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ABSTRACT

In a standard two country international macro model we ask whether imposing restrictions on international non-contingent borrowing and lending is ever desirable. The answer is yes. If one country imposes capital controls unilaterally, it can generate favorable changes in the dynamics of equilibrium interest rates and the terms of trade, and thereby benefit at the expense of its trading partner. If both countries simultaneously impose capital controls, the welfare effects are ambiguous. We identify calibrations in which symmetric capital controls improve terms of trade insurance against country specific shocks, and thereby increase welfare for both countries.

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1 Introduction

The question of whether capital controls might be welfare improving relative to unrestricted international capital mobility has recently received a lot of attention from academics and policymakers. This paper focuses on one particular rationale for introducing capital controls: a country that introduces capital controls can potentially change equilibrium international prices in its favor. We use a workhorse two-country business cycle model to analyze how capital controls can affect the dynamics of the equilibrium interest rate and the terms of trade, and to assess whether this mechanism offers a quantitatively compelling motivation for taxing capital flows.

Our environment is the two-country stochastic growth model developed by Backus, Kehoe, and Kydland (1994), with the asset structure used by Baxter and Crucini (1995). Each country uses capital and labor to produce a country-specific good that is imperfectly substitutable with the output of its trading partner. The only asset traded internationally is a noncontingent bond. Our model of capital controls is simple: the government in each country can tax its residents' interest income from the internationally traded bond. We restrict the policy space to the choice of a single number by restricting the tax rate on interest income to be proportional to the country's net foreign asset position, so that the capital control policy reduces to the choice of this constant of proportionality.

How do capital controls affect equilibrium prices in this framework? Suppose one country experiences a positive persistent productivity shock. Absent capital controls, the country will borrow internationally in the short run, implying a negative net foreign asset position, in order to finance increased investment. Subsequently, as long as the shock is nonpermanent, the more productive country will save and accumulate a positive net foreign asset position in order to smooth consumption into the future. Now suppose the country has a capital tax policy that subsidizes saving while it is a borrower and taxes saving while it is a lender. This policy will lead the country to borrow less from abroad in the short run and to save less in the long run. By itself, this would be detrimental to consumption smoothing and the efficient allocation of capital. To fully evaluate the impact of the policy on welfare, however, we need to also consider its impact on equilibrium prices. First, consider the impact on interest rates. Since the country will save more initially and consume more later (relative to the no-capital-control case), the equilibrium world interest rate will be lower in the initial phase in which the country is a borrower and higher in the later phase in which it is a lender. These changes in interest rates potentially leave the country better off, making introducing capital controls appealing. Now consider the impact on the terms of trade. In general, a positive productivity shock will worsen a country's terms of trade, as an increase in the supply of domestically produced goods lowers their relative price. In a model with endogenous production, capital controls will dampen the increase in investment undertaken in the more productive country and hence dampen this terms of trade response. This suggests a second possible motivation for introducing capital controls.

The structural model we develop in the rest of the paper can be used to analyze and quantify how the presence of capital controls mediates the impact of shocks on equilibrium quantities, prices, and welfare, and to explore how these pecuniary motives for capital controls depend on structural features of the economy. Section 2 of the paper lays out the basic environment, which is identical to Backus et al. (1994) and Heathcote and Perri (2002), and introduces our model of capital controls. We then analyze the impact of capital controls in several steps.

First, in Section 4.1, we take the standpoint of a single country and show that acting unilaterally a country will find it desirable to impose a substantial tax on international capital flows, such that under our baseline calibration, the average simulated absolute net foreign asset position is reduced by a factor of three relative to the case of free capital mobility. We find that the incentive to impose capital controls survives a wide range of alternative parameterizations. One case of particular interest is an example in which the country is small, so that it cannot much affect the world interest rate. Even here, the country wants to impose quantitatively significant capital controls, as long as it produces a differentiated good and can therefore influence its terms of trade. We also explore how the incentive to impose capital controls varies with the state of the economy, and find that relatively productive countries that are natural attractors of foreign capital want to impose especially large taxes.

Up to this point, we have considered one country's incentives to impose capital controls, ignoring both any possible reaction from its trading partner and also the effects on global welfare. This analysis can be viewed as a dynamic application of the old optimal tariff logic. In Section 4.2 we consider a model of capital control competition and compute the Nash equilibrium in the case in which both countries set taxes optimally, taking as given the tax policy of the other country. Under our baseline calibration, we find that the common tax policy that arises from capital control competition involves a very large reduction in intertemporal trade and outcomes that are Pareto dominated by free international capital mobility.

This result, however, does not mean that capital controls are never desirable from a global perspective. In fact, in our final set of results (Section 4.3), we show that there exists a range of calibrations in which a regime with capital controls Pareto-dominates a world with free bond trade, so that a global planner would choose to tax capital flows. A necessary condition for this result is that our free bond trade equilibrium is inefficient, because international asset markets are incomplete. In this context, capital controls can be welfare improving if they sufficiently improve international risk sharing. One source of consumption risk sharing emphasized by Cole and Obstfeld (1991) is that the terms of trade will typically move inversely to relative country productivity, providing an automatic form of insurance. By changing the dynamics of the terms of trade, capital controls can potentially improve this insurance. We identify two cases in which capital controls offer sufficiently superior terms of trade insurance that they are unconditionally desirable. In the first case, the goods traded are very poor substitutes, while in the second, the trade share of output is very high.

1.1 Related Literature

A large literature studies environments in which capital controls can be desirable (see Magud et al., 2011, for a review). A common theme of this literature is that competitive domestic agents do not take into account that borrowing and lending in international markets affects equilibrium prices, and restricting international borrowing and lending can therefore lead to change in prices that improve the welfare of domestic agents. More specifically, this literature can be roughly divided into two strands.

The first strand focuses on capital controls as a way to induce changes in international prices that are beneficial for the country that puts the controls in place, but detrimental to its trading partners. This literature builds on the optimal tariff argument (Johnson, 1953).

The second strand focuses on economies with frictions, where welfare can improve if capital controls induce changes in equilibrium international prices that reduce the impact of underlying frictions. Note that in these settings, the welfare increase can be global, as capital controls can potentially increase efficiency.

The first part of our paper is more related to the first strand of the literature, as we show that capital controls generally increase welfare for the country that puts them in place because they induce favorable changes in interest rates, the terms of trade, or both. The paper that is perhaps most closely related to ours is Costinot, Lorenzoni, and Werning (2014). In their setup, as in ours, countries can impose capital controls to obtain more favorable borrowing and lending rates. In contrast to our setup, their analysis is in the context of a simple stylized model, which allows them to more sharply characterize the optimal capital controls policy. Another relevant paper is Edwards (1989), which analyzes how capital controls can affect the terms of trade and the real exchange rate, again in the context of a stylized model. Our paper builds on these insights but considers a simple parametric form of capital control policy in the context of a fully fledged two-country macro model. This approach allows us to conduct a quantitative evaluation of the impact of these policies.

The second part of our paper is more related to the second strand of the existing literature, which studies capital controls in environments with frictions. The key friction in our environment is limited international risk sharing, and our contribution is to show that there are plausible parameter configurations under which capital controls can improve global efficiency by improving international risk sharing. Three existing papers are particularly related. The first is Newbery and Stiglitz (1984), which considers a simple environment and shows that shutting down trade in goods can lead to terms of trade movements that provide more insurance, and thereby induce Pareto-superior outcomes. One key difference between our paper and theirs is that they focus on restricting intratemporal trade, whereas we consider restrictions on intertemporal trade. The second related paper is De Paoli and Lipinska (2013), which considers an environment similar to ours and studies how taxes on international bonds can improve allocations for a given country. The key difference between our setup and theirs is that we consider an environment with capital accumulation. We find that the dynamics of capital accumulation are a crucial determinant of both relative demand and relative supply, and thereby of the dynamics of international prices. Because of this, our findings are quite different. For example, De Paoli and Lipinska find that imposing capital controls limits cross-border pooling of risk, whereas we find examples in which capital controls are beneficial exactly because they enable better cross-border risk sharing. Finally, Brunnermeier and Sannikov (2015) show how open international financial markets can lead to a terms of trade deterioration (as in our setup). However, their main focus is on how this deterioration can lead to a fall in net worth and subsequent financial instability and financial crises.

Researchers have highlighted many additional frictions that can justify capital controls (see

Fahri and Werning, 2013, for a review). Jeske (2006) studies an environment with limited enforcement of international contracts and argues that because individual agents do not internalize the impact of individual borrowing on the government's incentives to default, capital controls can mitigate default risk. Another set of interesting papers studies environments with borrowing constraints (see, for example, Korinek, 2010, Bianchi, 2011, and Benigno et al., 2015) and focuses on the effect that capital controls can have on domestic prices, which in turn can relax or tighten these constraints. Yet another justification for capital controls is that they can induce price changes that help overcome frictions in the labor market (see, for example, Schmitt-Grohe and Uribe, forthcoming). Finally, Martin and Taddei (2012) consider an environment with informational frictions, and show that capital controls can help mitigate the impact of these frictions. We view all these papers as complementary to ours, and integrating multiple possible rationales for capital controls is an important direction for future research.

2 The Model

We focus on the familiar two-country business cycle framework developed by Backus, Kehoe, and Kydland (1994) (henceforth BKK). The two countries, indexed $i = 1$ and $i = 2$, are each populated by mass one of identical, infinitely lived households. In each period t, the economy experiences one event $s_t \in S$. We denote by s^t the history of events up to and including date t. The probability at date 0 of any particular history s^t is given by $\pi(s^t)$.

