On the Desirability of Capital Controls

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Why Capital Controls?

- Imposing capital controls restricts agents' budget sets
- But constraining choices will change equilibrium prices
- Costinot, Lorenzoni & Werning (2014) show that capital controls can move the interest rates in a favorable direction
  - Logic: when borrowing is restricted, borrower countries will pay lower interest rates (same with saving)
- Brunnermeier and Sannikov (2014) argue that capital controls can move terms of trade in a favorable direction
  - Logic: when inflows of capital are restricted, less production of domestic good, better terms of trade

What We Do

- We explore a simple policy of capital controls, but with a more quantitative approach

  - Textbook two-country stochastic growth model (Backus, Kehoe & Kydland), which includes both motives for capital controls

  - Countries use capital and labor to produce and then trade differentiated goods

  - Compare free trade in a bond versus taxes on international borrowing and lending

- Is free capital mobility close to optimal, or should governments intervene to significantly limit international capital flows?

Key Findings

Starting from symmetric initial conditions with zero NFA position, find that:

1. Acting unilaterally, a country would like to tax net foreign saving and foreign borrowing
2. Taxes notably dampen average absolute NFA position
3. When a country start with productivity different from the one of its partner, it has a stronger incentive to tax capital flows
4. The Nash equilibrium when both countries set taxes optimally is close to financial autarky (inefficient)
5. Global optimum is typically, but not always, free bond trade, in some cases both countries find it optimal to restrict capital mobility (capital controls are efficient, as they can improve insurance)

Related Literature

- Most closely related papers:
  - Costinot, Lorenzoni and Werning (2014)
  - Brunnermeier and Sannikov (2014)
  - De Paoli and Lipinska (2013)
- Other related papers:
  - Newbery and Stiglitz (1984)
  - Bianchi (2011)
  - Bianchi and Mendoza (2013)
  - Korinek (2010)
  - Martin and Taddei (2012)

Model: BKK (1994)

- Two countries, $i = 1$ and $i = 2$
- Standard preferences and technology

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\log c_{it} - n_{it}^{1+\frac{1}{\phi}} \right]$$

$$y_{it} = \exp(z_{it}) k_{it}^{\theta} n_{it}^{1-\theta}$$

- Country 1 produces a (aluminum), country 2 produces b (bricks)
- Goods a and b are traded, combined to produce final consumption / investment good (houses)

$$\begin{aligned} c_{1t} + x_{1t} &= \left[\omega a_{1t}^{\frac{\sigma-1}{\sigma}} + (1-\omega) b_{1t}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \\ c_{2t} + x_{2t} &= \left[(1-\omega) a_{2t}^{\frac{\sigma-1}{\sigma}} + \omega b_{2t}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \end{aligned}$$

$$k_{i,t+1} = (1-\delta) k_{it} + x_{it}$$

Risk and Asset Markets

- Shocks

$$z_{i,t+1} = \rho z_{it} + \varepsilon_{i,t+1}$$

$$\begin{pmatrix} \varepsilon_{1,t+1} \\ \varepsilon_{2,t+1} \end{pmatrix} \sim N(0, \Sigma)$$

- Asset Market
  - One period risk free bond in zero net supply
  - Pays 1 unit of c_1 plus 1 unit of c_2

Capital controls

- Tax τ_{it} on interest income received or paid

$$c_{1t}+P_t b_{1,t+1} = w_{1t}n_{1t}+d_{1t}+b_{1,t}\left(1+rx_t\right)-\tau_{1t}\left[b_{1t}\left(1+rx_t\right)-P_{t-1}b_{1t}\right]+Tr_{1t}$$

$$\tau_{1t} = \tau_1 \frac{B_t}{GDP_t}$$

- When country saves ($B_t > 0$) govt. tax savers and subsidizes borrowers
- When country borrows ($B_t < 0$) govt. tax borrowers, subsidizes savers

Baseline Parameterization

- $\beta = 0.99$, $\phi = 1$
- $\theta = 0.36$, $\delta = 0.015$
- $\rho = 0.95$, $\sigma_\varepsilon = 0.02$, $corr(\varepsilon_1, \varepsilon_2) = 0.3$
- ω s.t. import share is 30%
- $\sigma = 1.5$

