The International Spillovers of Synchronous Monetary Tightening

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PRELIMINARY AND INCOMPLETE

Abstract

We use historical data and a calibrated model of the world economy to study how a synchronous tightening of monetary policy can amplify cross-border transmission of monetary policy. The empirical analysis shows that historical episodes of synchronous tightening are associated with tighter financial conditions and larger effects on economic activity than asynchronous ones. In the model, a sufficiently large synchronous tightening can disrupt intermediation of credit by global financial intermediaries causing large output losses and an increase in sacrifice ratios, that is, output lost for a given reduction in inflation. We use this framework to study the gains from coordination that would arise if countries set interest rates cooperatively rather than autonomously adjusting rates to stabilize domestic conditions.

KEYWORDS: Monetary Policy; International Spillovers; Inflation; Panel Data Estimation; Open Economy Macroeconomics.

JEL CLASSIFICATION: C33. E32. E44. F42.

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1 Introduction

Central banks across the world are tightening at an unprecedented pace to tame the ongoing global surge in inflation that started in 2021. The synchronous nature of global monetary tightening has caused concerns that interest rate hikes could be mutually compounding, with large cross-border spillovers, and result in an unintendedly deep downturn in global economic activity. Accordingly, some commentators have called on central banks to coordinate in their fight to tame inflation to avoid driving the world economy into an unnecessarily harsh contraction (Obstfeld, 2022).

There are two main reasons why international monetary policy spillovers can be large and international coordination can become critical in calibrating monetary policy. First, global trade integration implies that for many countries a substantial component of inflation is imported from abroad. When foreign central banks tighten, they affect the price of domestic imports and hence the monetary policy tradeoffs in the home country. While this channel is well understood, its quantitative relevance has grown over time as the international trade landscape has become more interconnected. Second, financial integration implies that tightening of financial conditions in one country can spill over to foreign economies by affecting the balance sheet of intermediaries that operate globally. This financial channel can have important nonlinear features. For small increases in global interest rates, balance sheets can remain relatively healthy and financial amplification of monetary policy shocks can be muted. When global financial conditions tighten enough to impair international financial intermediation, the same monetary shocks could be amplified by endogenous increases in credit spreads for domestic borrowers.

In this paper, we use historical data and a calibrated model of the world economy to study how the synchronous nature of monetary policy tightening can amplify cross-border transmission of monetary policy. In the model presented here, the amplification works through disruptions in the intermediation of credit by global financial intermediaries. Financial spillovers are the most natural channel to explore in studying potential nonlinearities in the response of the economy to global tightening shocks.

Following a large body of literature (see, for example Morelli et al. (2022)) we assume that global financial intermediaries' ability to intermediate assets depends on the level of their net worth, due to an agency problem similar to the one proposed by Gertler and Kiyotaki (2010). When net worth is high, global intermediaries absorb losses by raising more debt, guaranteeing a smooth functioning of international credit markets. When net worth is low, for instance due to a decline in asset prices caused by higher interest rates, financial intermediaries are limited in their ability to issue new debt and sell assets to prevent their leverage from increasing sizably. Assets are absorbed by less specialized buyers at a discount and, as a result, credit spreads rise rapidly.

The nonlinear amplification of global tightening shocks arises from the interaction between this "financial accelerator" mechanism and the global exposure of financial intermediaries. Given the geographic diversification of their portfolios, if only foreign central banks hike, global financial intermediaries suffer losses only on a portion of their assets. As a result, equity losses are contained and intermediaries' ability to issue debt is not impaired. In this case, debt issuance makes up for net worth losses and credit intermediation remains efficient. If many central banks hike synchronously, capital losses occur on many assets at the same time and cause intermediaries' equity to decline more. If the synchronous tightening is large enough, the financial accelerator channel is activated, and credit spreads rise rapidly across countries causing large spillovers.

The empirical analysis offers suggestive evidence that historical episodes of synchronous tightening are associated with tighter financial conditions and larger and more persistent effects on economic activity than asynchronous tightening. The simulations from the model show that if central banks simultaneously adopt a stance that is substantially tighter than what standard policy rules would imply, the global economy can move past a tipping point beyond which monetary spillovers are greatly amplified through financial channels. Additionally, this amplification effect is stronger on output than on inflation thus increasing sacrifice ratios, that is, output losses to achieve a given reduction in inflation. Thus, our analysis highlights that should central banks underestimate spillovers when tightening significantly and synchronously, they risk giving too much weight to inflation and too little weight to economic activity.

We use this framework to show that gains from monetary policy coordination can arise if countries set interest rates cooperatively to minimize a global loss function rather than autonomously adjusting rates to stabilize domestic conditions.

1.1 Related Literature

The mechanism in our model builds on an extensive literature that studies financial amplification of monetary policy shocks through their effects on borrowers' equity positions, starting from the seminal contribution by Bernanke et al. (1999). While the mechanism was originally applied to non-financial borrowers, Gertler and Karadi (2011) and Gertler et al. (2020) apply it to describe the transmission of various types of monetary and non-monetary shocks through financial intermediaries. Recent work has applied this mechanism to open-economy models, as for instance Ahmed et al. (2021) and Ferrante and Gornemann (2022).

The an empirical analysis contributes to the literature documenting the financial transmission of monetary policy shocks. Gertler and Karadi (2015) and Caldara and Herbst (2019) document that a monetary policy tightening raises spreads on corporate credit. Miranda-Agrippino and Rey (2020) show that US monetary policy shocks induce comovements in the international financial variables that characterize the global financial cycle. Iacoviello and Navarro (2019) find that international spillovers of higher U.S. interest rates are stonger for countries that are more financially vulnerable.

2 Empirical Analysis

2.1 Shares of CBs tightening

Over the past half century, central banks have tightened their stance of monetary policy synchronously on several occasions.

[TBA]

2.2 Simultaneous tightening events and event study analysis

Our first goal is to study the aftermath of policy tightening events across synchronous and asynchronous tightening episodes. To this end, we use quarterly data on GDP, unemployment, core inflation, policy interest rates, and (when available) corporate spreads for the 21 advanced economies starting in 1980Q1 and ending in 2019Q4.[1]

The key task is to identify the timing of policy tightening episodes for each country, and then to separate these episodes into synchronous and asynchronous.

First, we define a country's policy tightening event as happening in the quarter t^* when: (a) interest rates are higher by more than 5 basis points than in the previous quarter; (b) interest rates are higher by more than 5 basis points than four quarters before; (c) four quarters after t^* interest rates are lower than in t^*. If this criterion is satisfied in contiguous quarters, we select the first quarter in which the condition is met.

