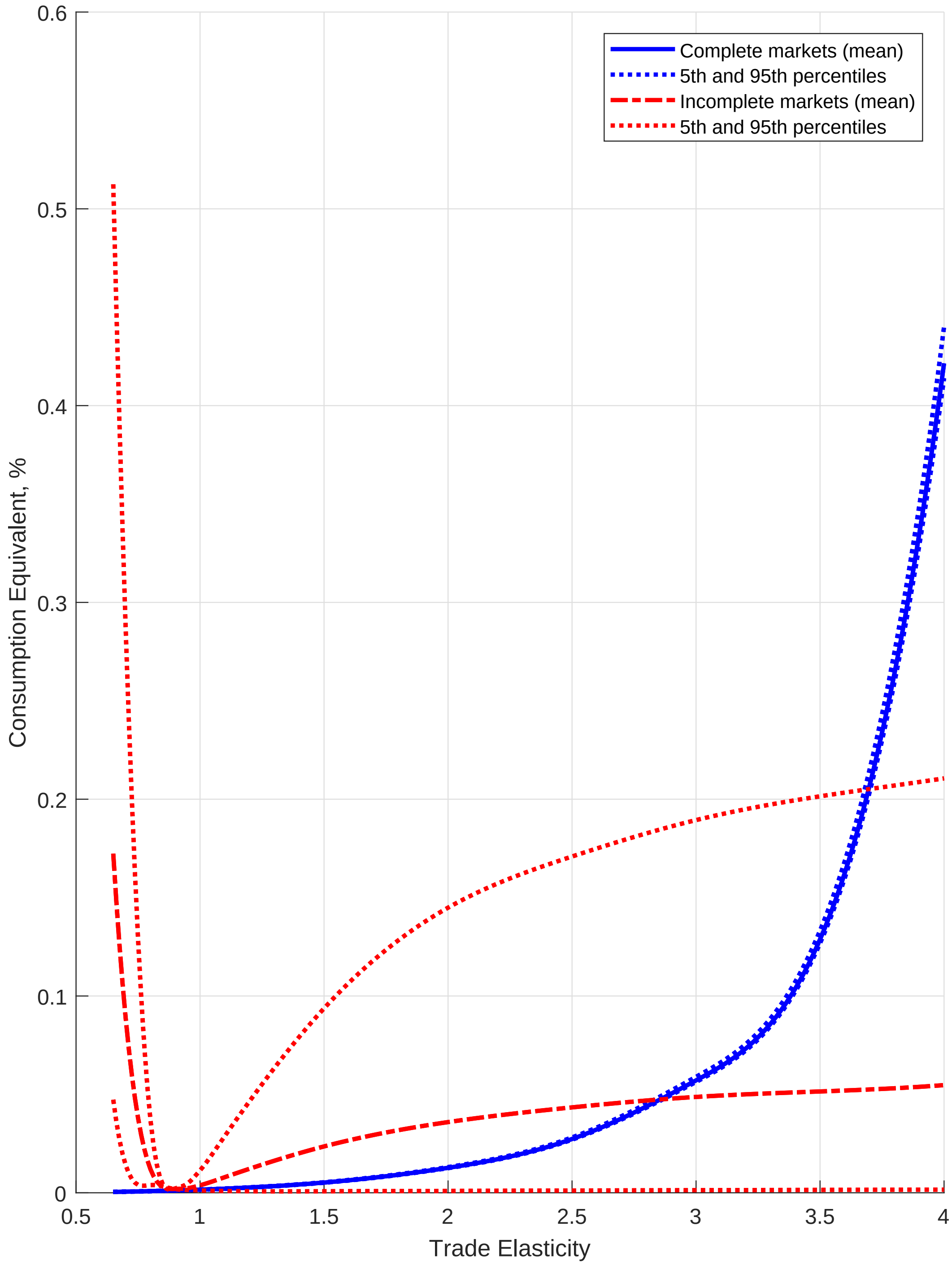
Parameter	**Used to Determine**	**Parameter**	**Used to Determine**
$\beta_1 = 1/1.005$	discount factor	$\sigma_1 = 1$	intertemporal consumption elasticity
$\chi_1 = 10$	labor supply elasticity = $\frac{2}{\chi_1}$	$\bar{L}_1 = 1/3$	steady state labor supply to fix χ_0
$\omega_1^c = 0.88$	home bias in consumption	$\tau_1^p = 0.1$	subsidy to producers
$\xi_1^p = 0.75$	Calvo price parameter	$\theta_p = 0.1$	steady-state price markup
$\xi_1^w = 0.75$	Calvo price parameter	$\theta_w = 0.1$	steady-state wage markup
$\phi_1^b = 10^{-4}$	governs bond intermediation cost	$\zeta_1 = 1$	relative country size
$\rho_1^z = 0.88$	persistence of tech. shock	$\sigma_1^z = 0.012$	std. of tech. shock
$\rho_1^p = 0.96$	persistence of cost push shock	$\sigma_1^p = 0.019$	std. of cost push shock
$\rho^\zeta = 0.73$	persistence of labor supply shock	$\sigma^\zeta = 0.043$	std. of labor supply shock