Unilateral Capital Controls

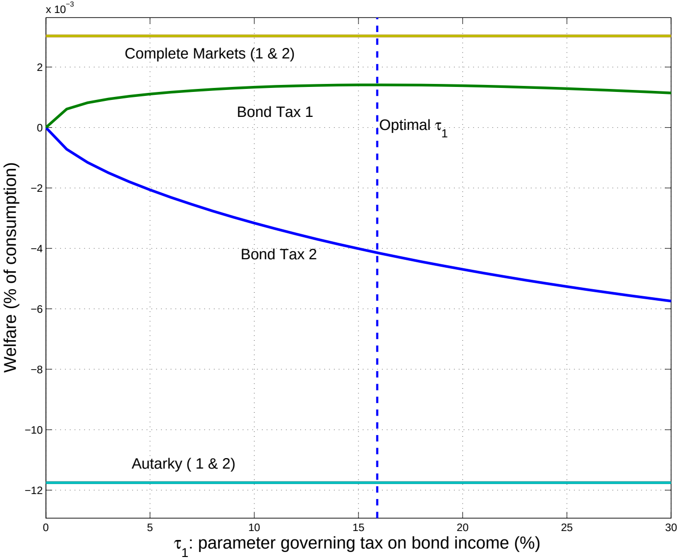
- Assumptions

  1. $\tau_2 = 0$
  2. State of the economy is non-stochastic steady state: $e^{z_1} = e^{z_2} = 1$, $k_1 = k_2 = k^*$, $B = 0$
  3. Govt. in country 1 chooses τ_1 once and for all

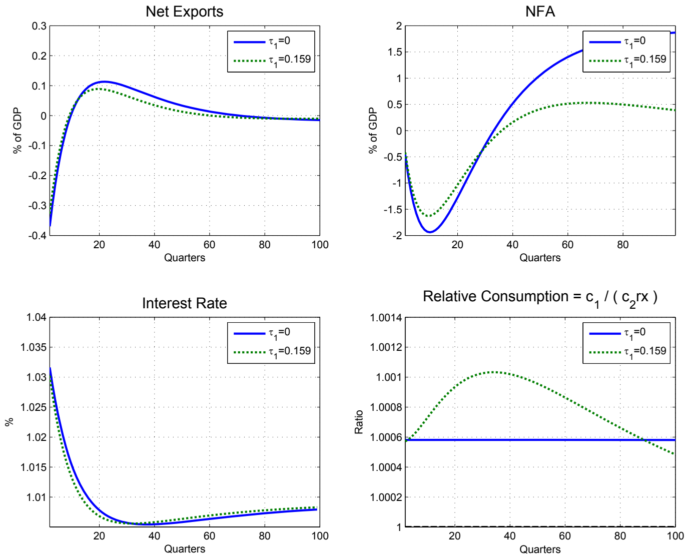
- Questions

  1. What τ_1 maximizes welfare for country 1?
  2. What are the welfare effects for both countries?
  3. How different are NFA dynamics relative to free capital mobility?

Welfare Gains from Unilateral Capital Controls



Impulse Responses with and without taxes



Unilateral Taxes

- Welfare maximizing tax parameter: $\tau_1 = 0.159$
- Welfare gain (rel. to zero tax) 0.0014% of cons.
  - Small, but equal to half welfare gain of completing markets
- Impact on average absolute NFA position significant:
  - $\tau_1 = 0.000 \Rightarrow E[\frac{|B|}{GDP}] = 45.2\%$
  - $\tau_1 = 0.159 \Rightarrow E[\frac{|B|}{GDP}] = 15.0\%$
    - (averages over 50 simulations, each of 400 periods)

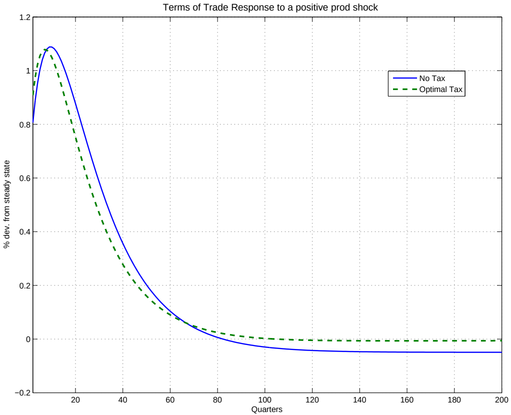
Importance of Initial Conditions

- When countries start from different initial conditions, taxes are a tool for dynamic terms of trade manipulation
- Small taxes can yield larger gain

z_1 ($z_2 = 0$)	τ_1^* (%)	Welfare Gain (%)
$-2 \times \sigma_\varepsilon$	6.7	0.0032
$-\sigma_\varepsilon$	8.3	0.0022
0	15.9	0.0014
σ_ε	37.5	0.0013
$2 \times \sigma_\varepsilon$	77.6	0.0022

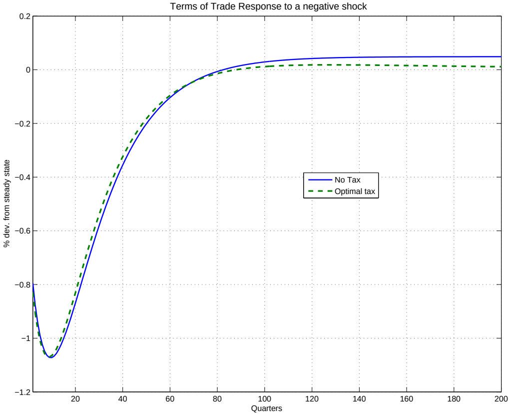
Dynamic terms of trade manipulation with pos. prod