2.1 Preferences and Technologies

The representative household derives utility from consumption, $c_i(s^t)$, and disutility from labor supply, $n_i(s^t)$. Preferences are given by

$$(1-\beta)\sum_{t=0}^{\infty}\beta^t\sum_{s^t}\pi(s^t)U\left(c_i(s^t), n_i(s^t)\right), \tag{1}$$

where the parameter β captures the rate of time preference. Period utility is

$$U\left(c_i, n_i\right) = \frac{c_i^{1-\gamma}}{1-\gamma} - \frac{n_i^{1+\frac{1}{\varepsilon}}}{1+\frac{1}{\varepsilon}}, \tag{2}$$

where ε is the Frisch elasticity of labor supply and γ controls risk aversion and the intertemporal elasticity of substitution.

Capital in place $k_i(s^{t-1})$ (chosen in the previous period) and labor are combined to produce two country-specific intermediate goods. These are the only tradable goods in the economy. The intermediate good produced in country 1 is labeled a, and the good produced in country 2 is labeled b. The intermediate goods production functions are Cobb-Douglas:

$$F_i\left(z_i, k_i, n_i\right) = \exp(z_i) k_i^{\theta} n_i^{1-\theta}, \tag{3}$$

where $z_i(s^t)$ is an exogenous productivity shock that follows a symmetric autoregressive process:

$$\begin{aligned}
\begin{bmatrix} z_1(s^t) \\ z_2(s^t) \end{bmatrix} &= \begin{pmatrix} \rho & \psi \\ \psi & \rho \end{pmatrix} \begin{bmatrix} z_1(s^{t-1}) \\ z_2(s^{t-1}) \end{bmatrix} + \begin{bmatrix} \varepsilon_1(s^t) \\ \varepsilon_2(s^t) \end{bmatrix} \\
\begin{bmatrix} \varepsilon_1(s^t) \\ \varepsilon_2(s^t) \end{bmatrix} &\sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_\varepsilon^2 & Corr_{\varepsilon_1,\varepsilon_2} \times \sigma_\varepsilon^2 \\ Corr_{\varepsilon_1,\varepsilon_2} \times \sigma_\varepsilon^2 & \sigma_\varepsilon^2 \end{pmatrix} \right].
\end{aligned}$$

Within each country, the intermediate goods a and b are combined to produce a country-specific nontradable final good that is used for both consumption and new investment. The final goods production technology is

$$G_i\left(a_i, b_i\right) = \begin{cases} \left(\zeta a_i^{\frac{\sigma-1}{\sigma}} + (1-\zeta) b_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}, & i = 1 \\ \left((1-\zeta) a_i^{\frac{\sigma-1}{\sigma}} + \zeta b_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}, & i = 2, \end{cases} \tag{4}$$

where $a_i(s^t)$ and $b_i(s^t)$ denote the quantities of intermediate goods a and b used in country i as inputs, σ is the elasticity of substitution between domestic and foreign-produced inputs, and ζ determines the extent to which there is a home or foreign bias in the composition of domestically produced final goods. We will calibrate ζ to replicate empirical measures for the volume of trade relative to GDP.

Investment augments the capital stock in the standard way:

$$k_i(s^t) = (1-\delta) k_i(s^{t-1}) + x_i(s^t), \tag{5}$$

where δ is the depreciation rate and $x_i(s^t)$ is the amount of the final good devoted to investment in country i.

The resource constraints for this economy are

$$a_1(s^t) + a_2(s^t) = F\left(z_1(s^t), k_1(s^{t-1}), n_1(s^t)\right), \tag{6}$$

$$b_1(s^t) + b_2(s^t) = F\left(z_2(s^t), k_2(s^{t-1}), n_2(s^t)\right), \tag{7}$$

and

$$c_i(s^t) + x_i(s^t) = G_i\left(a_i(s^t), b_i(s^t)\right), \qquad i = 1, 2. \tag{8}$$

2.2 Firm Problems

Households rent labor to competitive intermediate goods-producing firms at wage $w_i(s^t)$ (measured in units of the final good). These firms sell intermediate goods at prices $q_i^a(s^t)$, $q_i^b(s^t)$. Final goods-producing firms purchase the intermediate goods and produce the final consumption/investment good, solving the static problems

$$\max_{a_i(s^t), b_i(s^t)} \left\{ G_i(a_i(s^t), b_i(s^t)) - q_i^a(s^t)a_i(s^t) - q_i^b(s^t)b_i(s^t) \right\}. \tag{9}$$

Intermediate goods-producing firms hold capital and make investment decisions. The intermediate goods firm's maximization problem in country i is to choose $k_i(s^t)$, $n_i(s^t)$ for all s^t and for all $t \geq 0$ to maximize

$$\sum_{t=0}^{\infty} \sum_{s^t} Q_i(s^t) d_i(s^t)$$

taking as given $k_i(s^{-1})$, where $Q_i(s^t)$ is the price the firm uses to value dividends at s^t relative to consumption at date 0, and dividends (in units of the final good) are given by

$$d_1(s^t) = q_1^a(s^t) F\left(z_1(s^t), k_1(s^{t-1}), n_1(s^t)\right) - w_1(s^t)n_1(s^t) - x_1(s^t) \tag{10}$$

$$d_2(s^t) = q_2^b(s^t) F\left(z_2(s^t), k_2(s^{t-1}), n_2(s^t)\right) - w_2(s^t)n_2(s^t) - x_2(s^t). \tag{11}$$

The state-contingent consumption prices $Q_i(s^t)$ play a role in intermediate goods firms' state-contingent decisions regarding how to divide earnings between investment and dividend payments. We assume that firms use the stochastic discount factor of the representative local household to price the marginal cost of forgoing current dividends in favor of extra investment:

$$Q_i(s^t) = \frac{\pi(s^t)\beta^t U_i'(s^t)}{U_i'(s^0)}, \tag{12}$$

where $U_i'(s^t)$ denotes the marginal utility of consumption for the representative household in country i at s^t.

2.3 International Relative Prices

Movements in international relative prices will play an important role in our analysis. We define the terms of trade $p(s^t)$ as the price of good b relative to good a :

$$p(s^t) = \frac{q_1^b(s^t)}{q_1^a(s^t)} = \frac{q_2^b(s^t)}{q_2^a(s^t)}.$$

The real exchange rate $rx(s^t)$ is the price of foreign relative to domestic consumption. Because the law of one price applies to traded intermediate goods, this is equal to

$$rx(s^t) = \frac{q_1^a(s^t)}{q_2^a(s^t)} = \frac{q_1^b(s^t)}{q_2^b(s^t)}.$$

The assumptions built into preferences and technologies in the BKK framework imply a tight connection between equilibrium fluctuations in the terms of trade and the real exchange rate. In particular,

$$rx(s^t) = \left(\frac{\zeta^\sigma + (1-\zeta)^\sigma p(s^t)^{1-\sigma}}{(1-\zeta)^\sigma + \zeta^\sigma p(s^t)^{1-\sigma}}\right)^{\frac{1}{\sigma-1}}.$$

Note that when $\zeta = 0.5$, so that the two countries share identical preferences, there will be zero volatility in the real exchange rate, independent of the asset market structure. When $\zeta = 1$, so that preferences are completely specialized, the real exchange rate is equal to the terms of trade. For $\zeta > 0.5$, the terms of trade and the real exchange rate co-move positively, whereas for $\zeta < 0.5$ they co-move negatively.

2.4 Asset Markets and Capital Controls

Our main focus will be on a market structure in which only a noncontingent bond is traded internationally. We will model capital controls as a tax on interest income from bonds. To offer some perspective on the welfare consequences of capital controls, we will also compute models with zero and complete international financial markets.

A single noncontingent bond is traded. The bond has price $P(s^t)$ (in units of country 1's consumption good) at date t following history s^t and entitles the holder to half a unit of domestic consumption and half a unit of foreign consumption at date $t+1$. We assume this half-half payoff structure to preserve symmetry. It will be useful to differentiate between an atomistic agent's bond purchases and the per capita purchases for the country as a whole. We therefore let $b_i(s^t)$ denote the quantity of bonds bought by an individual household in country i after history s^t and let $B_i(s^t)$ denote per capita purchases by all households in country i. Bond interest income in period t (in units of country 1 consumption) is $\left[\frac{1}{2}\left(1+rx(s^t)\right)-P(s^{t-1})\right]b_i(s^{t-1})$, and this income is taxed at rate $\tau_i(s^t)$. The revenue from these taxes is rebated lump-sum as transfers $Tr_i(s^t)$.

The budget constraint for a household in country 1 is therefore

$$\begin{aligned} c_1(s^t)+P(s^t)b_1(s^t) &= w_1(s^t)n_1(s^t)+d_1(s^t)+b_1(s^{t-1})\left(\frac{1+rx(s^t)}{2}\right) \\ &\quad -\tau_1(s^t)\left(\frac{1+rx(s^t)}{2}-P(s^{t-1})\right)b_i(s^{t-1})+Tr_1(s^t). \end{aligned} \tag{13}$$

We assume that the tax rate on interest income $\tau_i(s^t)$ is proportional to the aggregate net foreign asset position, so that

$$\tau_i(s^t)=\tau_i\frac{B_i(s^{t-1})}{GDP_i(s^t)},$$

where $\tau_i\geq 0$ is a fixed parameter, and $GDP_1=q_1^aF\left(z_1,k_1,n_1\right),\, GDP_2=q_2^bF\left(z_2,k_2,n_2\right)$.