Note: This table summarizes the parameterization of the baseline two-country model described in Section at quarterly frequency. The parameters for country 2 are identical to those for country 1.

Table 2: Moments: model and data

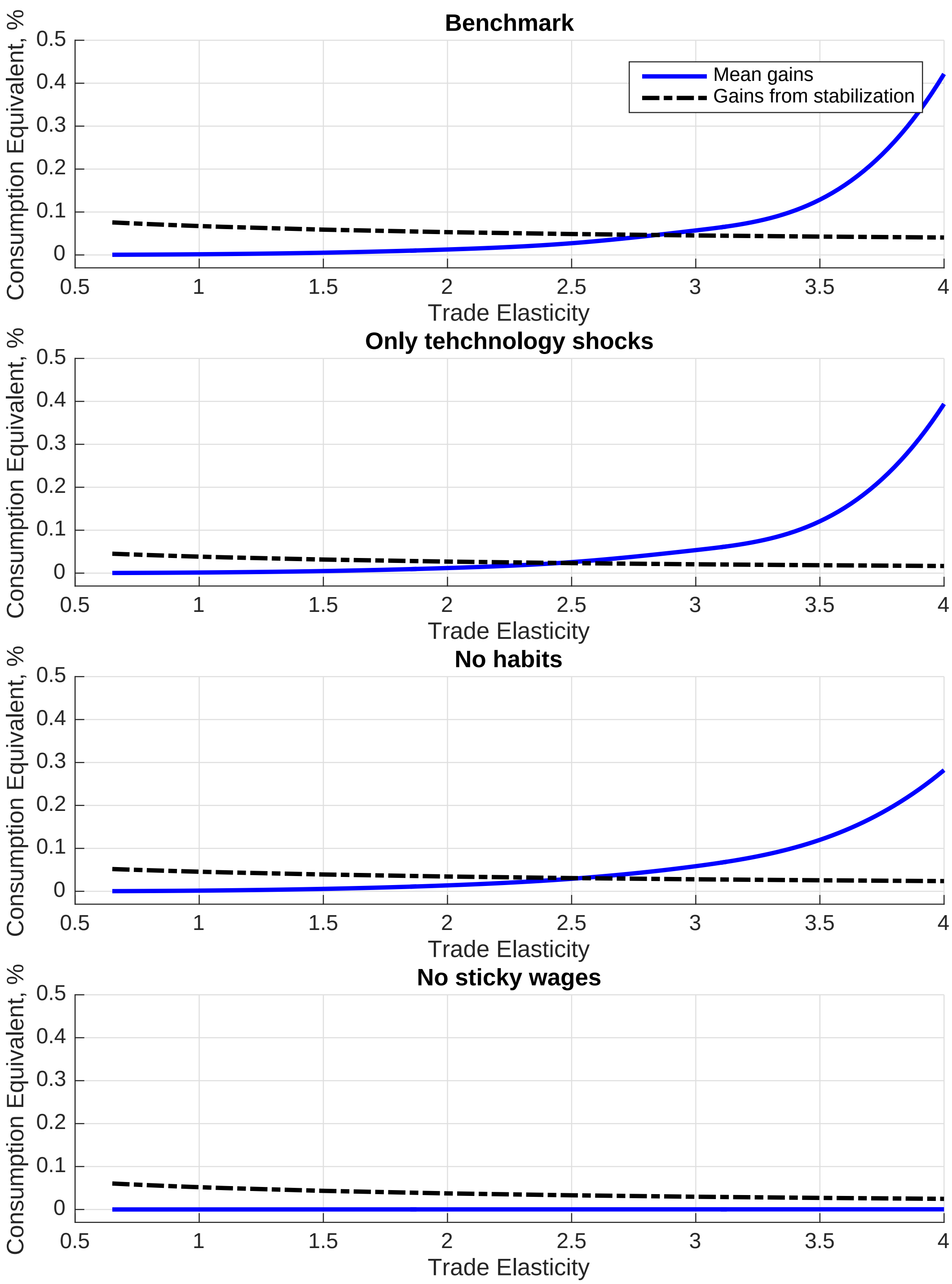
Moment	**Model**	**Model** (ex. labor supply shocks)	**Data**
Variance of hours worked	0.25	0.13	0.20
Variance of policy rate	0.82	0.66	0.84
Variance of inflation	0.22	0.18	0.29
Variance of output	1.39	1.18	1.37
Autocovariance of hours worked	0.83	0.79	0.92
Autocovariance of policy rate	0.82	0.81	0.97
Autocovariance of inflation	0.75	0.73	0.92
Autocovariance of output	0.90	0.89	0.91