- More productive country borrows to invest
- Sizeable bond tax reduces borrowing, investment, and future output, improves medium terms of trade



Dynamic terms of trade manipulation with neg. prod

- No tax: less productive country ends up poorer, working harder, producing more, hence worst terms of trade
- Small bond tax reduces long run imbalances, does little to short and medium run ToT, improves long run ToT



Example: Spain and Germany

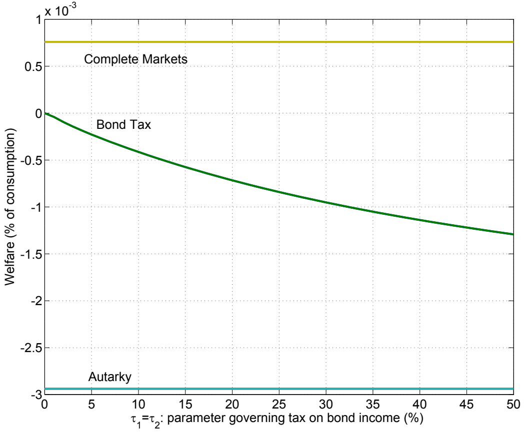
- Spain has highly productive tourism business
- Developers build hotels, borrowing from Germany
- Over time supply of Spanish hotels increases $\Rightarrow$ price of Spanish vacations falls, detrimental for Spain
  - Requires Spanish and German vacations imperfect substitutes

- Pecuniary externality: Individual developers do not internalize price effect and thus overbuild

- Might shed light on why fast-growing countries often do not borrow from abroad (Gourinchas and Jeanne, 2013)

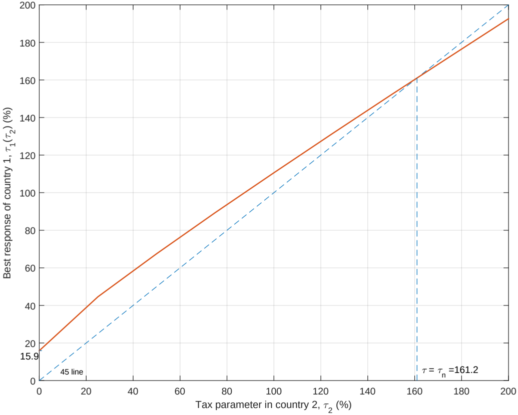
Capital Controls: Cooperation

- What common global tax rate maximizes expected welfare?
  - Baseline calibration: $\tau_1 = \tau_2 = 0$



Capital Controls: Competition

- What tax rate emerges if both countries play Nash?
  - Baseline calibration: $\tau_1 = \tau_2 = 161\%$
    $\Rightarrow$ Very large reduction in inter-temporal trade

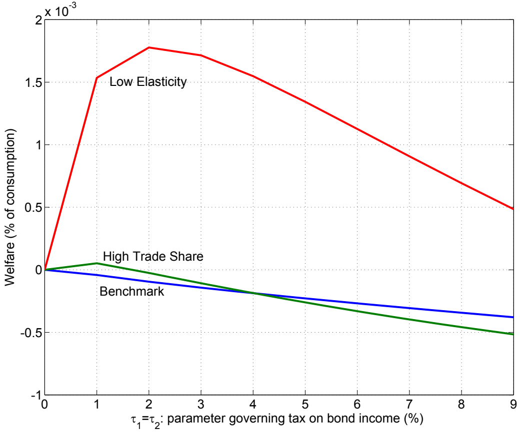


Mutually Beneficial Capital Taxes

- Asset market structure changes ToT dynamics
- With complete markets, prices induce efficient allocations $\Rightarrow$ messing with prices cannot be Pareto-improving
- But our baseline model has a friction: absence of insurance against shocks to relative permanent income
- ToT moves inversely with relative quantities, dampens fluctuations in relative permanent income, provides automatic insurance against country-specific shocks
  - Cole and Obstfeld, 1991
- Capital controls might improve or worsen this terms of trade insurance

Welfare, Global Capital Controls

1. Low elasticity of substitution $\sigma = 0.5$
2. High import share, 75%



Interpretation

- Consider a positive productivity shock in country 1
- Low elasticity case:
  - Large terms of trade response
    $\Rightarrow$ 1 relatively worse off
    $\Rightarrow$ Capital controls, by restricting investment in 1 improve ToT for 1
    $\Rightarrow$ Improve ex-ante insurance
- High trade share case:
  - Small terms of trade response
    $\Rightarrow$ 1 relatively better off
    $\Rightarrow$ Because high trade share, 1 runs impact surplus (most domestic good used abroad)
    $\Rightarrow$ Capital controls restrict outflows and foreign investment, tilt ToT against country 1
    $\Rightarrow$ Improve ex-ante insurance