Given this tax function, a domestic agent's intertemporal first-order condition for bond purchases is given by

$$U_1'(s^t)P(s^t)=\beta\sum_{s^{t+1}}\pi(s^{t+1}|s^t)U_1'(s^{t+1})\left[\frac{1+rx(s^{t+1})}{2}-\tau_1\frac{B_1(s^t)}{GDP_1(s^{t+1})}\left(\frac{1+rx(s^{t+1})}{2}-P(s^t)\right)\right].$$

If $\tau_1>0$, then when country 1 is a net foreign lender ($B_1(s^t)>0$), the capital control policy taxes saving and thus discourages capital outflows. Conversely, when the net foreign asset position is negative, the policy subsidizes saving and discourages borrowing from abroad.

Because each household is representative, in equilibrium $b_i(s^t)=B_i(s^t)$ and lump-sum transfers are given by

$$Tr_1(s^t)=\tau_1\frac{\left[B_1(s^{t-1})\right]^2}{GDP_1(s^t)}\left(\frac{1+rx(s^t)}{2}-P(s^{t-1})\right).$$

Given these transfers, the second line of the budget constraint eq. 13 nets out to zero.

The budget constraint for country 2 is analogous, and the first-order condition is

$$\frac{U_2'(s^t)P(s^t)}{rx(s^t)} = \beta \sum_{s^{t+1}} \pi(s^{t+1}|s^t)U_2'(s^{t+1}) \left[\frac{1+rx(s^{t+1})}{2rx(s^{t+1})} - \tau_2 \frac{B_2(s^t)}{GDP_2(s^{t+1})} \left(\frac{1+rx(s^{t+1})}{2rx(s^{t+1})} - \frac{P(s^t)}{rx(s^t)} \right) \right].$$

Several properties of this model of capital controls are worth noting. First, each country's capital control policy is summarized by a single policy parameter τ_i. Second, when $\tau_1 = \tau_2 = 0$, the economy is a standard frictionless bond economy. Third, for $\tau_i > 0$, bond interest is untaxed when the net foreign asset position is zero, whereas the tax rate increases linearly with the aggregate net foreign asset position. The tax rate $\tau_1(s^t)$ is exactly equal to τ_1 when the net foreign asset position is 100 percent of GDP. Thus, as the net foreign asset position rises, $\tau_1 > 0$ will increasingly discourage additional accumulation of foreign assets, which will tend to push the net foreign assets (NFA) position back toward zero. Conversely, when the aggregate NFA position is negative, so will the tax rate $\tau_1(s^t)$, which will discourage further borrowing. Fourth, the higher are the tax rate parameters τ_i, the more strongly are both saving and borrowing discouraged, and in the limit as $\tau_1 \to \infty$ and / or $\tau_2 \to \infty$, there will be no international bond trade, so allocations will correspond to financial autarky.

We emphasize that this model of capital controls is not the fully optimal policy. In a simpler endowment economy, Costinot et al. (2014) argue that the net foreign asset position is not a sufficient statistic for the optimal sign of taxes on taxes on capital flows. Furthermore, in our two-good production environment, additional instruments could give the planner additional leverage over equilibrium prices. First, when the domestic and foreign countries produce differentiated goods, a domestic planner would like to impose good-specific taxes, for the usual optimal tariff reasons. One motivation for ruling out such taxes (as we do) is that they would contravene free trade agreements. Second, in our production economy, the planner might benefit from instruments that would give it leverage over agents' labor supply and capital investment decisions, since these choices will impact the dynamics of output and thus of interest rates and the terms of trade. We also rule out any policy interventions of this sort.

Although we do not characterize the fully optimal state-contingent policy, our simple model of capital control policy has several merits. First, alternative choices of a single parameter allow it to subsume free bond trade, financial autarky, and a smooth range of intermediate cases. Second, since the net foreign asset position is a slow-moving variable, the model will imply taxes that are relatively stable over time. We will find that governments will want to use capital controls aggressively, notwithstanding the fact that we restrict them to a particular functional form. In Section 4.1.4 we will consider an alternative specification, according to which the tax rate on interest income is proportional to the change in the country's net foreign asset position, rather than being proportional to its level.

Financial autarky

In the financial autarky model, no assets are traded internationally; hence, the budget constraint for the representative household in country i is given by

$$c_i(s^t) = w_i(s^t)n_i(s^t) + d_i(s^t) \qquad i = 1, 2. \tag{14}$$

Complete markets

Here households trade a complete set of state-contingent claims. We assume the same denomination structure as in the noncontingent bond case. Let $B_i(s^t, s_{t+1})$ be the quantity of Arrow securities purchased by households in country i after history s^t that pay half a unit of domestic and half a unit of foreign consumption in period $t+1$ if and only if the state of the economy is s_{t+1}. Let $P(s^t, s_{t+1})$ be the price of this security. The budget constraint for the representative household in country 1 is then

$$c_1(s^t) + \sum_{s_{t+1}} P(s^t, s_{t+1})B_1(s^t, s_{t+1}) = w_1(s^t)n_1(s^t) + d_1(s^t) + B_1(s^{t-1}, s_t)\left(\frac{1 + rx(s^t)}{2}\right). \tag{15}$$

2.5 Household Problems and Definition of Equilibrium

Households choose $c_i(s^t) \geq 0$, $n_i(s^t) \geq 0$, and asset purchases for all s^t and for all $t \geq 0$ to maximize 1 subject to the appropriate sequence of budget constraints given by eq. 13, 14, or 15, taking as given initial productivity shocks, initial capital stocks, and the initial distribution of wealth.

An equilibrium is a set of prices for all s^t and for all $t \geq 0$ such that when households solve their problems taking these prices as given, all markets clear. The goods market-clearing conditions are 6 and 8. The asset market conditions for the bond and complete markets economies are, respectively,

$$B_1(s^t) + B_2(s^t) = 0 \tag{16}$$

$$B_1(s^t, s_{t+1}) + B_2(s^t, s_{t+1}) = 0, \qquad \forall s_{t+1} \in S. \tag{17}$$

3 Calibration

All parameters for the baseline calibration are reported in Table 1.

Table 1. Baseline Parameter Values

Preferences		
	Discount factor	$\beta = 0.99$
	Curvature	$\gamma = 1$
	Frisch elasticity	$\varepsilon = 1$
Technology		
	Capital's share	$\theta = 0.36$
	Depreciation rate	$\delta = 0.015$
	Elasticity of substitution	$\sigma = 1.5$
	Import share	$is = 0.3$
Productivity process		
	Persistence and spillover	$\rho = 0.95$ $\psi = 0.0$
	Variance and correlation	$\sigma_\varepsilon^2 = 0.02^2$ $Corr_{\varepsilon_1,\varepsilon_2} = 0.3$

The discount factor β is equal to 0.99, a standard value for a quarterly model. Utility is logarithmic in consumption, so the intertemporal elasticity of substitution for consumption is equal to one. The Frisch elasticity of labor supply, ε, is also equal to one. Capital's share of income θ and the depreciation rate δ are set to standard values.

We assume a symmetric process for productivity, with no spillovers: $\psi = 0$. The persistence parameter ρ is set to 0.95, which is in the middle of estimates in business cycles studies. We set the variance of innovations σ_ε^2 equal to 0.02^2 and the correlation of innovations across countries to 0.3. This generates plausible business cycle volatility and co-movement for a cross section of developed and developing countries.

The preference weight ζ controls the equilibrium volume of trade. As a baseline, we set ζ such that in steady state, imports are 30 percent of GDP, which is approximately the average trade share for OECD economies in 2014.

The elasticity of substitution σ is an important parameter, since it determines a country's ability to influence its terms of trade. In our baseline, we start with the commonly used value of $\sigma = 1.5$ (e.g., BKK, 1994).

In Section 4.1.1 we will conduct a sensitivity analysis with respect to the persistence and variance of shocks, ρ and σ_ε^2, and with respect to the trade share parameter ζ and the elasticity of substitution parameter σ. These parameters are all important for understanding the potential gains from international asset trade and thus the welfare implications of imposing capital controls.

3.1 Computation

Because welfare differences across market structures are generally small, it is important that we are able to accurately characterize equilibrium allocations. We take a third-order local approximation to all the equilibrium conditions around the non stochastic steady state, using the DYNARE package. By taking a third-order approximation, we both incorporate the effects of uncertainty on optimal choices and also capture how the impact of uncertainty varies with the levels of state variables. It is well known that if a two country (or small open) bond economy is approximated linearly, the resulting law of motion for the bond position is non-stationary. A subsequent literature emerged on "closing" small open economy models (Schmitt-Grohe and Uribe, 2003). Taking a second-order approximation to the same economy is sufficient to capture the precautionary motive for bond holding – which manifests as a lower average equilibrium interest rate – but it is not sufficient to capture how the strength of this precautionary motive varies with the net foreign asset position. As a result, the law of motion for bonds remains non stationary. A third-order approximation captures the fact that the precautionary motive is decreasing in net foreign wealth: as one country accumulates a large net position in risk-free bonds, while the other becomes more leveraged, the precautionary motive to save weakens in the first country and strengthens in the second, and these effects tend to push the net foreign asset position back toward zero. Thus, the net foreign asset position in our third-order-approximation-based simulations is stationary, even though we have not introduced any ad hoc devices (such as wealth-varying discount factors or quadratic bond holding costs) to make it so.

Nonetheless, absent a closed-form solution, it is difficult to assess the accuracy of any numerical approximation. With a local approximation, there is always the concern that while the approximation may be extremely good in the neighborhood of the steady-state, the approximation quality might deteriorate if large and persistent shocks push the state variables far from their steady-state values. To partially address this concern, we have also used global methods to solve for transitions to large one-off shocks. In particular, we use variants of shooting methods to solve for transitions in response to one-time shocks and compare the impulse responses to those in our model when the variance of innovations is set to zero. We find that the dynamics are virtually identical across the two solution methods.

4 Results

We start by describing how we compare welfare across market structures.