Figure 1: Gains from cooperation as a function of the elasticity of substitution between traded goods



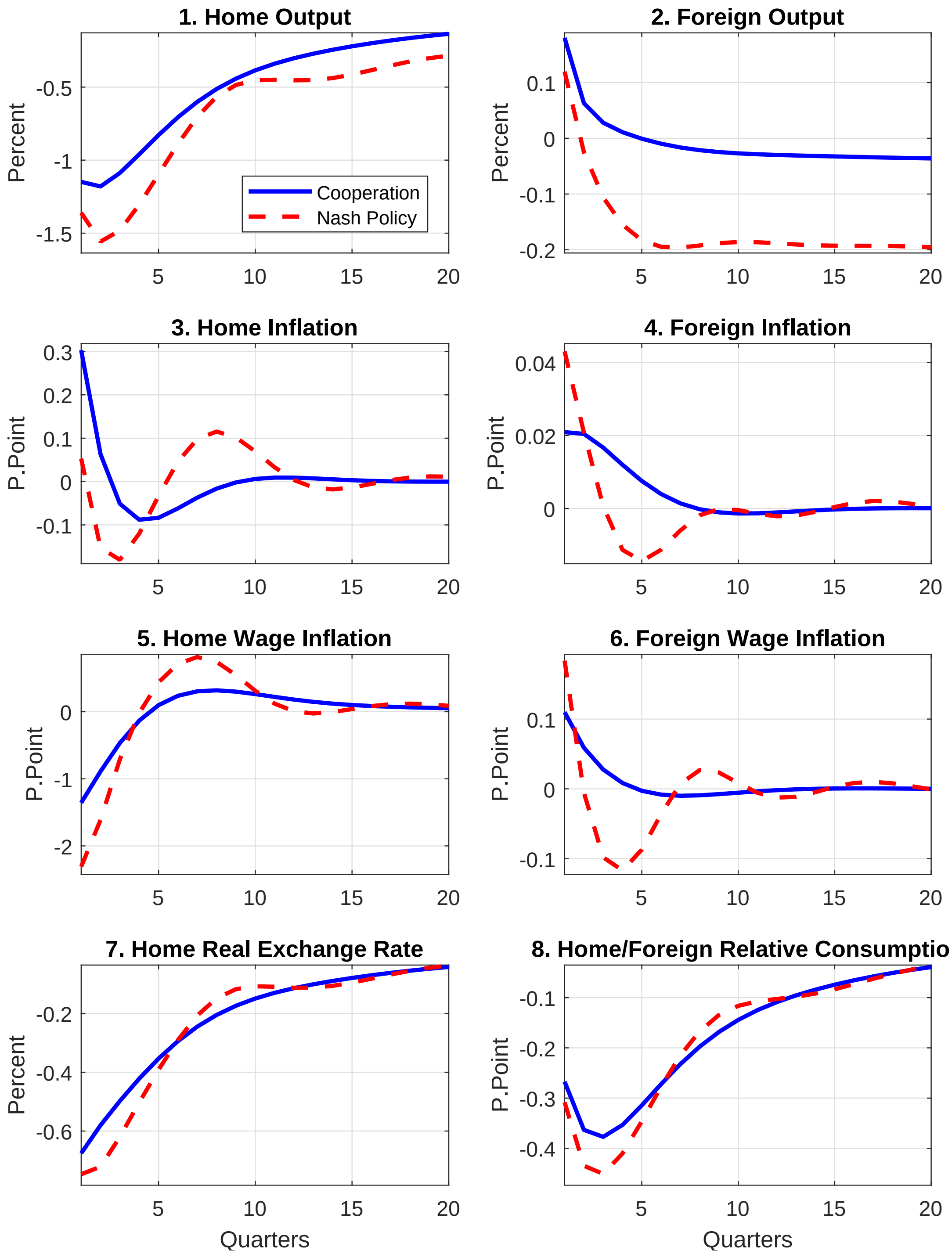
Note: For each value of the elasticity and financial market arrangement, we compute average conditional expected welfare in the cooperative equilibrium and in the Nash equilibrium for 1000 initial conditions randomly drawn from the support of the cooperative model. The welfare difference between the two policy arrangements is then translated into a consumption equivalent variation (CEV) as described in Section 4.1. The figure compares the CEV for the complete and the incomplete markets case under the benchmark calibration.