Small versus Large Countries

- Does the logic for capital taxes hinge on countries being big enough to influence world interest rate?
  - Yes in a 1-good model
  - No in a 2-good model
- Illustrate this by setting risk aversion close to zero
  - 1-good model: cannot move interest rate
  - 2-good model with home-bias in preferences:

    taxes change inter-temporal demand
    $\Rightarrow$ changes path for real exchange rate
    $\Rightarrow$ changes domestic interest rate

Unilateral Capital Controls, Interest Rates vs. Exchange Rates

Risk aversion γ	Elast. of subs. σ	τ_1^* (%)	Welfare Gain (%)
0.0001	500	0	0.00000
0.0001	1.5	0.3	0.00469
1	500	1.4	0.00545
1	1.5	15.9	0.00035

- Suppose risk-neutral + bonds denominated in foreign consumption $\Rightarrow$ foreign interest rate fixed
- If borrowing, want high RER today, low RER tomorrow (low domestic interest rate)
- If lending, want low RER today, high RER tomorrow (high domestic interest rate)
- Ex ante want taxes that will discourage (ex post) both borrowing and lending

Conclusions

- Capital controls typically welfare improving for one country at the expense of its trading partner
- Capital control competition leads to large taxes on capital flows
- Capital control coordination leads to smaller taxes $\Rightarrow$ role for institutions to promote coordination
- But taxes on capital flows are sometimes Pareto-improving relative to perfect capital mobility

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Preliminary

Abstract

In a standard two country international macro model we as whether imposing restrictions on international non-contingent borrowing and lending is ever desirable. The answer is yes. Imposing capital controls is unilaterally desirable when restricting bond trade generates a sufficiently favorable change in the expected interest rates and/or terms of trade. Imposing capital controls can be welfare improving for both countries for calibrations in which changes in equilibrium terms of trade movements induced by the controls improve insurance against country specific shocks.

Keywords: Capital Controls, Terms of Trade, International Risk Sharing

JEL classification codes: F32, F41, F42

1 Introduction

We revisit the question of whether capital controls might be welfare improving relative to the case of international capital mobility. Our framework will be a set of workhorse two-country business

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cycle models where countries trade a single non contingent bond and where each country produces a specific good that is imperfectly substitutable with the output of its trading partner.

The intervention we consider is a very simple form of capital controls; in particular we assume that a planner can impose a tax on income (received or paid) form investment bonds trade internationally.

In partial equilibrium (i.e. holding prices fixed) these capital controls would be never desirable because they would simply reduce the opportunities of intertemporal smoothing of a given country. In general equilibrium though these policies alter two key prices, namely the real interest rate and the real exchange rate, and change in these prices ingeneral make capital controls desirable form the point of view of one country, and sometimes of both countries.

In two good models, the asset market structure will affect the time paths for the relative supply of domestic and foreign produced goods, and also the paths for their relative demand. The time paths for relative supply and relative demand will in turn affect the relative price of domestically versus foreign-produced goods. Atomistic price-taking agents do not internalize the effects of their choices on prices, but collectively their choices impose pecuniary externalities on other agents. For example, if domestic agents work longer hours and thereby produce more of the domestic good, they will depress the relative price of this good on world markets, imposing a negative externality on other domestic agents. This argument has been used to motivate a possible role for tariffs and export taxes in the optimal tariff literature. Here we investigate the possibility that the same pecuniary externality could motivate policy interventions to prevent international borrowing and lending.

Consider the following simple example that illustrates the idea. Suppose the domestic country (country 1) is hit by a positive persistent productivity shock. It is well known that the typical response to such a shock in models with free trade in bonds is that country 1 should run a trade deficit in the near term to finance the construction of additional capital. This extra capital allows country 1 to produce more output during the transition as the shock decays. Put simply, capital flows make it easier to make more hay where the sun shines, which is in country 1. But if country 1 is producing hay and country 2 is producing corn, this extra production of hay will depress the relative price of hay, moving the terms of trade against country 1. Agents in country 1 do not internalize the impact of their international borrowing on the terms of trade, but the government in country 1 should understand the links between domestic supply and demand on the one hand, and the terms of trade on the other. If the negative terms of trade impact on domestic welfare outweighs the advantages bond trade offers in terms of inter-temporal consumption smoothing and a more efficient global allocation of capital, the government might decide that preventing international borrowing is the best interests of its citizens.

In this example, we emphasized the role of asset trade on the relative supply of domestically and foreign produced goods. But asset trade also potentially affects relative demand. In the near term, following a positive domestic productivity shock, the extra investment that is financed by bond trade will drive up relative demand for domestic goods, but in the longer term a negative net foreign asset position for country should reduce relative domestic demand, and thus improve the terms of trade from country 1's perspective. By considering a range of alternative models we are able to disentangle the supply and demand side effects of asset market structure on the time path for the terms of trade. A clean baseline is an endowment economy, in which both countries have identical preferences. Here there are no supply side effects – the relative supply of goods is exogenous – and the relative demand of the two countries does not matter either – since both countries consume the same mix of domestic and foreign produced goods. Thus there are no pecuniary externalities, and bond trade is unambiguously welfare improving. Introducing production (but maintaining common preferences) introduces a role for the asset market structure to impact the terms of trade via the supply channel. Introducing home bias in preferences (but abstracting from production) highlight the role of the demand channel. Our baseline model, which is the workhorse Backus, Kehoe and Kydland (1994) model, features both channels.