Let $V_i^{BE}(z_1, z_2, k_1, k_2, B_1; (\tau_1, \tau_2))$ denote expected lifetime utility for country 1 under the baseline bond economy market structure, conditional on a policy vector (τ_1, τ_2) and an aggregate state defined by the current log productivity vector (z_1, z_2), the inherited cross-country distribution of capital (k_1, k_2), and an inherited NFA position $B_1 = -B_2$. We take as our reference point for welfare comparisons the bond economy model with no taxes on capital flows in either country, so $\tau_1 = \tau_2 = 0$. Let asterisks $(*)$ denote deterministic steady-state values. We focus on comparing welfare when $k_1 = k_2 = k^*$, when $z_1 = z_2 = z^* = 0$, and when $B_1 = B_2 = 0$, though we will also explore how the incentive to impose taxes changes when countries start from asymmetric initial positions, for example, when one country is relatively more productive, so that the likely direction of capital flows is known ex ante.

We report three sets of results. The first, "unilateral capital controls," describes allocations and welfare as we vary the tax rate parameter τ_1 in country 1, holding the tax parameter in country 2 fixed at $\tau_2 = 0$. Within this section we analyze how the optimal value for τ_1 depends on (i) key model parameters, (ii) the initial state of the economy, (iii) the country's ability to influence the world interest rate, and (iv) the specific functional form for taxes.

In the second set of results, "capital control wars," we characterize a Nash equilibrium for the model, when each country maximizes its own citizens' expected welfare, taking as given the tax rate of its trading partner.

In the third set, "Pareto-improving capital controls," we consider whether and when symmetric capital controls can be welfare improving for both countries, relative to free trade in bonds.[1]

4.1 Unilateral Capital Controls

We define the welfare gains for country i from country 1 unilaterally imposing a tax rate parameter τ to be the constant percentage increase in consumption in all dates and states in the economy with $\tau_1 = \tau_2 = 0$ that leaves the representative agent in i indifferent between $\tau_1 = \tau$ and $\tau_1 = 0$ (holding fixed $\tau_2 = 0$). Given our baseline utility function (log separable in consumption), the welfare gain is

$$\omega_i^U(\tau) = \exp\left[V_i^{BE}(z^*, z^*, k^*, k^*, 0; (\tau, 0)) - V_i^{BE}(z^*, z^*, k^*, k^*, 0; (0, 0))\right] - 1. \quad (18)$$

We will be particularly interested in the value for τ that is optimal for country 1, from a unilateral perspective, given $\tau_2 = 0$. In order to put in perspective the magnitude of the welfare gains from imposing capital controls, we will also compute the welfare gains of moving from the bond economy with $\tau_1 = \tau_2 = 0$ to complete markets and to financial autarky.

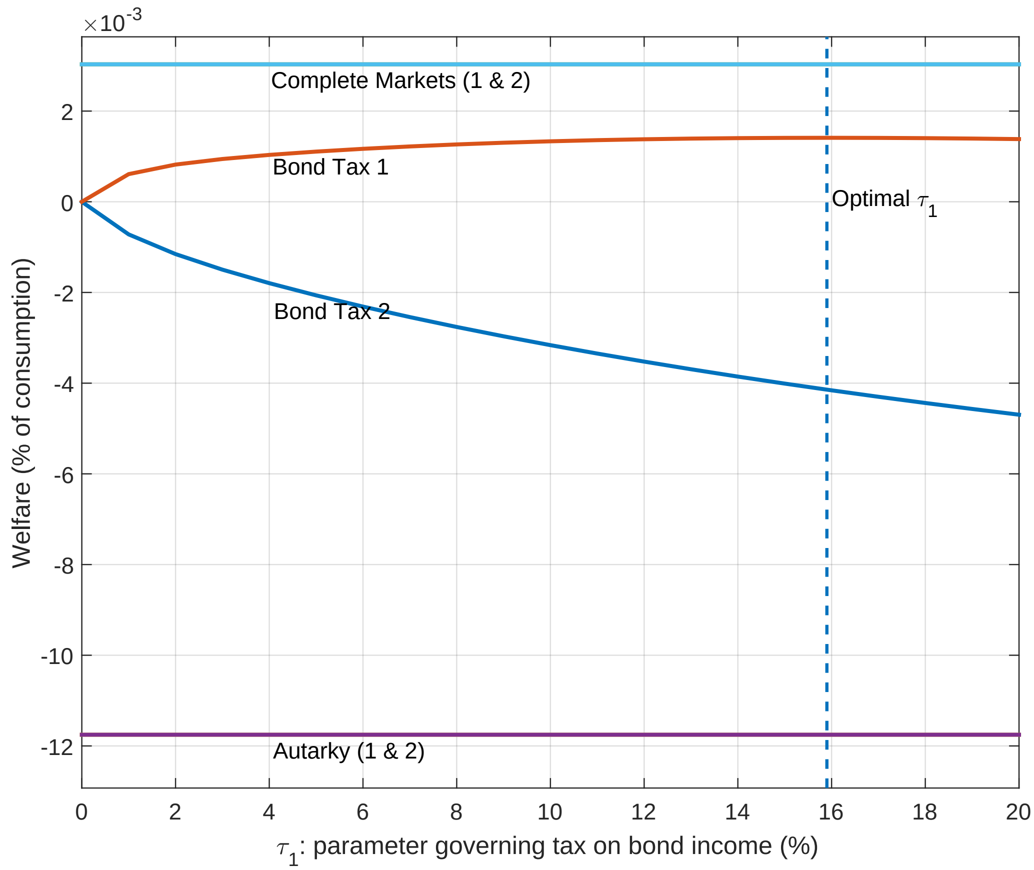
Figure 1 plots the welfare gains from unilateral capital controls for a range of values for country 1's tax rate on bond income. The first key message is that country 1 benefits from a positive tax rate on foreign bond income. The welfare-maximizing tax parameter is 0.159, meaning that if the NFA-to-GDP ratio were to reach 100 percent, bond income would be taxed at a rate of 15.9 percent.

The welfare gain from imposing the unilaterally optimal tax is equivalent to a permanent 0.0014 percent increase in consumption. This is roughly half the welfare gain of moving from an economy with only bond trade to one with complete markets. The welfare gain from completing markets is itself small, because the welfare cost of business cycles is small in this class of models (see Lucas, 1987).

While imposing a positive capital tax is welfare improving for country 1, these gains come at the expense of country 2. In fact, for any tax rate in country 1, the losses for country 2 exceed the

[1] See Heathcote and Perri (2014) for a general discussion of global efficiency in this class of models.

Figure 1: The welfare implications of unilateral taxes.



gains for country 1. As we will explain, this arises because taxing capital flows moves the world interest rate in a way that expands the feasible budget set for country 1 while shrinking the budget set for country 2.

To quantify the impact of imposing unilaterally optimal taxes on capital flows, we compared the average absolute NFA to GDP ratio across two versions of the model: one with zero taxes, and one in which country 1 imposes the unilaterally optimal tax. We ran 500 simulations of each economy, with the same sequence of shocks in each simulation pair and with each simulation of length 400 periods (100 years). The average absolute NFA position (as a share of GDP) is 45.2 percent without taxes but only 15.1 percent with the unilaterally optimal tax. The average absolute tax rate in the latter economy is 2.4 percent (this is the product of the tax parameter and the average absolute

NFA position). We conclude that the incentive to tax capital flows in the baseline calibration is large, in the sense that the unilaterally optimal tax substantially moderates net foreign asset positions.

Figure 2 plots impulse responses to a positive 1 standard deviation productivity shock in country 1, again using the parameters described in Table 1.[2] The blue lines report the responses assuming no taxes in either country. The red lines show the responses when country 1 imposes the unilaterally optimal tax ($\tau_1 = 0.159$). Panels A, B, C, and D report, respectively, net exports, the net foreign asset position, the ex post net return to domestic saving, and the ratio of consumption across countries.

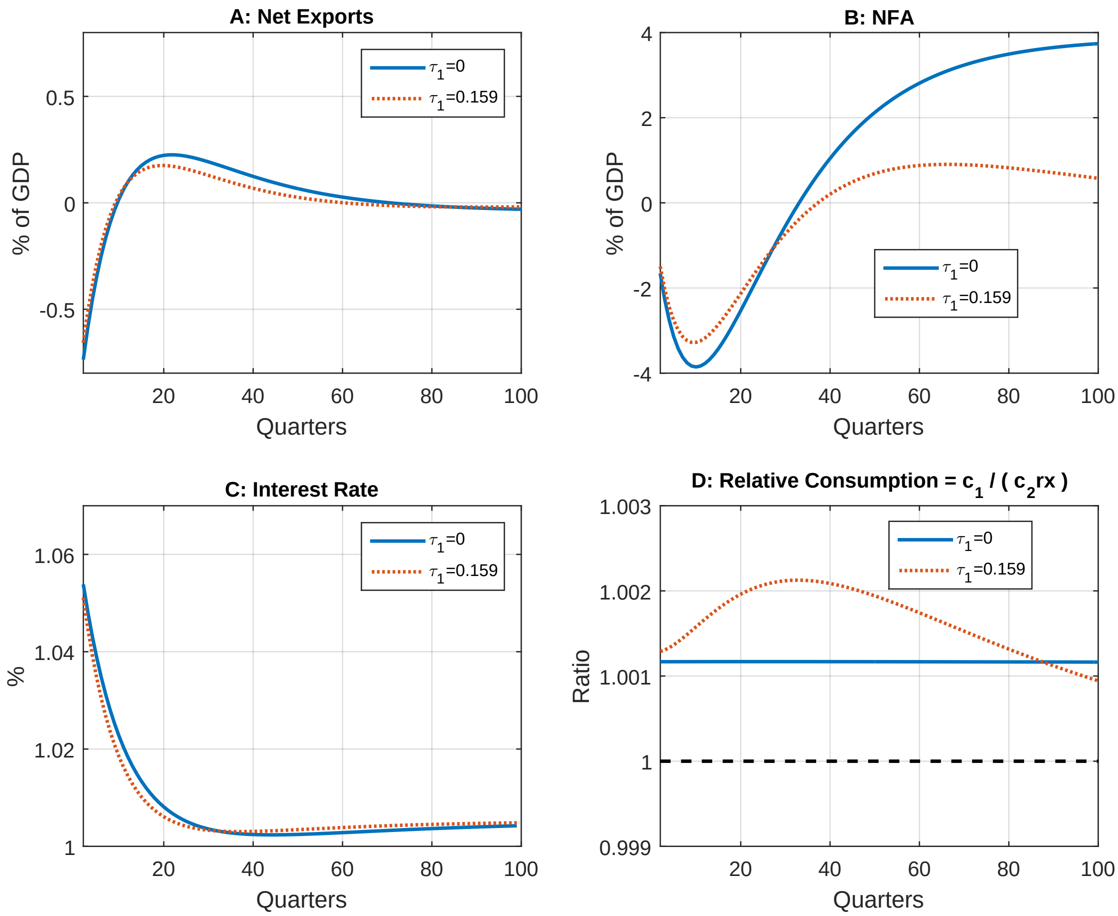
Absent a tax, the dynamics are well understood. Country 1 (with the positive shock) borrows initially to finance investment, and then runs a trade surplus to accumulate a positive NFA position. This saving phase reflects country 1's understanding that the gain to productivity is transitory. Interest rates rise on impact, reflecting an initial scarcity of capital relative to productivity, but decline quite swiftly as capital is accumulated and productivity decays. Relative consumption in country 1 jumps when the shock hits but remains constant thereafter.