Formally, the set $H(i)$ contains all quarters satisfying criteria (a),(b), and (c) in country i:

$$H(i) = \left\{ s \;\middle|\; \begin{array}{cc} r_s^i > r_{s-1}^i + .05 & (a) \\ r_s^i > r_{s-4}^i + .05 & (b) \\ r_s^i > r_{s+4}^i & (c) \end{array} \right\}$$

[1] The economies in the sample are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, United Kingdom and the United States. When policy interest rates are not available, we use 3-month Treasury Bill rates or an equivalent measure. GDP is expressed in each country in percent deviation from a log quadratic trend.

where r_s^i is the policy rate in coutnry i in quarter s. The set $T^*(i)$ isolates the first quarter satisfying (a),(b), and (c) among contiguous quarters:

$$T^*(i) = \left\{ \; s \in H(i) \quad | \quad if \; \exists t \in H(i) \; s.t. \; |t-s| = 1 \; then \;\; s < t \qquad \right\}$$

Our definition of the set T^* aims to isolate tightening cycles as individual episodes, rather than considering each hike in the cycle as a separate tightening. Also, by virtue of criterion (c), within each tightening cycle we select the quarter at or close to the end of the tightening cycle.

Using this criterion, we find a total of 127 tightening episodes, an average of about 6 per country over the sample. For instance, this criterion identifies six tightening episodes for the United States in the quarters 1984q1, 1989q1, 1995q1, 2000q1 2006q3, and 2018q4.

To split the tightening episodes into synchronous and asynchronous, we compute a global interest rate as the weighted average (using current dollar GDP weights) of each country's interest rate. That is

$$r_s^w = \sum_i w_{is} r_s^i$$

where the weights:

$$w_{is} = \frac{gdp_s^i}{\sum_j gdp_s^j}.$$

We define a global tightening event as happening in the quarter t^* when the global interest rate satisfies the same criterion for a country's tightening event described above, i.e. $t^* \in T^*(w)$. Using this criterion, we find 8 episodes of global tightening, occurring in 1980q4, 1984q1, 1989q4, 1994q4, 2000q2, 2007q1, 2011q2, 2018q4.

For each country, we then define synchronous tightening episodes as those happening within a two-year window since a global tightening (78 episodes out of 127), and asynchronous tightening episodes as those not happening within an eight-quarter window since a global tightening (49 episodes out of 127).[2] That is the set of global tightening episode in country i is given by:

$$S^*(i) = T^*(i) \cap W^*(w)$$

where $W^*(w)$ collects all quarters within the 8 quarters window from a global tightening:

$$W^*(w) = \{t \mid 0 \leq t \; - t^* \leq 8 \; \exists t^* \in T^*(w)\}.$$

[2] Using this definition, the US tightening episodes occurring in, say, 1984q1, 1995q1 and 2018q4 are considered synchronous, whereas the tightening episodes occurring in 1989q1 2000q1, and 2006q3 are asynchronous.

The set of asynchronous tightening is just the complement in $T^*(i)$:

$$A^*(i) = T^*(i) \setminus S^*(i).$$

To assess how macroeconomic variables behave in the aftermath of tightening episodes, we estimate the following event-study regression:

$$y_{it} = \gamma_i + \sum\nolimits_{\tau=-4}^{10} \sigma_\tau DS_{it-\tau} + \sum\nolimits_{\tau=-4}^{10} \alpha_\tau DA_{it-\tau} + \varepsilon_{it}, \tag{1}$$

where DS_{is} is an indicator function equal to 1 in the event of a synchronous tightening event in country i at time s, and DA_{is} is an indicator function equal to 1 in the event of an asynchronous tightening event in country i at time s:

$$DS_{is} = I_{\{s \in S^*(i)\}} \quad ; \quad DA_{is} = I_{\{s \in A^*(i)\}}$$

We normalize $\sigma_0 = \alpha_0 = 0$ and plot the sequence of regression coefficients σ_τ and α_τ in Figure 1 for interest rates, inflation, GDP, the unemployment rate, corporate credit spreads, and global interest rates. Asynchronous tightening episodes result in limited increases in unemployment and corporate spreads, and smaller declines in GDP relative to their jump-off points. By contrast, synchronous tightening episodes are associated with larger economic costs, with unemployment rising 1.5 percentage points after two years, and GDP declining by nearly 3 percent, in spite of a similar behavior of inflation. In addition, synchronous tightening episodes are associated with a greater deterioration in financial conditions, with corporate spreads rising by about 100 basis points relative to their jump-off point.

If we adopt a definition of synchronicity that relies on a narrower window, there are fewer synchronous episodes, but the results shown in Figure 1 are qualitatively similar.

This empirical analysis provides suggestive evidence that synchronous episodes might have disproportionately larger economic effects compared to asynchronous episodes, and that global monetary policy spillovers could be associated with a sizeable deterioration in financial conditions. These findings are in line with the financial spillover mechanisms in our model, to which we turn next.

2.3 Monetary Shocks

[TBA]

3 A Model of International Financial Spillovers

To quantify the nonlinear financial amplification channel of global tightening shocks, we use a New-Keynesian two-country DSGE model that includes a "U.S." (h) block and a "foreign" (f) block. The model's key feature is the presence of global financial intermediaries specialized in holding assets from multiple countries. Our definition of financial intermediaries is broad and includes banks and nonbanks, mostly with U.S. nationality. These institutions issue dollar-denominated liabilities to U.S. and foreign residents and use liabilities, together with their net worth, to fund assets both in the U.S. and abroad. Figure 2 provides a graphical representation of global financial intermediaries in our model.

Below we describe the details of our modelling framework.

3.1 Households

Households in country $i = h, f$ maximize

$$\max E_t \sum_{s \geq t} \beta^s \left[\frac{\left(C_{it} - hC_{it-1}\right)^{1-\rho}}{1-\rho} - \psi_i \frac{L_{i,t}^{1+\varphi}}{1+\varphi} - \frac{\chi_i^K}{2} \left(\frac{K_{i,s}^h}{K_{i,s}} - \gamma_i \right)^2 - \frac{\chi_i^D}{2} \left(D_{it} - D_i^{ss}\right)^2 \right]$$

Households are less efficient than banks at intermediating capital, and they pay quadratic non-pecuniary costs when the share of domestic capital held by households in country i, $\frac{K_{i,s}^h}{K_{i,s}}$ is larger than a steady state ratio γ. In addition, we allow for the possibility that households also face adjustment costs for holding deposits issued by the global bank, D_{it}.

Households' budget constraint in real terms is given by

$$C_{i,t} + X_{hit} D_{i,t} + Q_{i,t} K_{i,t}^h = w_{it} L_{i,t} - T_{i,t} + \Pi_{i,t} + X_{hit} D_{i,t-1} R_t^d + \left(z_{i,t} + (1-\delta) Q_{it}\right) K_{i,t-1}^h \quad (2)$$

where X_{ijt} represents the real exchange rate of goods from country i to country j (so that $X_{ii} = X_{jj} = 1$), w_{it} represents the real wage, z_{it} is the real rental rate and Q_{it} is the price of capital.

Optimality conditions are given by

$$\psi_i L_{i,t}^{\varphi} = U_{cit} w_{it} \quad (3)$$

$$1 = \beta E_t \Lambda_{it+1} \frac{X_{hit+1}}{X_{hit} + \chi_j^D \left(D_{it} - D_i^{ss}\right)} R_{t+1}^d \quad (4)$$

$$1=\beta E_t\Lambda_{it+1}\frac{\left(z_{it+1}+(1-\delta)\,Q^k_{it+1}\right)}{Q^k_{i,t}+\chi^K_i\left(\frac{K^h_{i,s}}{K_{i,s}}-\gamma_i\right)C^\rho_{it}} \tag{5}$$

where $U_{cit}=(C_{it}-hC_{it-1})^\rho+\beta hE_t\left(C_{it+1}-hC_{it}\right)^\rho$ and $\Lambda_{i,t+1}=\frac{U_{cit+1}}{U_{cit}}$.