Throughout the paper we will consider two sets of welfare calculations defining, respectively, conditional and unconditional desirability of capital controls. Capital controls are conditionally desirable at a particular point in the state space if at least one country prefer not to trade an international bond. We focus on exploring how the desirability of capital controls varies with current country-specific productivity, conditional on both countries having capital at the non-stochastic steady state value, and conditional on the foreign country having steady state productivity. Our key finding here is that having experienced a relatively modest positive productivity shock (relative to the symmetric mean of the process) is sufficient to leave a country better off under financial autarky rather than with a bond.

We next consider whether and when capital controls are unconditionally desirable. We define capital controls to be unconditionally desirable if both countries would prefer to live in financial autarky, when alternative regimes are evaluated starting from the symmetric non-stochastic steady state and prior to the realization of any shocks that generate differential productivity. A surprising finding is that there do exist parameterizations in which imposing capital controls is Pareto improving. To understand why this is possible, 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. Bond trade should improve productive efficiency, since it allows capital to flow across countries to equalize expected returns. So for autarky to be welfare improving, the autarky market structure must deliver superior consumption 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. We identify two cases in which financial autarky offers sufficiently superior terms of trade insurance that capital controls are unconditionally desirable. The first is when the elasticity of substitution between tradable goods is low, so that fluctuations in the terms of trade are too large from the perspective of providing insurance. In this case, restricting capital flows dampens fluctuations in relative output and thus also dampens fluctuations in the terms of trade. The second is when the elasticity is high, but the trade share exceeds 50 percent. In this 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.

1.1 Related literature

Our paper belongs to a recent theoretical literature which studies environments where capital controls can be desirable. A common theme of this literature is that, because competitive agents do not take into account that borrowing and lending in international markets can affect international prices, restricting international borrowing and lending can lead to change in prices that improve welfare. More precisely, welfare improves if capital controls induce changes in equilibrium international prices that can reduce the impact of underlying fundamental frictions. One seminal contribution to this literature is the work of Newbery and Stiglitz (1984) which shows how in environments without perfect insurance, shutting down trade in goods can lead to terms of trade movements that provide more insurance, and hence induce Pareto superior outcomes.

Three recent papers in this area that are quite related to ours are Brunnermeier and Sannikov (2014), Costinot, Lorenzoni and Werning (2014), and De Paoli and Lipinska (2013). Brunnermeier and Sannikov (2014) show how open international financial markets lead to a terms of trade deterioration (as in our set-up). However, their main focus is on how this deterioration can lead to a fall in net worth and subsequent financial instability and financial crises. We view their channel as potentially complementary to ours.

Costinot et al. (2014) focus on intertemporal prices (i.e. interest rates) and their key rational for capital controls is that when countries are monopolists in intertemporal markets they can obtain more favorable international interest rates by restricting capital flows.

Finally, De Paoli and Lipinska (2013) consider an environment similar to ours and study how taxes on an international bond can improve allocations for a given country. The key difference between our set-up 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. They find that imposing capital controls "can be beneficial for individual countries, although it would limit cross-border pooling of risk". In our set-up we find that, in some instances, capital controls can be beneficial exactly because they enable better cross-border pooling of risk.

Note that we abstract from default risk, and thus our rational for capital controls is different from Bianchi and Mendoza (2013), who argue that individual agents do not internalize the impact of individual borrowing on the government's incentives to default. Also our environment has no borrowing constraints linked to asset prices, and so our effects do not depend on capital flows relaxing or tightening borrowing constraints (as in, for example, Bianchi, 2011 and Korinek, 2009). Finally our environment features no private information, so capital controls play no role in improving on informational frictions as in Martin and Taddei (2012).

2 The Model

We focus on the familiar two country business cycle framework developed by Backus, Kehoe, and Kydland (1995) (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

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

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:

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

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 constant returns to scale:

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

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 ω determines the extent to which there is a home or foreign bias in the composition of domestically-produced final goods. We will calibrate ω 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). They also trade intermediate goods at prices $q_i^a(s^t)$, $q_i^b(s^t)$. Final goods-producing firms purchase the intermediate inputs 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 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,

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

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

2.4 Asset Market Structure

Our main focus will be on a market structure in which only a non-contingent bond is traded internationally. We will model capital controls as a tax on interest income from bonds.

Bond economy with capital controls

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 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.