Figure 2: Gains from cooperation under complete markets: sensitivity



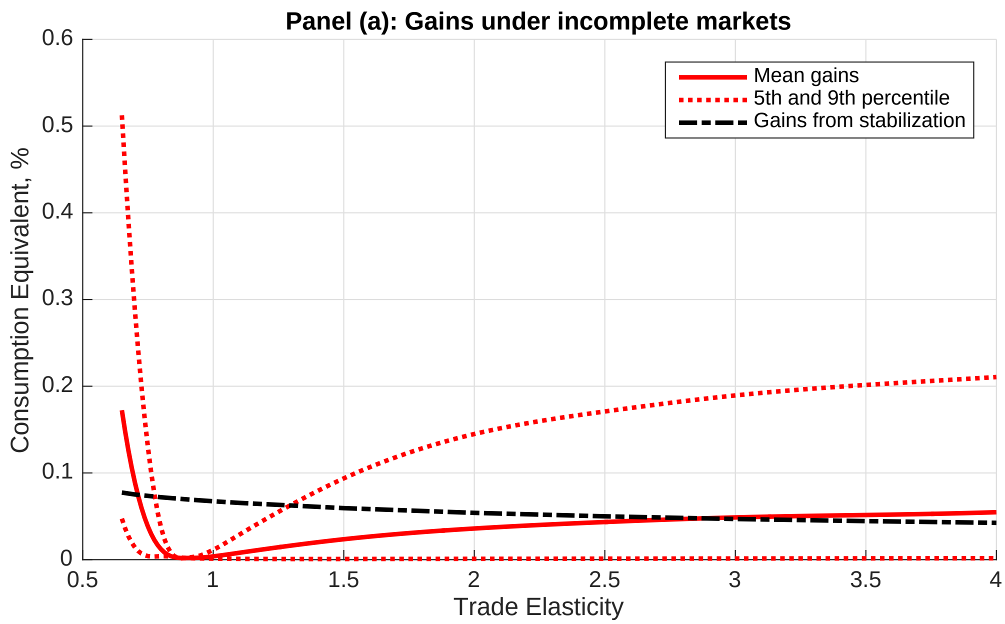
Note: The figure compares the gains from cooperation, expressed as consumption equivalent variation (CEV), for the complete markets case under four different calibrations: (1) the benchmark calibration; (2) a calibration that only includes technology shocks; (3) a calibration that excludes consumption habits; and (4) a calibration that excludes sticky wages. The CEV for the gains from cooperation is defined in Section 4.1. The gains from economic stabilizaton are defined in Section 4.2.