In addition, the deposit rate satisfies

$$R^d_t=R_{ht-1} \tag{6}$$

where R_{ht} is the real rate in country h.

3.2 Final Goods Production

Final goods in country i are a CES bundle of domestically produced goods Y_{iit}, with nominal price P_{iit}, and imported goods Y_{ijt}, with nominal price P_{ijt},

$$Y_{it}=\left[\omega_i^{\frac{1}{\theta}}Y_{iit}^{\frac{\theta-1}{\theta}}+(1-\omega_i)^{\frac{1}{\theta}}\,Y_{jit}^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta-1}{\theta}} \tag{7}$$

where ω_i represents the home bias parameter, and θ is the trade elasticity.

If we define P_{it} as the price of the final good bundle, we can write the cost minimization problem as

$$\max_{Y_{iit},Y_{ijt}} P_{it}Y_{it}-P_{iit}Y_{iit}-P_{ijt}Y_{ijt} \tag{8}$$

which implies.

$$Y_{iit}=p_{iit}^{-\theta}\omega_iY_{it} \tag{9}$$

$$Y_{jit}=p_{jit}^{-\theta}\left(1-\omega_i\right)Y_{it} \tag{10}$$

where $p_{iit}=P_{iit}/P_{it}$ and $p_{jit}=P_{jit}/P_{it}$ are real prices.

In addition, give that

$$Y_{iit}=C_{iit}+I_{iit} \tag{11}$$

$$Y_{jit}=C_{jit}+I_{jit} \tag{12}$$

we can also write domestic absorption as

$$Y_{it}=C_{it}+I_{it} \tag{13}$$

where C_{it} and I_{it} represent aggregate consumption and investment.

3.3 Intermediate Goods Production

Intermediate goods firms produce output using labor and capital according to a Cobb-Douglas production function

$$\bar{Y}_{it} = L_{it}^{1-\alpha} K_{it-1}^{\alpha} \tag{14}$$

They sell to retailers at a real price mc_{it} and their optimization problem is

$$\max_{L_{it}, K_{it}} mc_{it} \bar{Y}_{it} - w_{it} L_{it} + z_{it} K_{it} \tag{15}$$

The first order conditions are given by

$$w_{it} = mc_{it} \left(1 - \alpha\right) \left(\frac{K_{it}}{L_{it}}\right)^{\alpha} \tag{16}$$

$$z_{it} = mc_{it} \alpha \left(\frac{L_{it}}{K_{it}}\right)^{1-\alpha} \tag{17}$$

which imply

$$mc_{it} = \left(\frac{w_{it}}{1-\alpha}\right)^{1-\alpha} \left(\frac{z_{it}}{\alpha}\right)^{\alpha} \tag{18}$$

3.4 Retailers

Retailers in country i purchase intermediate goods, bundle them and sell final goods, domestically and internationally, at prices P_{iit} and P_{ijt}. We consider two possible price-setting frameworks for domestically consumed and exported goods.

3.4.1 Producer Currency Pricing (PCP)

Under PCP, retailers only set one price P_{iit} for the domestically-produced good, while the price of exports adjusts according to

$$e_{jit} P_{ijt} = P_{iit} \tag{19}$$

where e_{jit} is the nominal exhange rate from country j to country i.

The final good produced by retailers is a CES aggregate given by

$$\bar{Y}_{it} = \left[\int \left(\bar{Y}_{it}\left(s\right)\right)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{20}$$

which implies

$$\bar{Y}_{it}\left(\frac{P_{iit}(s)}{P_{iit}}\right)^{-\varepsilon}=\bar{Y}_{it}(s) \tag{21}$$

Retailers face Rotemberg costs on adjusting the nominal price of their good proportional to their output, and their objective is given by

$$\max\sum\beta^t\Lambda_{t,t+i}\Pi^f_{it+i}=\sum\beta^t\Lambda_{t,t+i}\left[P_{iit}(s)-MC_{it}\right]\frac{\bar{Y}_{it}(s)}{P_{it}}-\frac{\kappa}{2}\left(\frac{P_{iit}(s)}{P_{iit-1}(s)}-1\right)^2\bar{Y}_{it}(s) \tag{22}$$

$$s.t.$$

$$\bar{Y}_{it}\left(\frac{P_{iit}(s)}{P_{iit}}\right)^{-\varepsilon}=\bar{Y}_{it}(s) \tag{23}$$

The first order conditions of this problem imply a standard Phillips curve fore domestic price inflation

$$\kappa\left(\pi_{iit}-1\right)\pi_{iit}=\left[mc_t\varepsilon-(\varepsilon-1)\,p_{iit}\right]+\kappa\beta E_t\Lambda_{t,t+1}\left(\pi_{iit+1}-1\right)\pi_{iit+1}\frac{\bar{Y}_{it+1}}{\bar{Y}_{it}} \tag{24}$$

where

$$\pi_{iit}=\frac{P_{iit}}{P_{iit-1}}=\frac{p_{iit}}{p_{iit-1}}\frac{P_{it}}{P_{it-1}}=\frac{p_{iit}}{p_{iit-1}}\pi_{it} \tag{25}$$

In addition, the pricing of exports can be rewritten as

$$X_{jit}p_{ijt}=p_{iit} \tag{26}$$

3.4.2 Local Currency Pricing (LCP)

Under LCP retailers set two different prices: one for domestic goods, $P_{iit}(s)$, and one for exports, $P_{ijt}(s)$. Export prices are set and are rigid in the destination currency. This feature implies that the pass-through of exchange rate changes into import prices is very low for all exporters in the U.S. and abroad.

The final demand for domestic and exported goods is given by

$$Y_{iit}=\left[\int\left(Y_{iit}(s)\right)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{27}$$

$$Y_{ijt}=\left[\int\left(Y_{ijt}(s)\right)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{28}$$

The price setting problem for domestic goods is given by

$$\max \sum \beta^t \Lambda_{t,t+i} \Pi^f_{it+i} = \sum \beta^t \Lambda_{t,t+i} \left[P_{iit}(s) - MC_{it}\right] \frac{Y_{iit}(s)}{P_{it}} - \frac{\kappa}{2}\left(\frac{P_{iit}(s)}{P_{iit-1}(s)} - 1\right)^2 Y_{iit}(s)$$

$$s.t.$$

$$Y_{iit}\left(\frac{P_{iit}(s)}{P_{iit}}\right)^{-\varepsilon} = Y_{iit}(s)$$

which implies a Phillips curve for domestic inflation given by

$$\kappa(\pi_{iit} - 1)\pi_{iit} = \left[mc_t\varepsilon - (\varepsilon - 1)p_{iit}\right] + \kappa\beta E_t \Lambda_{t,t+1}(\pi_{iit+1} - 1)\pi_{iit+1}\frac{Y_{iit+1}}{Y_{iit}} \tag{29}$$