The budget constraint for a household in country 1 is therefore

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

We assume that the tax rate on interest income $\tau_i(s^t)$ is proportional 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 τ_i is a fixed parameter, and $GDP_1 = q_1^a F\left(z_1, k_1, n_1\right), GDP_2 = q_2^b F\left(z_2, k_2, n_2\right)$.

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

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

Thus, when the country is a net foreign lender ($B_1(s^t) > 0$), the capital control policy taxes foreign saving. Conversely, when the net foreign asset position is negative, the policy subsidizes saving.

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

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

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 their first-order condition is

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

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, while the tax rate increases linearly with the aggregate net foreign asset position. The tax rate $\tau_1(s^t)$ is exactly 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 NFA position back towards zero. Conversely, when the aggregate NFA position is negative, so will be 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 $\tau_1 = \tau_2 \to \infty$, there will be no international bond trade, so allocations will correspond to financial autarky. Thus by varying a single parameter, the economy will vary smoothly between free bond trade and financial autarky.

We emphasize that this model of capital controls is not the fully optimal one. For example, Costinot et al. (2014), in a simpler environment, argue that the net foreign asset position is not a sufficient statistic for the optimal sign of capital taxes. Still, our capital control policy has several merits: it is simple, and since the net foreign asset position is a slow moving variable, it will imply taxes that are relatively stable over time. Moreover, we will find that governments will want to use this policy instrument aggressively, notwithstanding the fact that we restrict them to a particular functional form. At the end of the paper 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 non-contingent 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

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

2.5 Household Problems and Definition of Equilibrium

Households choose $c_i(s^t) \geq 0$, $n_i(s^t) \in [0, 1]$ and asset purchases (if assets are traded) 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, if assets are traded internationally, 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 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 and Computation

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 is equal to a standard value for a quarterly model: $\beta = 0.99$. Utility is logarithmic in consumption, so the inter-temporal 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.

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 $XXXX$) but we will later report how our results change with alternative elasticicities.

We assume a symmetric process for productivity, with no spill-overs ($\psi = 0$). We set the persistence parameter to $\rho = 0.95$ which lies in the middle of the estimates for this parameter 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 cross section of developed and developing countries. We will also report how results vary with more persistent and more volatile shocks, given that developing economies seem to experience larger and more persistent fluctuations (see, e.g., Neumeyer and Perri, 2005, and Aguiar and Gopinath 2007).

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

3.1 Key parameters for welfare comparisons

Part of our analysis will involve comparing welfare across alternative market structures. Three important parameters for this exercise are (i) the persistence of the shocks ρ, (ii) the import share defined by ω, and (iii) the elasticity of substitution between imported and domestically produced intermediates σ.

The reason ρ is important is two-fold. First, if country-specific shocks are relatively transitory, the gains from being better able to smooth them via international asset trade will also be small. This is related to Lucas' (1987) famous result that the welfare cost of aggregate risk is small. Lucas was implicitly thinking about smoothing transitory deviations from trend. If shocks are very persistent, the potential welfare gains from international risk sharing are potentially much larger.[1] A second reason that ρ matters is that it is well known that if shocks are not too persistent, allocations with free trade in a bond are very similar to those under complete markets (Baxter and Crucini, 1995).

The reason the import share matters for welfare comparisons across market structures is that gains from trade in assets are closely tied to gains from trade in goods. In the limit $\omega \to 1$ in which countries are only interested in consuming locally-produced goods (so that there are no gains from trade in goods) there are also no gains from trade in assets. Brandt, Cochrane and Santa-Clara

[1] Heathcote and Perri (2014) compute welfare under complete markets, with international bond trade, and under financial autarky, in a model in which countries face long run growth rate risk – they might grow like Argentina has done since 1960, or they might grow like Korea. The differences in expected welfare across alternative international asset market structures are very large in this case.

(2006) make this point eloquently in an example discussing hypothetical asset trade between Earth and Mars.

The reason the elasticity of substitution σ matters is that when countries produce and trade imperfectly substitutable goods, movements in the terms of trade tend to provide automatic insurance against country specific shocks to supply. Cole and Obstfeld (1991) showed that in an endowment economy, this insurance is perfect (in the sense that financial autarky delivers the same allocations as complete markets) when $\gamma = 1$ (unitary inter-temporal elasticity of substitution) and $\sigma = 1$ (unitary intra-temporal elasticity of substitution between traded goods). This result extends to our production economy under one additional parametric restriction, namely that $\omega = 0.5$, so that both countries have identical preferences and are equally keen on consuming domestic and imported intermediates.