When country 1 taxes capital flows at the ex ante unilaterally optimal rate, the tax initially operates as a tax on borrowing (since the NFA position is negative in the period immediately following the shock). Thus, the tax initially increases aggregate world demand for saving and drives down the pre tax interest rate. Later, in the phase when country 1 is a net creditor, the tax operates as a tax on saving, driving up the pre tax interest rate. The policy therefore allows country 1 to borrow more cheaply when it wants to borrow, and to earn higher returns on its saving when it wants to save.

A related way to understand the source of welfare gains is that in the initial phase, country 1 has high demand relative to its own output (it is a net importer), and it is therefore in country 1's interests to cheapen output (relative to output at other dates), which it can do by restraining domestic demand. In the later phase, country 1 has low demand relative to its output (it is a net exporter), and country 1 therefore wants to make its output more expensive, which it can

[2]The starting point for these impulse responses is the non stochastic steady state. In the first period, country 1 receives a one standard deviation innovation to productivity. In each subsequent period (and in both countries), the innovations to productivity are such that realized productivity in each country i at each date t is equal to its expected value at $t-1$.

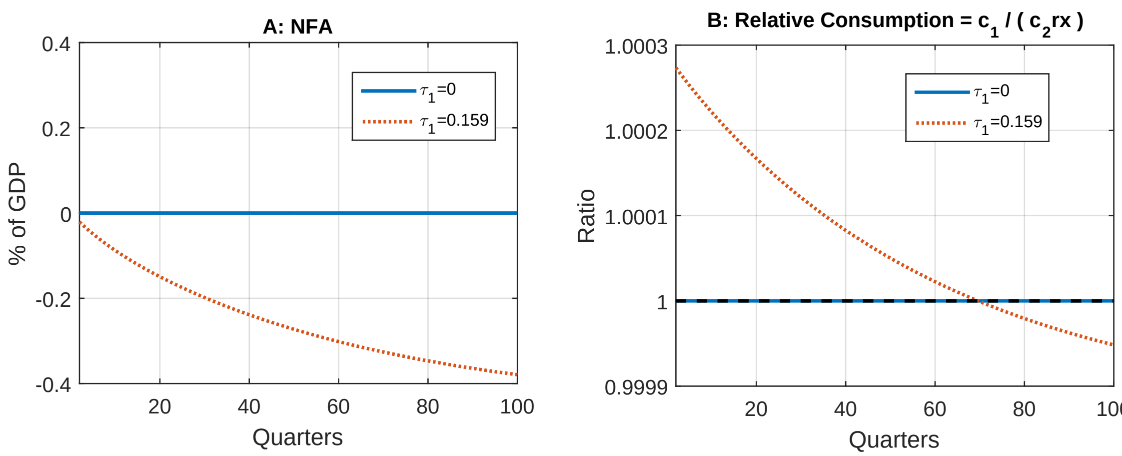
Figure 2: Responses to a 1 s.d. productivity shock in country 1 with and without capital controls.



achieve by stimulating domestic demand. By moving the intertemporal relative price of output (i.e., the interest rate) in this way, country 1 can increase its average consumption relative to its average output. Panel D shows that the capital control policy allows country 1 to generate higher consumption, relative to country 2, over the first 90 quarters of transition. This partially accounts for country 1's welfare gain. Another portion of country 1's welfare gain comes from working fewer hours.

To further highlight the welfare gains offered by unilateral capital controls, Figure 3 plots impulse responses identical to those in Figure 2, except that here there are no shocks at date zero (as in Figure 2, there are no shocks at any future dates either). With $\tau_1 = 0$, and in the absence of any shocks countries are symmetric and there are, naturally, no dynamics for the net foreign asset position (the solid line in panel A). In the economy with $\tau_1 = 0.159$, by contrast, even though countries start from a symmetric state and face identical realizations for productivity, country 1 increases initial consumption relative to country 2, which it finances by running a trade deficit. The logic is that agents make decisions taking as given a positive expected variance for shocks. They anticipate that these shocks will drive fluctuations in the net foreign asset position and that country 1's capital tax policy will systematically move up the interest rate in states when country 1 is a net creditor and down in periods when country 1 is a net debtor. Given these expectations, agents in country 1 feel rich relative to those in country 2 (even though productivity is identical across countries) and adjust consumption accordingly.

Figure 3: Responses to a 0 s.d. productivity shock in country 1 with and without capital controls.



4.1.1 Sensitivity

We now conduct sensitivity analysis with respect to four important parameters: (i) the persistence of the shocks ρ, (ii) the variance of shocks, σ_ε^2, (iii) the elasticity of substitution between imported and domestically produced intermediates σ, and (iv) the import share defined by ζ. The results are reported in Table 2.

The case with more persistent shocks ($\rho = 0.995$ versus 0.95 in the baseline) is interesting given that developing economies seem to experience larger and more persistent fluctuations (see, e.g., Neumeyer and Perri, 2005, and Aguiar and Gopinath 2007). With more persistence, the optimal tax parameter is smaller, but the welfare gains from imposing capital controls are similar.

The unilaterally optimal value for τ is independent of the variance of productivity shocks. However, the welfare gains from imposing capital controls quadruple when the variance of shocks is doubled.

The welfare gains from capital controls are larger when the elasticity of substitution between traded goods (σ) is either larger or smaller than our baseline case ($\sigma = 1.5$). With a low elasticity ($\sigma = 0.5$), changes in demand have a large impact on the intratemporal terms of trade, and the potential gains from imposing capital controls become quite large: 0.05 percent of consumption. In Section 4.1.3 we dig deeper into how changes in the time path of the (intra-temporal) terms of trade effectively translate into changes in the domestic interest rate. With higher elasticities, the potential gains from capital controls are again larger than under the baseline calibration, reaching 0.02 percent when $\sigma = 100$, in which case the two goods are near perfect substitutes.

This result indicates that the logic for taxing capital flows in this model is not simply that capital controls are a second-best substitute for optimal static good-specific tariffs, since with such a high elasticity of substitution the terms of trade is essentially fixed. Thus, with $\sigma = 100$, the incentive to tax capital flows derives solely from the incentive to manipulate the interest rate. With highly substitutable goods, international capital flows are large, since productivity shock driven fluctuations in relative investment are not tempered by offsetting movements in the terms of trade. Because there is more international borrowing and lending, net foreign asset positions are larger: in the case $\sigma = 100$, the average absolute NFA position in our 400-period simulations is almost 400 percent of GDP, absent any taxes on capital flows. Given these large NFA positions, countries have more to gain from interest rate manipulation.

Welfare gains from imposing capital controls are smaller the more closed is the economy, because taxes imposed unilaterally in one country have less and less of an impact on world prices. Consider, as an extreme, the Brandt, Cochrane, and Santa-Clara (2006) example of hypothetical trade between Earth and Mars. In this case ($\zeta = 1$ in the context of our model) ,country 1 (Earth) would clearly have nothing to gain from unilaterally imposing capital controls.

In sum, the countries that likely have the most to gain from imposing capital controls are those that are very open and face large and/or persistent productivity shocks.