The pricing of exports is chosen to maximize

$$\max \sum \beta^t \Lambda_{t,t+i} \Pi^f_{it+i} = \sum \beta^t \Lambda_{t,t+i} \left[e_{jit}P_{ijt}(s) - MC_{it}\right] \frac{Y_{ijt}(s)}{P_{it}} - \frac{\kappa}{2}\left(\frac{P_{ijt}(s)}{P_{ijt-1}(s)} - 1\right)^2 Y_{ijt}(s)$$

$$s.t.$$

$$Y_{ijt}\left(\frac{P_{ijt}(s)}{P_{ijt}}\right)^{-\varepsilon} = Y_{ijt}(s)$$

which implies

$$\kappa(\pi_{ijt} - 1)\pi_{ijt} = \left[mc_{it}\varepsilon - (\varepsilon - 1)X_{jit}p_{ijt}\right] + \kappa\beta E_t \Lambda_{t,t+1}(\pi_{ijt+1} - 1)\pi_{ijt+1}\frac{Y_{ijt+1}}{Y_{ijt}} \tag{30}$$

where

$$\pi_{ijt} = \frac{P_{ijt}}{P_{ijt-1}} = \frac{p_{ijt}}{p_{ijt-1}}\pi_{jt} \tag{31}$$

3.5 Capital goods production

Capital producers create new capital, which is sold at price Q^k_{it}, using the final good as input and face convex adjustment costs $S(\frac{I_t}{I_{t-1}}) = \frac{\gamma_k}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$ proportional to total investment.

Their optimization problem is

$$\max E_t \Lambda_{t+1}\left[Q^k_{it} I_{it} - I_{it} - \frac{\gamma_k}{2}(\frac{I_t}{I_{t-1}} - 1)^2 I_t\right]$$

which implies the following first order condition

$$Q_{it}^k = 1 + \frac{\gamma_k}{2}(\frac{I_{it}}{I_{it-1}} - 1)^2 + \gamma_k \frac{I_{it}}{I_{it-1}}(\frac{I_{it}}{I_{it-1}} - 1) - \beta \Lambda_{it+1} \gamma_k \left(\frac{I_{it+1}}{I_{it}}\right)^2 (\frac{I_{it+1}}{I_{it}} - 1) \tag{32}$$

3.6 Global Banks Problem

An important element of our model is the presence of financial institutions that specialize in intermediating assets globally. We have in mind a broad definition of financial intermediaries, including "nonbank" financial institutions. These intermediaries hold imperfectly liquid assets financed partly by short-term debt. Intermediaries are highly levered, in a way that magnifies the effects on the health of their balance sheets of a given movement in asset values.

There is a continuum of global banks , owned by agents in country h, which use their net worth (n_t) and dollar deposits (d_t) to finance investement in domestic and foreign capital, s_{ht} and s_{ft}, and possibly in foreign bonds b_{ft}^b, in line with figure 2. With a probability $1-\sigma$ global banks exit and pay dividends to the household of country h. Exiting bankers are replaced by an equal mass of new bankers. When raising funds, global banks face an agency problem as in Gertler and Karadi (2011), which we explain in detail below.

The balance sheet of an individual bank is given by

$$s_{ht} + X_{fht} s_{ft} \leq n_t + d_t \tag{33}$$

where the evolution of net worth follows

$$n_{t+1} = \left\{ R_{ht}^s s_{ht-1} + R_{ft}^s X_{fht} s_{ft-1} - d_{t-1} R_{it}^d \right\} \tag{34}$$

where R_{ht}^s represents the return on domestic assets, R_{ft}^s represents the return on foreign assets, and R_{ft}^b represents the return on foreign bonds.

The problem of a global bank is given by

$$V_t^b = \max \beta E_t \Lambda_{ht+1} \left\{ (1-\sigma) \, n_{t+1} + \sigma V_{t+1}^b \right\}$$

subject to (33), (34) and to the incentive constraint

$$V_t^b \geq \theta_h^s s_{ht} + \theta_f^s X_{fht} s_{ft} \tag{35}$$

As in Gertler and Karadi (2011), equation (35) represents an incentive constraint due to an agency problem in which the bank can abscond a fraction of its assets from its depositors. When the constraint binds, it will limit the ability of global banks to inetermediate risky assets, generating a wedge between the expected return on banks assets and liabilities.

It can be shown that the banker's value function is linear in net worth according to $V_t^b = \psi_t n_t$, where ψ_t only depends on aggregate quantities and satisfies

$$\psi_t = \beta E_t \Lambda_{ht+1} \Omega_{t+1} \left[\phi_{ht}^s \left(R_{ht+1}^s - R_{it+1}^d \right) + \phi_{ft}^s \left(R_{ft+1}^s \frac{X_{fht+1}}{X_{fht}} - R_{it+1}^d \right) + R_{it+1}^d \right] \tag{36}$$

where $\Omega_{t+1} = (1 - \sigma + \sigma \psi_{t+1})$ and $\phi_{ht}^s = \frac{s_{ht}}{n_t}, \phi_{ft}^s = \frac{s_{ft}}{n_t}$.

In addition, we can rewrite the incantive constraint as

$$\psi_t \geq \left(\theta_h^s \phi_{ht}^s + \theta_f^s \phi_{ft}^s \right) = \tilde{\phi}_t \tag{37}$$

where $\tilde{\phi}_t$ represents an adjusted leverage. This constraint indirectly sets a limit on banks' total leverage

$$\phi_t = \left(s_{ht} + X_{fht} s_{ft} \right) / n_t \tag{38}$$

If we define μ_t as the multiplier on the incentive constraint, we can write the optimality conditions as

$$E_t \Lambda_{ht+1} \Omega_{t+1} \left(R_{ht+1}^s - R_{it+1}^d \right) = \theta_h^s \mu_t \tag{39}$$

$$E_t \Lambda_{ht+1} \Omega_{t+1} \left(R_{ft+1}^s \frac{X_{fht+1}}{X_{fht}} - R_{it+1}^d \right) = \theta_f^s \mu_t \tag{40}$$

together with the complementary slackness condition

$$\mu_t \left[\tilde{\phi}_t - \psi_t \right] = 0 \tag{41}$$

As a result, when the constraint is not binding ($\mu_t = 0$) the expected returns on bank assets are equal to the deposit rate. When banks net worth is low, and $\tilde{\phi}_t$ is larger than ψ_t, the constraint binds and banks are forced to deleverage. The assets sold by intermediaries can be acquired by other entities (which we broadly call "non-specialists") but these other agents are less efficient than global financial institutions at intermediating assets, which implies that they will only purchase assets at a discount. Lower asset prices then feed into lower net worth, further tightening intermediaries' constraints. In this way nonlinear "financial accelerator" dynamics arise, and spreads on assets returns arise endogenously, as μ_t becomes positive. As shown by the banks first order contitions, such spreads are proportional to the parameters θ_h^s, θ_f^s and θ_f^b which govern the severity of the agency problem for each asset class.

Finally, using the linearity of the policy functions, we can aggregate the balance sheets of the global banks and rewrite

$$S_{ht} + X_{fht} S_{ft} \leq N_t + D_t \tag{42}$$

while the evolution of aggregate net worth N_t follows

$$N_t = \sigma_b \left\{ R_{ht}^s S_{ht-1} + R_{ft}^d X_{fht} S_{ft-1} - D_{t-1} R_{it}^d \right\} + \xi S_{ht-1} \tag{43}$$

where ξS_{ht-1} represents an endowment that households provide to entering bankers.