3.2 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 incorporate both 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 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 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 towards 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 will 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 conditional on a policy vector (τ_1, τ_2) given 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 the inherited bond position is $B_1 = -B_2$. 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 will first focus on comparing welfare when $k_1 = k_2 = k^*$, when $z_1 = z_2 = z^* = 0$, and when $B_1 = B_2 = 0$. In particular we will consider the 3 following cases. The first (Unilateral capital controls) characterizes allocations and welfare as we vary the tax rate parameter τ_1 in country 1, holding fixed τ_2 at zero. In the second case (Capital control wars) we characterize a Nash equilibrium for the bond economy model with capital controls, where both countries maximize their welfare, taking as given the tax rate of the partner. The final experiment (Conditional Capital Controls) studies how the incentive to set capital controls change when countries start from asymmetric initial position, for example different productivities.

4.1 Unilateral Capital Controls

We define the welfare gain from country 1 unilaterally imposing a tax rate τ as 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 country 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 for country i is

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

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 the magnitude of the welfare gains from imposing capital controls in perspective, we will also compute the welfare gains of moving from the bond economy with $\tau_1 = \tau_2 = 0$ to complete markets, and of moving to autarky.

Figure 1 plots the welfare gains relative to the bond economy model with zero taxes for a range of values for country 1's tax rate on bond income. The first key message is that country 1 is better off by choosing a substantial positive tax rate on foreign bond income. In fact, the figure shows that 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%.

The welfare gain from imposing the unilaterally optimal tax is equivalent to a permanent 0.00035% increase in consumption. This is roughly half the welfare gain of moving from an economy with only bond trade to 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.

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 gains for country 1. As we will explain, this arises because taxing capital flows moves the world interest rate in such a way to expand 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 average absolute net foreign asset 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 22.6 percent without taxes, but only 7.5 percent with the unilaterally optimal tax. The average absolute tax rate in the latter economy is 1.2 percent (this is the product of the tax parameter and the average absolute asset position). We conclude that the incentive to tax capital flows in the baseline calibration is large, in the sense that these taxes substantially moderate net foreign asset positions.

Figure 2 plots impulses responses to a positive 1 standard deviation (1 percent) 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 rate ($\tau_1 = 0.159$). 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 risk 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

[2] The starting point for these impulse responses is the non-stochastic steady state. In the first period, country 1 receives a 1 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 $t-1$.

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 achieve by stimulating domestic demand. By moving the inter-temporal price of output (the interest rate) in this way, country 1 can increase its average consumption relative to its average output. Panel D shows that by manipulating the interest rate in this fashion, country 1 generates 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.

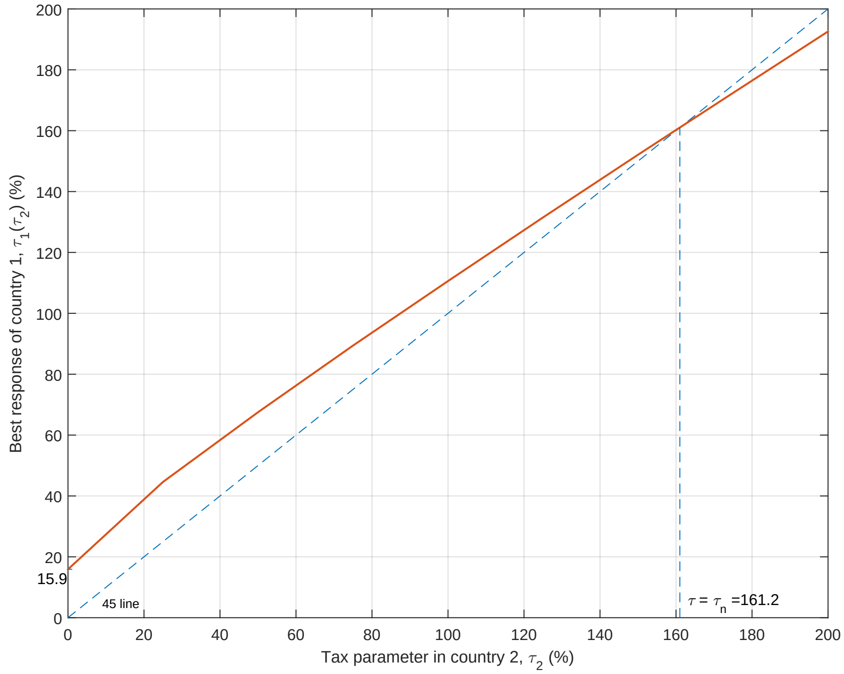
To further highlight the welfare gains from unilateral capital controls, Figure 3 plots impulse responses identical to those in Figure 2, except that here there are no shocks at date zero (as in Figure 2 there are no shocks at any future dates either). With $\tau_1 = 0$, there are, naturally, no dynamics for net exports or the net foreign asset position in the absence of any shocks. In the economy with $\tau_1 = 0.159$, by contrast, 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 the interest rate up 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 actual productivity is identical) and adjust consumption accordingly.