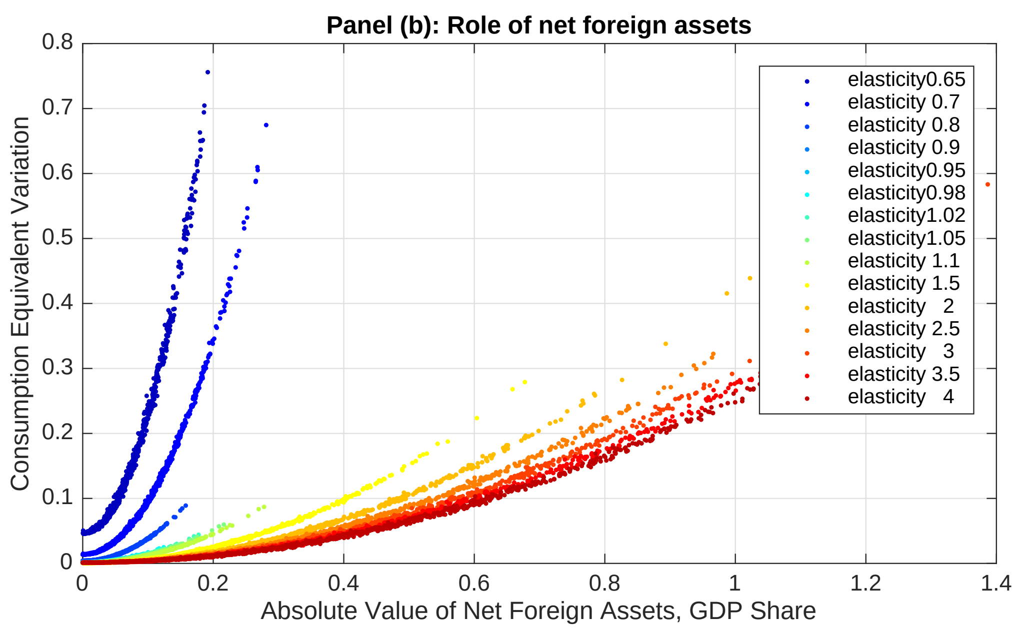
Figure 3: Impulse responses to a technology shock under complete markets



Note: Impulse responses to a technology shock in the home country in the cooperative and the Nash equilibrium when financial markets are complete, and both prices and wages are sticky.