3.7 Non-financial Firms

Non-financial firms in country i are one period lived entities which finance their capital purchases by using debt B_{it} and equity from the global banks S_{it}, according to the following budget constraint

$$Q_{it}^k K_{it}^b = B_{it} + S_{it} \tag{44}$$

We assume that the amount of debt is limited to a fraction λ of total capital, according to

$$B_{it} \leq \lambda_i Q_{it}^k K_{it}^b \tag{45}$$

The problem of the firm is to maximize its profits V_{it}

$$\max E_t \Lambda_{it+1} V_{it+1} = \max E_t \Lambda_{it+1} \left\{ R_{it+1}^k Q_{it}^k K_{it} - B_{it} R_{it} (1 - \tau) - R_{it+1}^s \left(Q_{it}^k K_{it} - B_{it} \right) \right\}$$

$$s.t. \quad B_{it} \leq \lambda_i Q_{it}^k K_{it}^b$$

where τ represents an (infinitesimal) tax advantage for debt, which guarantees that the borrowing constraint binds, and where

$$R_{it+1}^k = \frac{z_{it+1} + (1 - \delta) Q_{it+1}^k}{Q_{it}^k}$$

Substituting the constraint into the objective functionIf the constraint binds you can rewrite the optimization problem as

$$\max E_t \Lambda_{it+1} Q_{it}^k K_{it} \left\{ R_{it+1}^k - \lambda_i R_{it} (1 - \tau) - R_{it+1}^s (1 - \lambda_i) \right\}$$

which implies the first order condition

$$E_t\Lambda_{it+1}\left\{R^k_{it+1}\frac{1}{1-\lambda_i}-\frac{\lambda_i}{(1-\lambda_i)}R_{it}\left(1-\tau\right)-R^s_{it+1}\right\}=0 \tag{46}$$

We assume that S_{it} represent a state-contingent claim to firms' profits, whose return satisfies the equation above period by periods, so that we can write

$$R^s_{it}=\frac{1}{(1-\lambda_i)}R^k_{it}-\frac{\lambda_i}{(1-\lambda_i)}R_{it-1}\left(1-\tau\right) \tag{47}$$

As a result, a larger firm leverage (that is a lower λ), will imply a larger exposure of bank asset returns to R^k_{it}. We use this reduced-form assumption to capture the possibility that banks' asset returns might be more volatile than what implied by the fluctuations in the price of capital, possibly because of default risk or additional financial frictions at the firm level, which we do not model directly. When $\lambda=0$ it is as if the bank is directly holding capital, as, for example, in Gerlter and Karadi (2011).

Finally, bank assets will be linked to firms' capital by

$$S_{it}=\left(1-\lambda_i\right)Q_{it}K^b_{it}\frac{\mathcal{N}_j}{\mathcal{N}_i}\text{ for } i=\{h,f\} \tag{48}$$

where $\mathcal{N}_i$ represents the population size of country i.

3.8 Government

Monetary policy follows a standard Taylor rule in both countries

$$\log\left(R^n_{it}\right)=\left(1-\rho_r\right)R_{SS}+\rho_r\log\left(R^n_{it-1}\right)+\varphi_\pi\log\left(\pi_{iit}\right)+\varepsilon^m_{it} \tag{49}$$

The Fisher equation is given by

$$R_{it}=E_t\Lambda_{it+1}\frac{R^n_{it}}{\pi_{it+1}} \tag{50}$$

wher R_{it} is the real rate in country i, and $\pi_{it}=P_{it}/P_{it-1}$.

3.9 Market Clearing

Market clearing in the goods market requires

$$\bar{Y}_{it} = C_{iit} + I_{iit} + \frac{\mathcal{N}_j}{\mathcal{N}_i} Y_{ijt} \left(C_{ijt} + I_{ijt}\right) = Y_{iit} + \frac{\mathcal{N}_j}{\mathcal{N}_i} Y_{ijt} \quad \text{for} \quad i \in \{h, f\} \tag{51}$$

Market clearing for capital requires

$$K_{it} = K_{it}^{h} + K_{it}^{b} \text{ for } \ i \in \{h, f\} \tag{52}$$

Market clearing for bank deposits

$$D_t = D_{ht} + D_{ft} \tag{53}$$

Finally, by combining the budget constraint of the representative household in country h, with the bank's balance sheet we can derive the balance of payment equation as

$$C_{ht} + I_{ht} = p_{hht}\bar{Y}_{ht} + \left(D_{ft} - D_{ft-1}R_t^d\right) + X_{fht}\left(R_{ft}^s S_{ft-1}^b - S_{ft}^b\right) \tag{54}$$

We now turn to a more quantitative description of the dynamic response of the economy to synchronous and asynchronous tightening in our model.

4 Calibration and Simulations Results

4.1 Calibration and Solution

We calibrate the model so that in the steady state the leverage constraint on global banks is not binding. We then simulate the economy using the OccBin toolkit to capture the nonlinearities which might arise if banks' net worth is too low.

Table 1 reports our baseline calibration. The first 16 parameters in table 1 are conventional, for which we select values in line with the existing literature. The rest of the parameters are specific to our model, and are related to the global financial sector.

A key element of our calibration is the exposure of global banks to foreign economies, which is important because it gauges how movements in asset values in the U.S. and abroad affect the net worth of global banks, and ultimately drives how exposed global banks are to monetary tightening episodes in either jurisdiction. We use BIS data on exposure to foreign economies of U.S.-headquartered banks, which suggests an average ratio of foreign exposure to total assets of around one quarter over the last decade, and adjust the parameters γ_h and γ_f to hit this target. In addition, we target global banks' leverage ratio in steady state, ϕ, to around 5. This value should be considered an average of the leverage ratio of several types of financial institutions that operate internationally, for instance broker dealers, hedge funds, and money market funds. Related literature has used a range of values for target leverage, with a value of 5 being relatively conservative. For example, Morelli et al. (2022) and Gertler and Kiyotaki (2010) target a leverage of 4, while Gertler et al. (2020) target a much larger value of 10. We assume that $\lambda_h = 0$ and $\lambda_s = .66$ (which implies a non-financial leverage of 3), in order to obtain that, in the unconstrained regime, the global banks net worth decline in response to a foreign monetary tightening is about one third of the decline caused by a US tightening. The parameters χ_h^k, χ_f^k, θ_h^s and θ_f^s are jointly calibrated to obtain an increase in average global spreads in the baseline experiment with syncronous tightening of about 60bps compared to the asyncronous tightening, in line with the evidence in figure 1, with the increase in the US spread equal to about one and half times of the increase in foreign spreads. We adjust foreign holding of global banks deposits, D_f, to obtain balanced trade in steady state.