Table 2: Sensitivity Analysis

	τ_1^* (%)	welfare (%) $\omega_1^U(\tau_1^*)$		τ_1^* (%)	welfare (%) $\omega_1^U(\tau_1^*)$
persistence of shocks			variance of shocks		
$\rho = 0.9$	29.3	0.0014	$\sigma_\varepsilon^2 = 0.01$	15.9	0.00035
$\rho = 0.95$	15.9	0.0014	$\sigma_\varepsilon^2 = 0.02$	15.9	0.0014
$\rho = 0.995$	1.73	0.0015	$\sigma_\varepsilon^2 = 0.04$	15.9	0.0056
elasticity of substitution			imports/GDP		
$\sigma = 0.5$	10.1	0.0499	$is = 0.15$	41.6	0.0012
$\sigma = 1.5$	15.9	0.0014	$is = 0.3$	15.9	0.0014
$\sigma = 5.0$	1.55	0.0089	$is = 0.75$	5.1	0.0022
$\sigma = 100$	1.36	0.0198			

4.1.2 Conditional Capital Controls

To this point, we have assumed that the capital control policy is imposed once and for all at a time when the two countries are perfectly symmetric. However, we can also ask whether there are incentives to tax capital flows when the initial state vector, in particular productivity, is asymmetric. There are two reasons to do this. The first is that this experiment sheds light on whether a policy of capital controls is, loosely, time consistent. The second is that we know that the benefits from international capital flows are larger when countries have different initial productivity so one might think that with different initial productivity, the case for capital controls might be weakened. Table 3 reports optimal tax parameters and the resulting welfare gains when country 1 starts with different levels of initial log productivity, z_{10}. In each case, country 2 initial log productivity is fixed at $z_{20} = 0$.

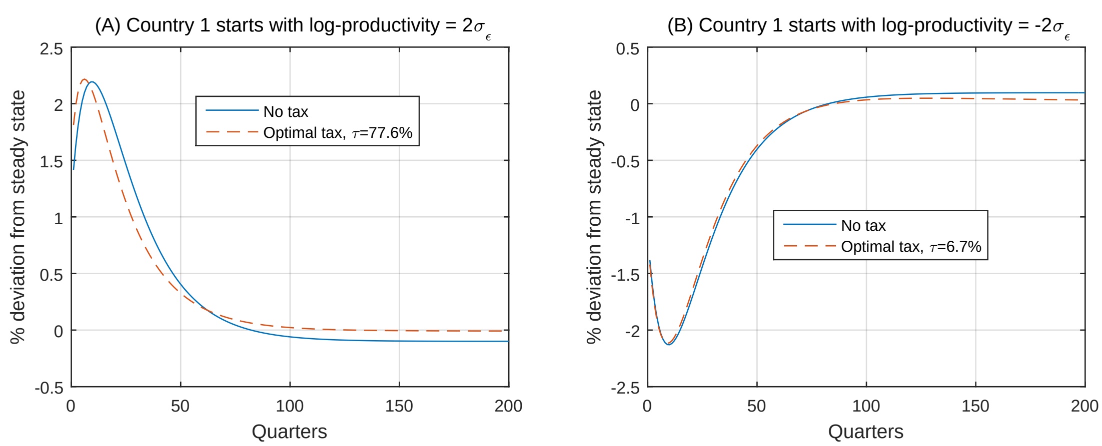
Table 3. Conditional Capital Controls

Initial log productivity in country 1 z_{10}	$\tau_1^*(z_{10})$ (%)	welfare (%) $\omega_1^U(\tau_1^*(z_{10}))$
$2\sigma_\varepsilon$	77.6	0.0022
σ_ε	37.5	0.0013
0	15.9	0.0014
$-\sigma_\varepsilon$	8.3	0.0022
$-2\sigma_\varepsilon$	6.7	0.0032

The optimal tax parameter for country 1 is always positive and is increasing in its own productivity. Notice also that the welfare gains are U-shaped: when country 1 starts with either much higher or much lower productivity than its partner, it has stronger incentives to set capital controls than when the two countries are equally productive. In order to understand the economics behind these results, it is useful to focus on two roles played by capital controls. The first role is the one highlighted in the previous section: capital controls give the country that imposes them more favorable interest rates on intertemporal trade. Naturally, when countries start from asymmetric positions, there is more equilibrium intertemporal trade (the country with higher productivity borrows from the less productive country to finance investment) and thus larger potential gains from imposing capital controls.

The second role of capital controls is to change the dynamic response of the terms of trade to a productivity shock. Figure 4 depicts the response of the terms of trade when country 1 starts with log productivity z_{10} equal to $2\sigma_\varepsilon$ (panel A) and when country 1 starts with $z_{10} = -2\sigma_\varepsilon$ (panel B). In each scenario, the solid line shows the case with no taxes, and the dashed line shows the case with initial-condition-specific optimal taxes: $\tau_1^*(2\sigma_\varepsilon) = 77.6$ percent and $\tau_1^*(-2\sigma_\varepsilon) = 6.7$ percent. Recall that the terms of trade is defined as the price of good b relative to good a, so country 1 prefers a low terms of trade.

Figure 4: Dynamics of the terms of trade.



Focus first on the solid line in panel A. When country 1 experiences a positive shock, the terms of trade jumps on impact as the higher supply of the domestic good reduces its price. The terms of trade keeps increasing as country 1 increases investment to take advantage of (temporarily) higher productivity and finally slowly falls. Notice that in the long run the terms of trade falls below its steady state level. The reason is that country 1 ends up with persistently higher wealth, and hence country 1 works less and produces less of good a. Now consider the effect of the tax on capital inflows (the dashed line). The tax reduces capital inflows and investment in the short run. In the very short run, less investment (which is intensive in the domestic good) reduces the demand for good a, and thus deteriorates the terms of trade. In the medium run, though, less investment means less production of the domestic good, and thus a more favorable terms of trade. In the long run, the tax reduces the accumulation of foreign assets, and this deteriorates the terms of trade. The key question is which of these three phases dominates. To answer this, we compute, along the entire impulse response, the net present value of the change in the terms of trade brought about by the optimal capital control policy when country 1 starts with a given productivity, that is, the quantity

$$G(z_{10}) = (1-\beta)\sum_{t=0}^{\infty}\beta^t\left(p_t^{\tau_1=\tau_1^*(z_{10})} - p_t^{\tau_1=0}\right)|_{z_{10}},$$

where $p_t^{\tau_1=\tau_1^*(z_{10})}$ and $p_t^{\tau_1=0}$ represent the terms of trade under the optimal initial-condition-specific tax parameter and under zero taxes.[3] We find that for the impulse response plotted in Figure 4, $G(2\sigma_\varepsilon) < 0$. This suggests that the quantitatively dominant effect of taxes on the terms of trade is that high taxes on capital inflows reduce output and improve the terms of trade in the medium run. This is one channel through which capital controls improve welfare in country 1. This finding can perhaps shed light on the long-standing puzzle that capital does not appear to flow into fast-growing countries (Gourinchas and Jeanne, 2013). Restricting capital inflows in such countries restrains the increase in the relative supply of locally produced goods, translating into a more favorable time path for the terms of trade.

Now consider the case of a negative productivity shock (panel B). Here the dynamics are reversed as country 1 exports resources on impact and ends up with a long run negative net foreign asset

[3]The quantity G is of a similar magnitude if instead of discounting future values for the terms of trade at a constant rate β, we discount using the domestic household's marginal rate of substitution.

position. Capital controls in this case improve country 1's terms of trade in the short and in the long run, and worsen the terms of trade in the medium run. We find that in this case a large tax is not desirable, because it would induce a large unfavorable medium-run change in the terms of trade. But a small tax generates a favorable pattern for the terms of trade (the dashed line) because with a small tax the long-run improvement dominates, (i.e., $G(-2\sigma_\varepsilon) < 0$). This finding suggests that the dynamic terms of trade changes brought about by taxes are key to explaining why a small (but not a large) tax is desirable when a country starts with low productivity relative to its trading partner.

To summarize, this section establishes that the incentive to unilaterally set capital controls remains strong for countries that start with productivity that is either higher or lower than their trading partner, and that a key reason why is that in both situations, capital controls can induce favorable changes in the terms of trade for the country which imposes them. Thus, countries will be tempted to unilaterally impose capital controls even in situations in which differential productivity makes international capital flows particularly valuable from a global perspective.

4.1.3 Interest Rates versus Exchange Rates

Thus far, we have considered the case for capital controls in an environment with two large countries. Each country, by unilaterally enacting policies to stimulate consumption or saving, can influence both the world interest rate and the equilibrium terms of trade. We now explore the extent to which the logic for capital controls hinges on a country's ability to affect the interest rate in the rest of the world. We consider two alternative ways to reduce country 1's ability to influence interest rates. In the first, we assume $\gamma = 0.01$, so that the intertemporal elasticity of substitution is very large. In this case, unilaterally imposing a tax $\tau_1 > 0$ will have a negligible impact on the foreign interest rate, which will always approximately equal the rate of time preference. In the second, we assume that country 1 is small relative to country 2, by recalibrating such that steady-state GDP in country 1 is only one twentieth that of country 2. In this case, we retain the assumption that imports are 30 percent of GDP in country 1, which mechanically implies a much smaller trade share for country 2. Results are in Table 4.

Table 4 : Interest Rates versus Exchange Rates

σ	τ_1^* (%)	welfare (%) $\omega_1^U(\tau_1^*)$	τ_1^* (%)	welfare (%) $\omega_1^U(\tau_1^*)$	τ_1^* (%)	welfare (%) $\omega_1^U(\tau_1^*)$
	Baseline calibration		Low risk aversion $\gamma = 0.01$		Asymmetric size $\frac{GDP_1}{GDP_2} = \frac{1}{20}$	
1.5	15.9	0.0014	0.31	0.0133	20.6	0.0016
5	1.55	0.0089	0.14	0.0034	0.24	0.0026
100	1.36	0.0198	3.90	0.0047	0.044	0.0007

The parameterization with $\gamma = 0.01$ is a simple way to assess the incentives to tax capital flows for a country that is too small to influence the world interest rate, but which has some influence over its terms of trade because it exports particular goods or varieties that are imperfect substitutes for those produced abroad. When the elasticity of substitution σ between domestic and foreign intermediates is 1.5, the unilaterally optimal tax is $\tau_1 = 0.31$, and the corresponding welfare gain (relative to free bond trade) is 0.0133 percent of consumption, an order of magnitude larger than under the baseline calibration with $\gamma = 1$. In contrast, with higher elasticities of substitution σ, the welfare gains from capital controls are smaller than in the corresponding cases with $\gamma = 1$.