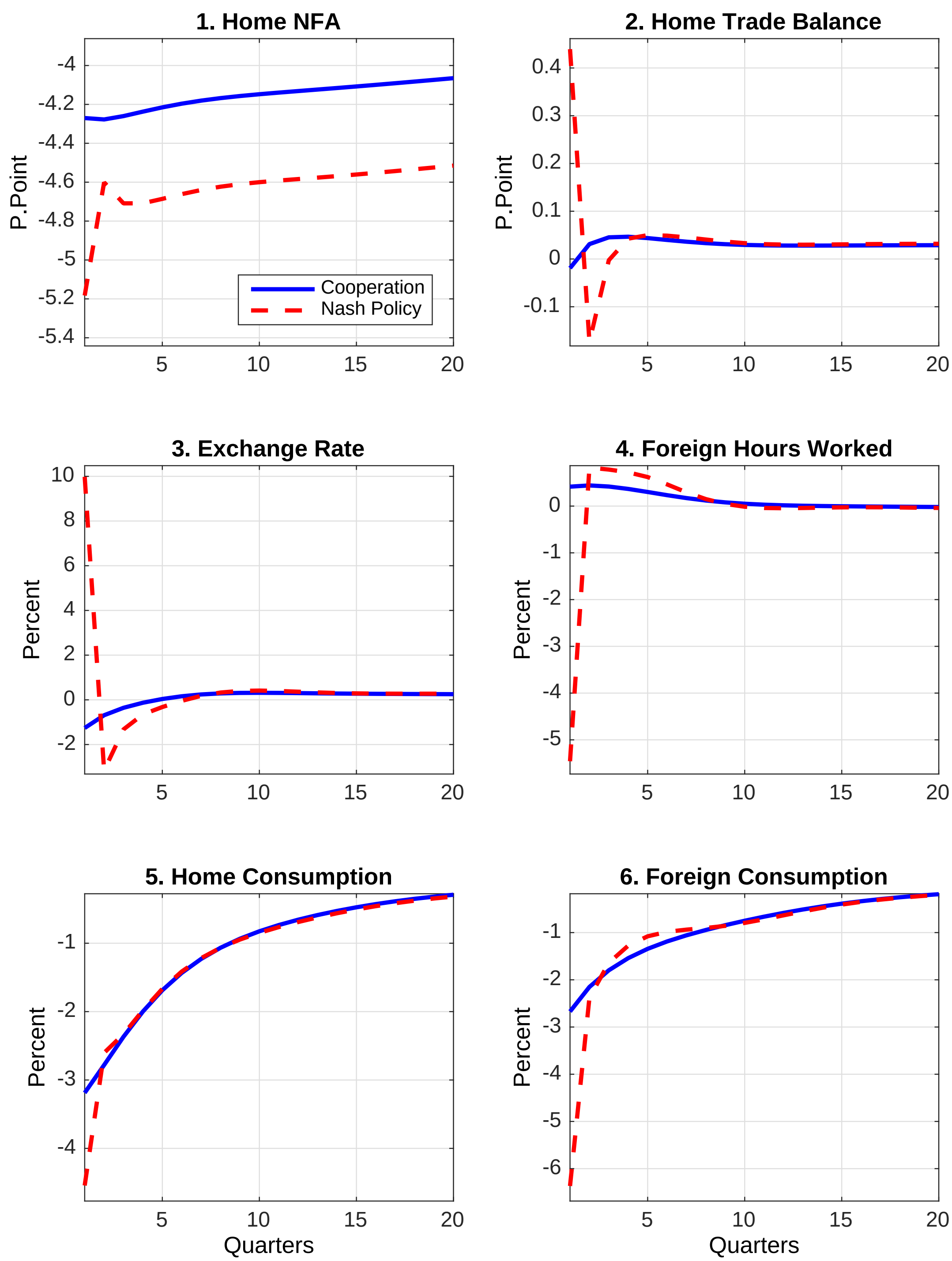
Figure 4: Gains from cooperation under incomplete markets