Finally, in order to focus on financial spillovers, we assume that all exporters set prices in the destination currency (LCP). [3]

4.2 Global Tightening Experiments

A key feature of our model is that nonlinearities may arise from a global monetary tightening, which imply that the effect of a syncronous tightening is larger than the sum of the effects of individual rate hikes. A monetary tightening in a given foreign country triggers a decline in the value of the assets from that country in the bank's portfolio. To the extent that these assets are a small fraction of the total, the resulting hit to net worth N_t is small. By contrast, when the tightening happens synchronously, assets across all geographic areas lose value, causing a much larger drop in N_t, which may lead to the bank's leverage constraint to bind.[4]

Figure 3 provides a graphical description of the mechanism, showing the response of financial intermediaries' equity, U.S. corporate credit spreads, and 1-year ahead U.S. GDP growth following U.S. monetary policy shocks of different sizes, ranging between 0 and 200 basis points on the x-axis. The blue lines report the effects for simulations in which the foreign central bank follows what the policy rule would imply. When foreign economies do not hike synchronously, the U.S. policy shock must be larger than 160 basis points to reach the tipping point where the constraint becomes

[3] This assumption implies a small pass-through of exchange rates on export prices, allowing us to abstract from the spillovers due to movements in exchange rates. An extension we are considering is to allow for global dollar pricing of exports, as in the dominant currency pricing paradigm of Gopinath et al. (2020), to study how the central role of the dollar in trade and finance interact to shape global monetary policy tradeoffs.

[4] Nonlinearities arise also if the individual tightening causes the constraint to bind for a few periods, while the joint tighening causes the constraint to bind for longer.

binding, represented by the kink after which equity starts declining faster. For U.S. monetary policy shocks above this threshold, corporate spreads rise by more and output losses become larger. The red lines report the effects for simulations in which the foreign central bank raises the interest rate 100 basis points more than what the policy rule would imply. When foreign economies hike synchronously, the tipping point is reached for smaller values of U.S. monetary policy shocks.

To illustrate the aggregate implications of this mechanism, figure 4 reports the impulse responses of the model to individual and syncronous tighening. The red bars show the effects of foreign central banks deviating from the baseline reaction function and increasing policy rates by an additional 100 basis points on average over the first year, with the U.S. central bank following its baseline reaction function. The responses of foreign and U.S. variables show how the foreign tightening can reduce foreign GDP and inflation by significant amounts but has little spillovers on U.S. activity and inflation.

The blue bars consider a symmetric experiment and show the effects of the U.S. central bank deviating from the baseline reaction function and increasing policy rates by an additional 100 basis points on average in the first year, with the foreign central bank following its baseline reaction. A U.S. tightening has larger spillovers on foreign economies because, in our model, it has larger effects on global financial intermediaries' balance sheets, as shown by the modest increase in spreads in the right panels. That said, spillovers remain relatively contained compared to the direct effects on the domestic economy.

The black line shows the effects of combining the U.S. and foreign monetary policy shocks. In the model, the synchronous tightening pushes the system past the tipping point where monetary spillovers are greatly amplified, and it causes spreads to rise significantly, especially abroad. As a result, the effect of a global tightening is much larger than the sum of the effects of individual tightening, which is given by the sum of the blue and red bars. Moreover, the nonlinear amplification effect, measured by the yellow bars, is stronger on output than on inflation, which increases sacrifice ratios, that is, output losses relative to inflation reductions.

5 Policy Coordination in a Global Inflation Surge

In this section we explore the consequences of policy coordination in the face of global inflation pressures. We consider the following experiment. A positive one-time global shock to retailers' desired markups (engineered through a decrease in the substitution elasticity ε) triggers inflationary pressures in both countries simultaneously. The shock is sized to induce a rise in inflation of about 3 percentage points above target on impact, and has auto-regressive parameter equal to 0.5, so that inflation remains above target for roughly a year.

We then assume that policymakers in each country set the policy rule parameter φ_π so as to minimize a loss function that depends on inflation and output deviations. Specifically, policymakers' objective is assumed to be

$$\mathcal{L} = \sum_{t=0}^{T} \beta^t (\pi_t^2 + y_t^2), \tag{55}$$

where π_t is annualized inflation and y_t is output in deviation from steady state.

We first consider the "Nash" case in which each country chooses φ_π unilaterally taking the other country's response coefficient as given. As shown in the left panel of figure 5, if the foreign country sets $\kappa_\pi^f = 1.45$, the home central bank finds it optimal to set is response coefficient to $\kappa_\pi^h = 1.6$. At the same time, if home's coefficient is set to 1.6, the optimal response for the foreign central bank is to set $\kappa_\pi^f = 1.45$. Thus, these two coefficient values constitute a Nash equilibrium.

We then consider, in figure 6, the joint optimal choice of $\kappa_\pi^f = 1.45$ with the goal of minimizing the average of the loss functions in the two countries. We find that in this case, the optimal choice of the home response coefficient is 1.35, while foreign sets 1.55. Thus, under cooperation home responds considerably less aggressively to the inflation surge than under the Nash case, while the foreign response is not much changed. This lower aggressiveness leads to smaller pressure on global banks' net worth, and consequently to a noticeably smaller rise in credit spreads.

[TO BE COMPLETED]

6 Conclusion

[TBA]

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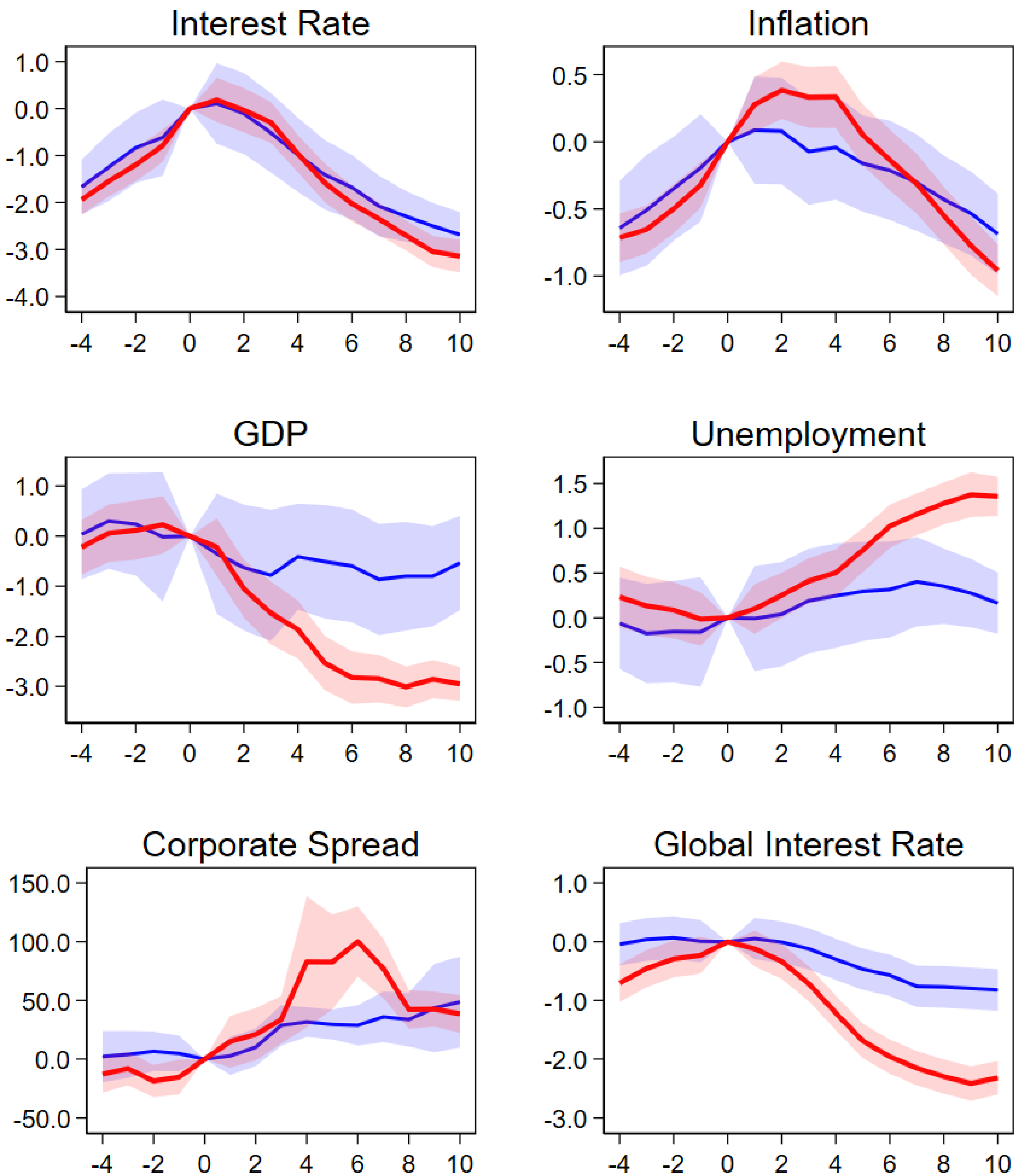
Table 1: Parameter Values