Results in the asymmetric size case are qualitatively similar. Again, the main takeaway is that even if a country is small, so that it cannot affect the world interest rate very much, the country can still gain from unilaterally imposing taxes on capital flows, as long as it still has some ability to influence the terms of trade. The incentive to impose capital controls only becomes small when a country is both small and also produces a good that is a near perfect substitute for goods produced abroad ($\sigma = 100$), in which case it has little power to influence any prices. However, most trade models assume that countries produce differentiated goods, since this is a natural way to motivate the very existence of trade. The very high elasticity case is therefore less empirically relevant than the other parameterizations.

To understand why a country can gain from taxing capital flows, even though it cannot influence the rest-of-world interest rate, consider a slight modification to the model such that agents are perfectly risk neutral and such that the bond traded internationally pays one unit of country 2 consumption.[4] In that case, because the pre-tax gross return to saving in country 2 is pinned down at β^{-1}, the bond price (in units of domestic consumption) is simply $P(s^t) = \beta rx(s^t)$. Thus, the

[4] The expressions that follow still apply with the original symmetric bond payout, subject to a minor approximation..

gross pretax return to saving in country 1 is $\beta^{-1} rx(s^{t+1})/rx(s^t)$. By subsidizing saving at date t, country 1 can reduce demand at t relative to $t+1$, causing the real exchange rate to appreciate in expected terms between t and $t+1$ (i.e., causing rx to fall). This reduces the expected pre-tax return to saving at date t in country 1. More concretely, in the event of a positive productivity shock in country 1 at date t, country 1 will naturally borrow heavily both to finance investment and to increase consumption (country 1's preferences are tilted toward the now relatively abundant good a). If country 1 has set $\tau_1 > 0$, the extent of this borrowing will be reduced, lowering aggregate demand for good a and depreciating the real exchange rate (increasing rx) relative to the free trade case. A higher value for $rx(s^t)$ means that country 1 can sell bonds at a higher price (i.e., it can borrow more cheaply).

We conclude that the case for imposing capital controls that this paper explore does not apply exclusively to countries that are large enough to influence world interest rates. Rather, as long as countries produce differentiated goods, policies that encourage or discourage domestic demand and supply will change the path of the terms of trade and the real exchange rate, and thereby affect the return to international borrowing and lending.

4.1.4 Alternative Model for Taxes

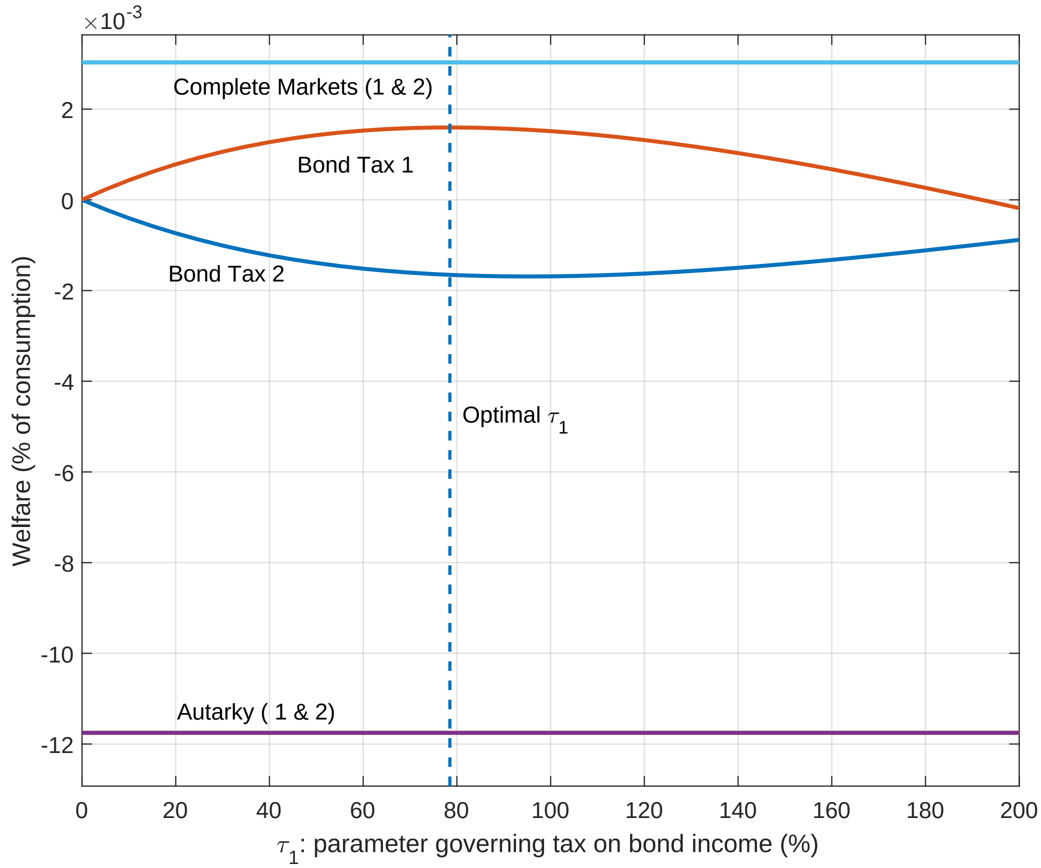
Our baseline model for taxes hard-wires that taxes or subsidies on saving are proportional to the NFA to GDP ratio. We now consider one alternative, which is to make the tax proportional to the change in the NFA position:

$$\tau_i(s^t) = \tau_i \frac{\left[B_i(s^{t-1}) - B_i(s^{t-2})\right]}{GDP_i(s^t)}.$$

In this case, if $\tau_i > 0$, then saving will typically be discouraged when net exports are positive, so that a country is a net seller of output, and discouraged with net exports are negative. In this case, under our baseline calibration, we find that the value for τ_1 that maximizes expected welfare for country 1 given $\tau_2 = 0$ is 78.5 percent, and the corresponding welfare gain is 0.0016 percent of consumption, which is similar to the welfare gain under our baseline tax specification (0.0014). However, implementing such a tax system would likely imply more high-frequency volatility in tax rates, given that changes in NFA positions are more volatile than the level of the NFA position.

Figure 5 plots the analogue to Figure 1 for this model of taxes.

Figure 5: The welfare implications of unilateral taxes, under the alternative model for taxes.

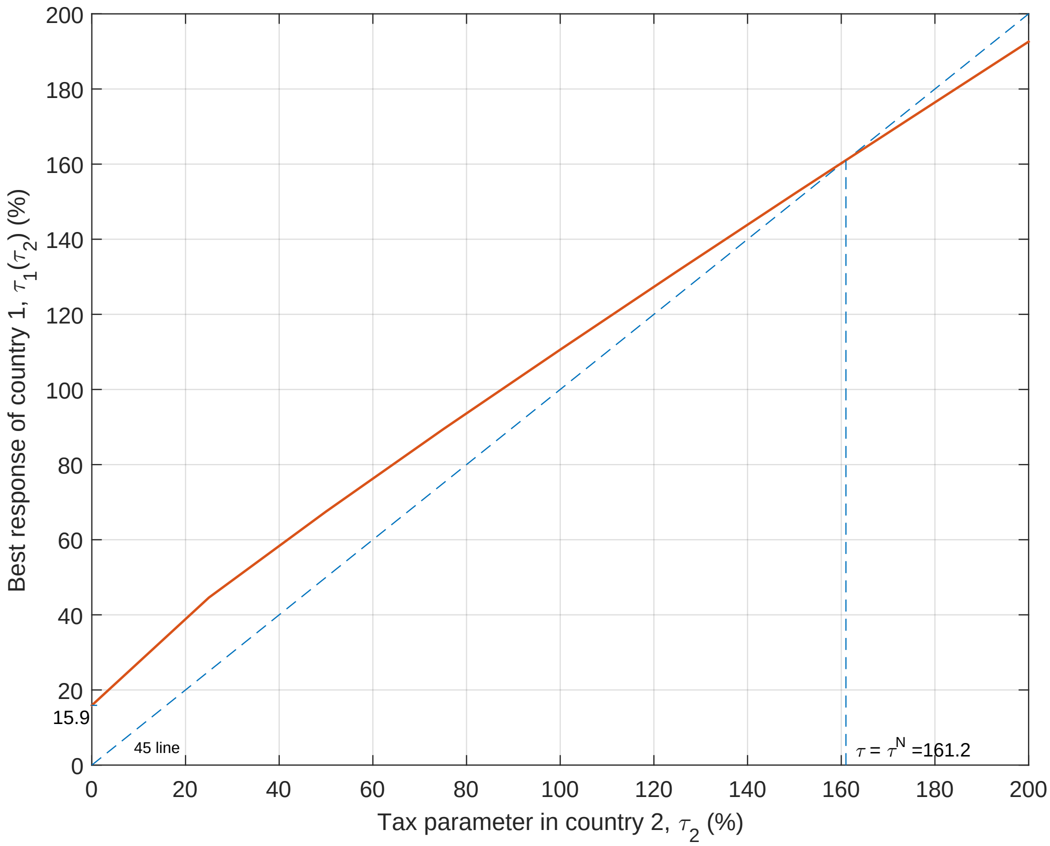


4.2 Capital Control Wars

So far we have analyzed the case in which country 1 sets τ_1 optimally and country 2 does not react. We now consider the case in which both countries set taxes optimally, taking as given the policy choice of their trading partner. In particular, we compute the optimal value for τ_1 for any given value for τ_2 and look for a fixed point τ^N such that if $\tau_2 = \tau^N$, then the welfare maximizing value for τ_1 is also τ^N. Because we search for this fixed point at the symmetric steady state, a solution τ^N that is a best response for country 1 given $\tau_2 = \tau^N$ is also a best response for country 2 given $\tau_1 = \tau^N$.