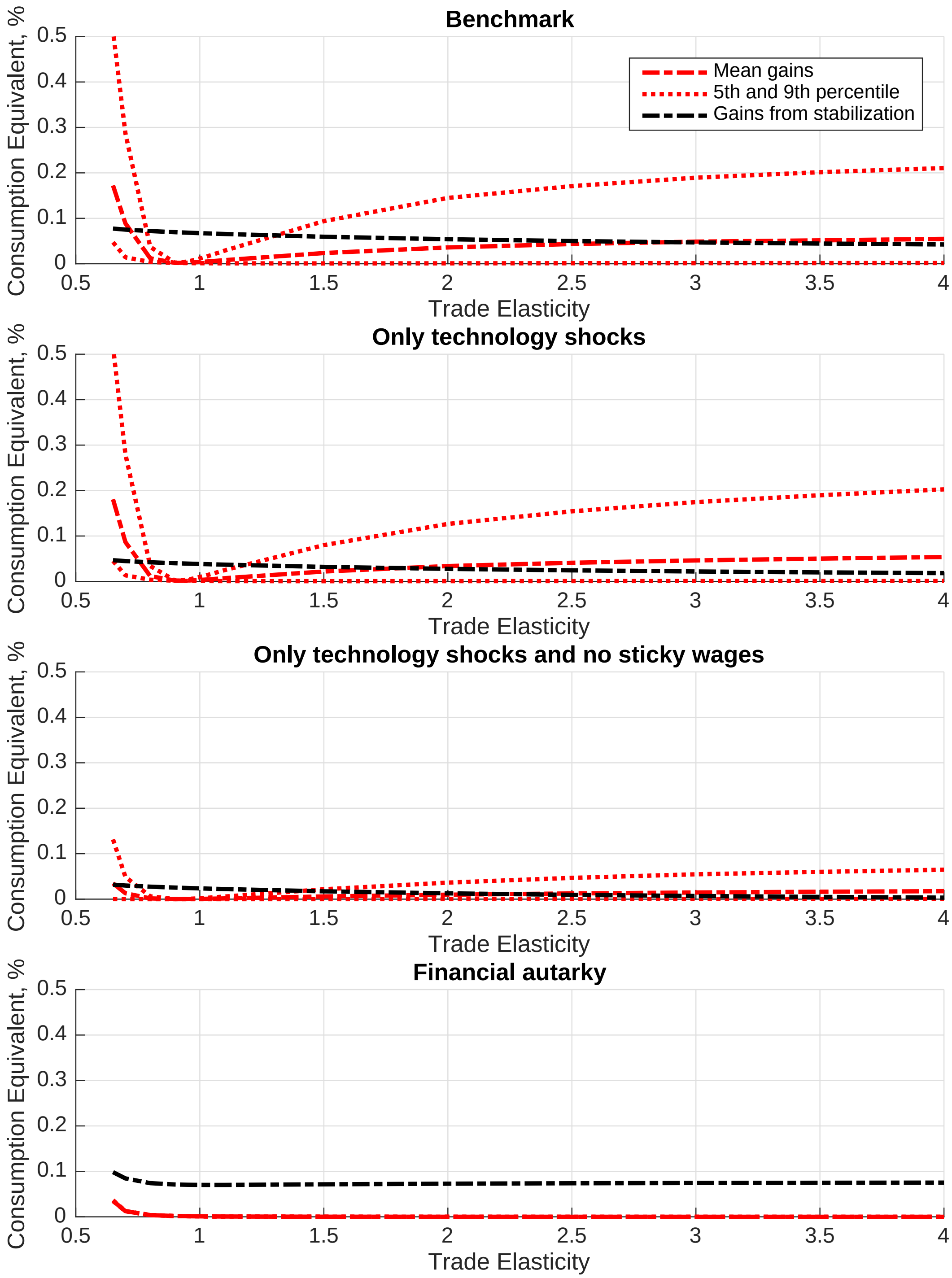
Note: The model features incomplete financial markets, sticky prices and weages, and shocks to price markups, technology, and labor supply. In panel(a), the solid lines depict plots the mean gain from cooperation and the dotted lines indicate the 5th and the 95th percentile. The panel also shows the cost of economic fluctuations. The consumption equivalent variations used to size the gains from cooperation and the cost of fluctuations are defined in Section 4.1. The gains from stabilization are defined in Section 4.2. For given values of the trade elasticity, Panel (b) plots the gain as a function of the initial position of net foreign assets. The support of the initial distribution of net foreign assets is endogenous and varies with the value of the trade elasticity.

Figure 5: From cooperation to competition



Note: Starting from initial conditions drawn from the model's ergodic distribution under cooperation, the figure shows paths (with no further shocks) that converge towards the stochastic fixed point for economies that continue to cooperate under the case labeled "cooperation" and that switch to Nash policies in the other case. The switch occurs in period 1 and is unexpected.

Figure 6: Gains from cooperation under incomplete markets: sensitivity analysis



Note: For ease of comparison, the top panel replicates the top panel of Figure 4. The panel labeled "Only technology shocks" strips away markup and labor supply shocks. The panel labeled "Only technology shocks and no sticky wages" also strips away sticky wages. The panel labeled "Financial autarky" returns to the benchmark calibration, but imposes that trade flows balance in every period. The gains from cooperation are defined in Section 4.2, and the gains from stabilization in Section 4.2.