Parameter	Symbol	Value	Target/Source
Discount Factor	β	0.9975	Standard
Intertemporal Elasticity of Substitution	ρ	1	Standard
Frish Elasticity	φ	1	Standard
Habit parameter	h	0.9	Standard
Disutility of Labor	ψ_i for $i = \{h, f\}$	.85	$L_i = 1$ for $i = \{h, f\}$
Home Bias	ω_h,ω_f	0.85,0.90	$X_{hf} = 1$
Country Size	$\mathcal{N}_h, \mathcal{N}_f$	1,3	Standard
Trade Elasticity	θ	1.05	Standard
Capital Depreciation Rate	δ	.025	Standard
Capital Share	α	.33	Standard
CES Elasticity	ε	11	Standard
Rotemberg costs	κ	375	Phillips Curve slope=0.03
Investment adjustment cost	γ_k	2	Standard
Taylor rule coefficient on inflation	φ_π	1.5	Standard
Taylor rule inertia	ρ_r	0.75	Standard
Government bond supply	$\bar{B}_f$	0	
Households capital holding costs	χ_h^K, χ_f^K	10	Global spreads rise by 100bps with global tightening
Households deposits holding costs	χ_h^D, χ_f^D	0	
Households bonds holding costs	χ_h^B, χ_f^B	0	
Share of capital held by households	γ_h, γ_f	.25,.5	Banks foreign asset share=0.25
Banks survival rate	σ_b	0.95	Standard
Bank endowment	ξ	.013	SS leverage=5
Agency problem parameters	θ_h^s, θ_f^s	0.1,0.5,0	Ratio of foreign spread to home spread =1.5
Firms' leverage constraint	λ_h, λ_f	0,0.66	$\downarrow N_t$ from foreign tightening =1/3 of US tightening
Foreign deposits	D_f	9	Net foreign asset positions =0

Figure 1: Historical Behavior around Synchronous and Asynchronous Monetary Tightening Episodes



Note: Evolution over time of interest rates, inflation, unemployment rate, and corporate spreads around episodes of interest rate tightening episodes in selected advanced foreign economies since 1980. Each period is one quarter. Synchronous (asynchronous) tightening episodes are those that occur (do not occur) within two years of a U.S. tightening. Synchronous lines are red and asynchronous lines are blue. The lines are constructed using event-study regressions. The shaded regions show 80% confidence intervals. In the unemployment graph, an increase indicates higher unemployment.