Figure 6 displays the reaction function of country 1, that is the optimal value for τ_1 given many

Figure 6: Best response capital control policy



possible values for τ_2. Note that the function has an intercept equal to 15.9 percent (the optimal unilateral tax studied in Section 4.1), that it is increasing and concave, and that it has a fixed point for a value of the tax parameter of $\tau^N = 161.2$ percent. The intuition for why the reaction function is increasing and concave is as follows.

As we discussed earlier, a country imposes taxes because they induce a change in the interest rate in its favor; thus the benefit of the tax is proportional to the amount which is borrowed or lent in equilibrium. The cost of tax is that it reduces the opportunity for intertemporal smoothing. The optimal tax is the one that equates costs and benefits on the margin. When the foreign country imposes no tax, there is a large amount of equilibrium intertemporal trading, and a small tax can yield a large enough benefit to offset the cost. When the foreign country imposes a larger tax, an equally large domestic tax is required to ensure that equilibrium international prices favor neither country. Pushing taxes even higher to allow the domestic country to regain relatively favorable prices becomes less attractive as tax rates in both countries rise, because with less intertemporal trading, the value of interest rate manipulation declines, and at the same time the cost of forgoing consumption smoothing increases.

Table 5 reports welfare and the average absolute net foreign asset position over GDP (a measure of intertemporal trade) for three versions of the model: (i) free bond trade (which is also the solution for a global planner who can choose τ to maximize average expected welfare across both countries), (ii) for the Nash equilibrium described earlier, and (iii) for financial autarky. In each case, tax parameters and welfare are identical across countries. For the three respective values for the tax parameter ($\tau = 0$, $\tau = \tau^N$, and $\tau = \infty$), welfare is defined as

$$\omega^G(\tau) = \exp\left[V^{BE}(z^*, z^*, k^*, k^*, 0; (\tau, \tau)) - V^{BE}(z^*, z^*, k^*, k^*, 0; (0, 0))\right] - 1.$$

Table 5. Welfare and Intertemporal Trade under Three Regimes

	tax parameter τ (%) $\tau_1 = \tau_2 = \tau$	avg. $\frac{\lvert NFA \rvert}{GDP}$ (%)	welfare (%) $\omega^G(\tau)$
Free Bond Trade	0	45.2	0
Capital Control Wars	161.2	2.9	-0.0082
Autarky	∞	0.0	-0.0117

The table shows that in the case of capital control wars, both countries suffer a welfare loss of 0.0082 percent relative to the free bond trade, a loss that is comparable to what countries would experience if they were in financial autarky. Another way of looking at the effect of these taxes is to observe that the average absolute net foreign asset position falls from 45 percent of GDP to 2.9 percent of GDP.[5] Thus, a regime of tax competition yields inefficient outcomes and a large reduction in intertemporal trade.

4.3 Pareto-Improving Capital Controls

We now move to establish a novel result, which is that symmetric capital controls imposed in both countries can be unconditionally welfare improving starting from a symmetric initial state. For

[5]The statistics are computed averaging across 500 simulations, each 400 periods long.

this result, it is essential that ours is an environment in which international financial markets are incomplete. With complete markets, the undistorted equilibrium would be efficient, and introducing any taxes could only reduce welfare.

Formally, we consider a scenario in which both countries are initially identical, with productivity and capital at their nonstochastic steady-state values. We then compare ex ante welfare (equal across countries) when bonds are traded freely to welfare when both countries impose identical tax parameters $\tau_1 = \tau_2 = \tau$. We compute the value for τ that maximizes welfare for a utilitarian global planner, $\tau^{GP} = \arg\max_\tau V^{BE}(z^*, z^*, k^*, k^*, 0; (\tau, \tau))$. We then report the welfare gain of moving from $\tau = 0$ to $\tau = \tau^{GP}$, $\omega^G(\tau^{GP})$, and also the gain of moving from $\tau = 0$ to $\tau = \infty$ (i.e., the gain from imposing financial autarky), $\omega^{GP}(\infty)$.

Table 6 reports these statistics for six alternative parameterizations of the model. The first row is the baseline. The second is a low elasticity case with $\sigma = 0.5$ (similar to the value used by Corsetti, Dedola, and Leduc, 2008). The third is a high trade share case of 75 percent. Trade shares above 50 percent are quite common: examples include Poland, Czech Republic, Saudi Arabia, Korea, Malaysia, and Thailand. The remaining three rows in the table revisit the same three parameterizations but with more persistent productivity shocks: $\rho = 0.995$ versus $\rho = 0.95$.

Table 6. Pareto-Improving Capital Controls

other parameters	τ^{GP} (%)	welfare (%) $\omega^G(\tau^{GP})$	welfare (%) $\omega^G(\infty)$
baseline persistence: $\rho = 0.95$			
baseline	0.0	0.0000	−0.0117
$\sigma = 0.5$	2.1	0.0071	−0.0382
$is = 0.75$	0.5	0.0003	−0.0099
high persistence: $\rho = 0.995$			
baseline	0.0	0.0000	−0.0203
$\sigma = 0.5$	∞	0.0415	0.0415
$is = 0.75$	∞	0.0021	0.0021

Note, first, that in the baseline parameterization, the globally optimal tax is zero. Thus, if a global planner could coordinate capital control policy, it would choose zero taxes. Recall that the Nash equilibrium for this case, when countries pursue unilaterally optimal policies, is $\tau = 161$ perecent. It follows that under this parameterization, there are potential welfare gains from promoting tax collaboration rather than tax competition.

In the other cases reported in Table 6, in contrast, the welfare-maximizing tax rate τ^{GP} is strictly positive. To understand why, recall that international asset trade plays two roles in this class of models: it affects cross-country consumption risk sharing and, in an environment with production, it affects productive efficiency. Lower taxes on bond trade should improve productive efficiency, since taxes slow the flows of capital across countries and introduce a cross-country wedge in expected returns. So for nonzero taxes to be welfare improving, their presence must enhance consumption risk sharing.

One source of consumption risk sharing emphasized by Cole and Obstfeld (1991) is that the terms of trade will move inversely to relative country productivity, providing an automatic form of insurance. By changing the dynamics of the terms of trade, capital controls can potentially improve this insurance. In the low elasticity of substitution case, fluctuations in the terms of trade are too large from the perspective of providing insurance: in response to a positive productivity shock, the terms of trade moves so much that the more productive country is left relatively worse off. In this case, restricting capital flows dampens fluctuations in relative output and thus also dampens fluctuations in the terms of trade, thereby improving terms of trade insurance.

In the high trade share case, fluctuations in the terms of trade are too small from the perspective of providing insurance, but eliminating asset trade now amplifies (rather than dampens) terms of trade movements, since the cyclicality of net exports is reversed.

Given our baseline shock persistence, the low elasticity and high trade share cases are examples in which small positive taxes are Pareto improving, but ruling out international asset trade altogether is welfare reducing. When shocks are more persistent, however, financial autarky ($\tau = \infty$) is the globally optimal policy (within the class of policies we consider) in both the low elasticity and high trade share cases. The intuition is that when shocks are only moderately persistent, free trade in bonds delivers allocations that are similar to complete markets, so that cross-country consumption insurance is close to perfect. In contrast, when shocks are near permanent, trade in a noncontingent bond is of more limited value as a form of insurance. In this case, therefore, the fact that imposing capital controls can improve terms of trade insurance is of much greater potential value.

5 Conclusion

We have explored the welfare effects of imposing capital controls within a textbook international business cycle model. We found that under all plausible model parameterizations, countries can benefit by imposing taxes that restrict international borrowing and lending. Furthermore, the capital control policies that are optimal from a unilateral standpoint have quantitatively large effects and preclude the emergence of large net foreign asset positions. When countries set capital control policies in a noncooperative competitive fashion, the taxes that emerge in equilibrium are much higher again, such that allocations and welfare are similar to those under financial autarky.

More surprisingly, we also found that for certain parameterizations, imposing capital controls is Pareto improving. We traced this result to the fact that in a two-good world with incomplete markets, movements in the terms of trade are an important form of insurance against shocks to relative income. Ruling out asset trade changes the cyclical dynamics of international relative prices, and in some cases improves insurance to the point that both countries prefer permanent financial autarky to permanent free bond trade.

The simple models that we have used abstract from a variety of features that may be important when considering the possible welfare effects from introducing capital controls. For example, we have not addressed the interaction of capital controls with other policies such as the choice of exchange rate regime and other dimensions of monetary policy. We have also not discussed the perceived excessive volatility of international capital flows or the possibility of overborrowing in environments with default risk. Introducing trade in additional assets is another avenue for future research, since additional risk-sharing possibilities may reduce the scope for Pareto-improving capital controls (see, e.g., Heathcote and Perri, 2013).

Abstracting from all these features has allowed us to isolate and better understand the impact of capital controls on the dynamics of international prices and, through prices, on welfare. We found, consistent with previous work in similar settings (e.g., Cole and Obstfeld, 1991), that the welfare effects of changing international financial integration are small in absolute terms, and thus that the welfare effects of imposing capital controls are also small. Nevertheless, the policy interventions we have considered are quantitatively relevant: optimal unilateral capital controls offer welfare gains that are roughly half of those from completing markets, and capital control competition leads to allocations that are similar to financial autarky. In settings in which changes in equilibrium prices have larger effects on allocations, such as models with nominal rigidities in labor or product markets, the rationale for capital controls that we have studied would likely translate into larger effects on welfare.

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