A Appendix: Sizing the consumption equivalent variation

Consider the utility functions of the two countries, repeated here for convenience:

$$\mathcal{U}_{1,t} = E_t \sum_{j=0}^{\infty} \beta^j \left\{ \frac{1}{1-\sigma} \left(C_{1,t+j} - \kappa C_{1,t+j-1} \right)^{1-\sigma} + \frac{\chi_0 \zeta_{1,t+j}}{1-\chi_1} \left(1 - L_{1,t+j} \right)^{1-\chi_1} \right\},$$

and

$$\mathcal{U}_{2,t} = E_t \sum_{j=0}^{\infty} \beta^j \left\{ \frac{1}{1-\sigma} \left(C_{2,t+j} - \kappa C_{2,t+j-1} \right)^{1-\sigma} + \frac{\chi_0 \zeta_{2,t+j}}{1-\chi_1} \left(1 - L_{2,t+j} \right)^{1-\chi_1} \right\}.$$

Define the conditional welfare to be $Welf_t = \frac{1}{2}\mathcal{U}_{1,t} + \frac{1}{2}\mathcal{U}_{2,t}$. For given consumption and labor paths in the two countries, we are interested in sizing a permanent subsidy (or tax, depending on the sign) τ applied to the consumption utility stream of country 1 that would deliver a level of welfare equal to $\overline{Welf}$. Thus,

$$\begin{aligned} & \omega E_t \sum_{j=0}^{\infty} \beta^j \left\{ \frac{1}{1-\sigma} \left((1+\tau) \left(C_{1,t+j} - \kappa C_{1,t+j-1} \right) \right)^{1-\sigma} + \frac{\chi_0 \zeta_{1,t+j}}{1-\chi_1} \left(1 - L_{1,t+j} \right)^{1-\chi_1} \right\} \\ + & \quad (1-\omega) E_t \sum_{j=0}^{\infty} \beta^j \left\{ \frac{1}{1-\sigma} \left(C_{2,t+j} - \kappa C_{2,t+j-1} \right)^{1-\sigma} + \frac{\chi_0 \zeta_{2,t+j}}{1-\chi_1} \left(1 - L_{2,t+j} \right)^{1-\chi_1} \right\} = \overline{Welf}. \end{aligned}$$

Define $Welf_{1,t}^C = E_t \sum_{t=0}^{\infty} \beta^t \frac{(C_{1,t+j} - \kappa C_{1,t+j-1})}{1-\sigma}$ as the contribution of consumption in country 1 to welfare, and $Welf_{1,t}^L = E_t \sum_{t=0}^{\infty} \beta^t \frac{\chi_0 \zeta_{1,t+j}}{1-\chi_1} \left(1 - L_{1,t+j} \right)^{1-\chi_1}$as the contribution of leisure in country 1 to welfare. With analogous definitions for country 2, these definitions satisfy $Welf = \frac{1}{2}\left(Welf_1^C + Welf_1^L + Welf_2^C + Welf_2^L \right)$. Accordingly

$$\omega \left((1+\tau)^{1-\sigma} Welf_{1,t}^C + Welf_{1,t}^L \right) + (1-\omega) \left(Welf_{2,t}^C + Welf_{2,t}^L \right) = \overline{Welf}.$$

Rearranging,

$$(1+\tau)^{1-\sigma} = \frac{\overline{Welf} - (1-\omega) \left(Welf_{2,t}^C + Welf_{2,t}^L \right) - \omega Welf_{1,t}^L}{\omega Welf_1^C}.$$

Subtracting and adding the term $\omega Welf_{1,t}^C$

$$(1+\tau)^{1-\sigma} = \frac{\overline{Welf} - (1-\omega) \left(Welf_{2,t}^C + Welf_{2,t}^L \right) - \omega Welf_{1,t}^L - \omega Welf_{1,t}^C + \omega Welf_{1,t}^C}{\omega Welf_1^C}.$$

Regrouping,

$$\tau = \left(\frac{\overline{Welf} - Welf_t}{\omega Welf_{1,t}^C} + 1 \right)^{1-\sigma} - 1.$$

By construction, if $\overline{Welf}$ is taken to be the level of welfare obtained under the cooperative equilibrium and $Welf_t$ is the level of welfare corresponding to Nash equilibrium, τ will be positive. In this case, τ yields the consumption equivalent variation that would be needed to obtain, under Nash competition, a level of welfare equal to the level under cooperation.