Figure 2: Model of the World Economy

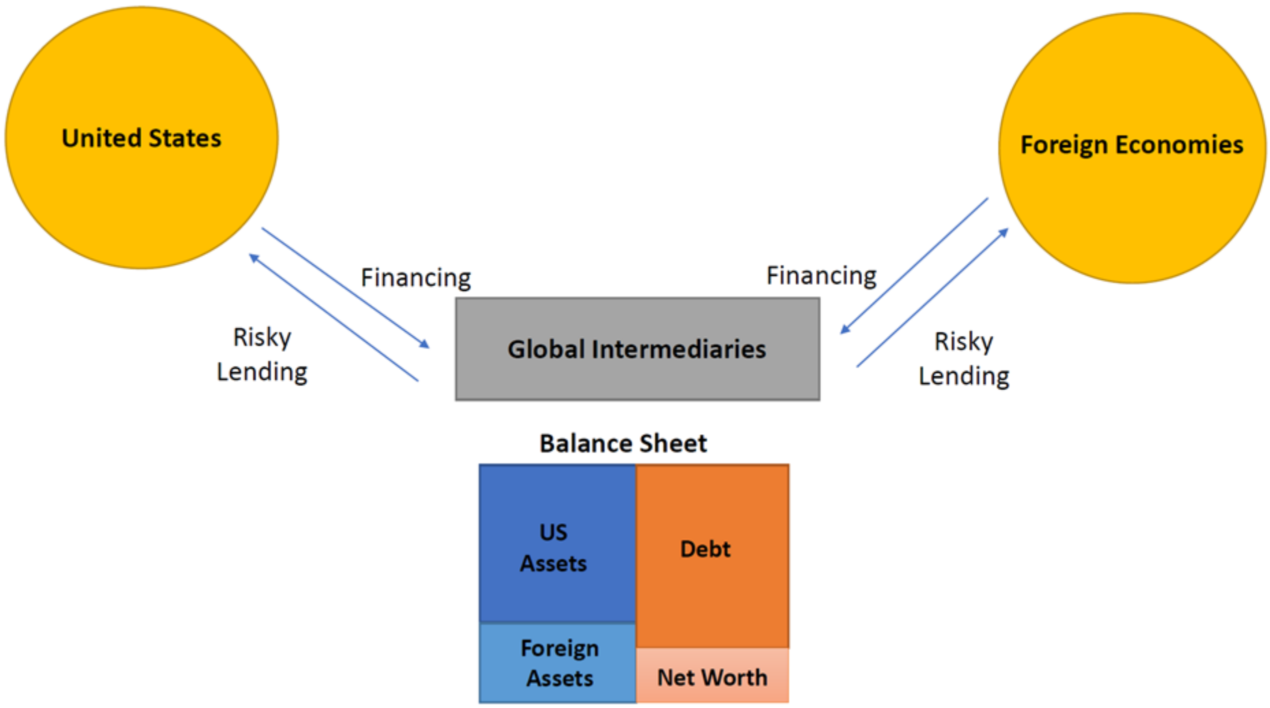
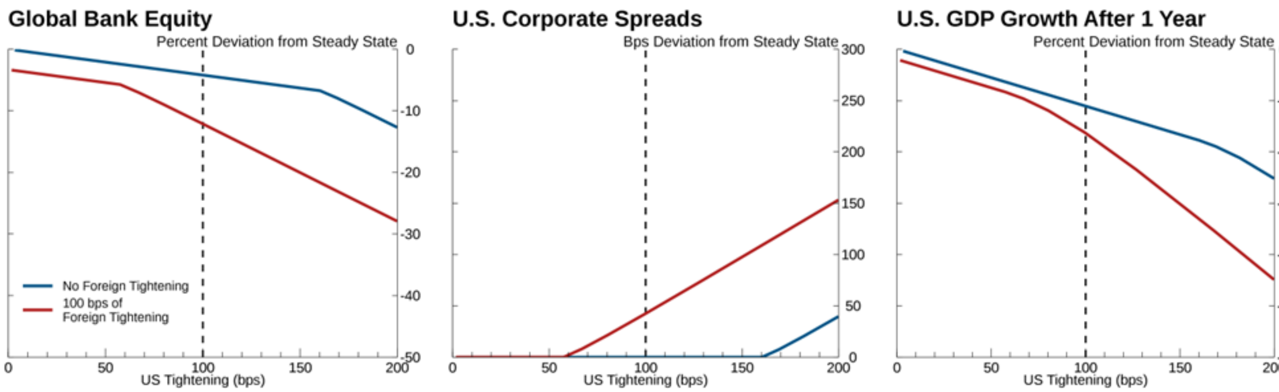
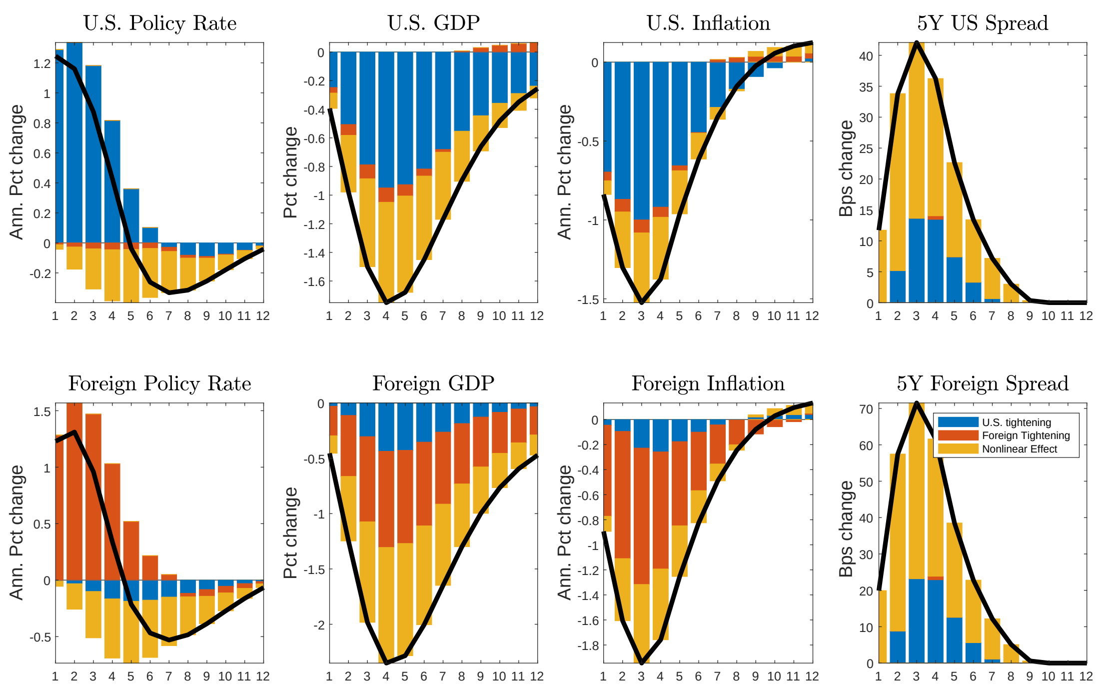


Figure 3: Nonlinear Financial Amplification of Monetary Policy Shocks of Different Sizes



Note: The panels in the figure report the response of financial intermediaries' equity, U.S. corporate credit spreads, and 1-year ahead U.S. GDP growth following U.S. monetary policy shocks of different sizes, ranging between 0 and 200 basis points. The blue lines report the effects for simulations in which the foreign central bank follows what the policy rule would imply. The red lines report the effects for simulations in which the foreign central bank raises the interest rate 100 basis points more than what the policy rule would imply.

Figure 4: Model Simulations of Synchronous and Asynchronous Monetary Tightenings



Note: All variables are in deviation from steady state.

Figure 5: Loss with other country's policy taken as given

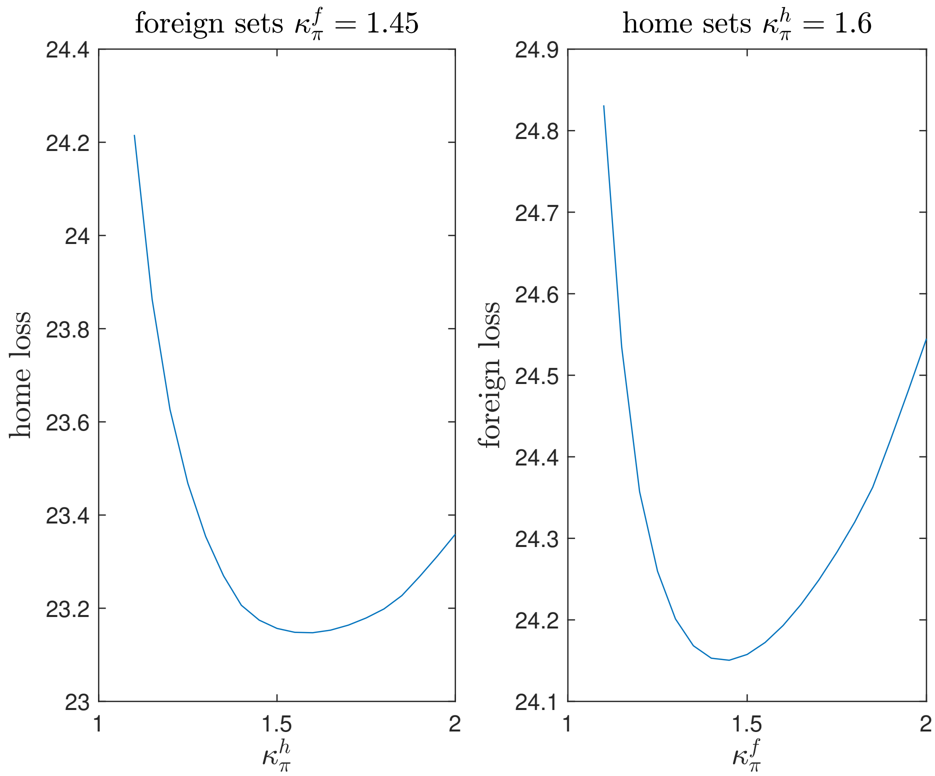


Figure 6: Loss under cooperation