4.1.1 Capital Control Wars

In this subsection 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 $\tau_2 = \tau_n$ 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 1 displays the reaction function of country 1 i.e. the optimal value of τ_1 for many possible values of τ_2. Note that the function has an intercept equal to 15.9% (the optimal unilateral tax studied in the previous subsection), that it is increasing and concave, and it has a fixed point for a value of the tax parameter of 161.2%. The intuition for why the reaction function is increasing and

Figure 1: Best response taxes



concave is as follows. As we discussed earlier, a country imposes taxes because they induce a change in interest rate in its favor; thus the overall benefit of taxes is proportional to the amount which is borrowed/lent in equilibrium. The cost of tax is that it reduces the opportunity for inter-temporal smoothing. The optimal tax equates these costs and benefits. When the foreign country imposes no tax, there is a large amount of equilibrium inter-temporal trading and hence a small tax can yield large enough benefits to offset the costs. When the foreign country imposes a larger tax, equilibrium inter-temporal trading is reduced and thus a larger tax is necessary to get the same benefits. As taxes become larger and larger though, the distortion and the costs becomes larger and larger as well, so the rate of increase of taxes falls. For reference table 2 below reports the welfare and the average absolute foreign asset position over GDP (a measure of intertemporal trade) for free bond trade ($\tau_1 = 0, \tau_2 = 0$), which is also the solution of world planner who can choose the value for τ that maximizes the average expected welfare of agents in country 1 and country 2, for the Nash equilibrium described above and for autarky.

Table 2. Welfare and Intertemporal Trade under three regimes

	Taxes	Avg. Absolute NFA	Welfare loss
Free Bond Trade	$\tau_1 = \tau_2 = 0$	22%	0
Capital Control Wars	$\tau_1 = \tau_2 = \tau_n = 161\%$	1.4%	0.0024%
Autarky	$\tau_1 = \tau_2 = \infty$	0%	0.0029%

The table shows that in the case of capital control wars both countries suffer a welfare loss of 0.0024% relative to the free bond trade, a loss that is simlar to what countries would experience if they were in financial autarky. Another way of looking at the effect of these taxes this is that the average absolute net foreign asset position falls from about 22% of GDP to 1.4% of GDP.[3]Overall the figures in the table suggest that a regime of tax competition can be yield inefficient outcomes and large reduction of intertemporal trade.

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 differential incentives to tax capital flows if the initial state vector is asymetric. This allow us to shed some light on the decision of government which comes into power at a given point during the cycle, and can decide whether to estabilish a new regime of capital controls. In particular we will focus on productivity differences and on difference in intial net foreign asset position. Table 3 below reports the welfare gain that country 1 imposing the same capital tax as in the unilateral case (15.9%), but under different initial conditions

	Welfare gain
baseline	
high z	0

5 Small versus Large Countries

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

[3]The statistic is computed averaging across 500 simulations, each 400 period long.

the logic for capital controls hinges on a country's ability to affect world prices by considering two alternative variations on our baseline calibration. In the first, we assume that $\gamma = 0.0001$, so that agents are close to risk neutral and the inter-temporal elasticity of substitution is very large. In this case, if one country unilaterally imposes a tax $\tau_i > 0$ this will have a negligible impact on the foreign interest rate, which will always approximately equal the rate of time preference. In the second variation, we set $\sigma = 500$, so that the two traded goods are close to perfect substitutes. In this case, capital controls cannot affect the terms of trade or the real exchange rate, which will always approximately equal one.

If we assume both $\gamma = 0.0001$ and $\sigma = 500$, then capital controls can affect neither the terms of trade nor the world interest rate. We have verified that in this case the optimal unilateral tax for country 1 is $\tau_1 = 0.$ irrespective of the value for τ_2. The logic is that in this framework a country only uses capital controls to move prices in their favor, and when prices are unmovable there is no reason to impose them.

Now suppose $\gamma = 0.0001$, but $\sigma = 1.5$. One could think of this as 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 subsitutes for those produced abroad.[4] In this case the unilaterally optimal tax is $\tau_1 = 0.3$, and the corresponding welfare gain (relative to free bond trade) is 0.0047% of consumption, an order of magnitude larger than under the baseline calibration.

To understand this, 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.[5] In that case, because the pre-tax 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 gross pre-tax return to saving in country 1 is $rx(s^{t+1})/(\beta rx(s^t))$. By taxing (subsidizing) saving at s^t, country 1 can increase (reduce) current relative to future demand, causing the real exchange rate to depreciate (appreciate) in expected terms between t and $t+1$, thereby raising (lowering) the expected return to saving. More concretely, in the event of a positive productivity shock in country 1 at s^t, country 1 will naturally borrow heavily both to finance investment and to increase consumption (country 1's

[4]Most trade models assume that countries produce differentiated goods, since this is a natural way to motivate the very existence of trade.

[5]The expressions below still apply with the original symmetric bond payout, subject to a minor approximation..

preferences are tilted towards 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 $rx(s^t)$) 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 have also explored the opposite parameter configuration, namely $\gamma = 1$ and $\sigma = 500$. This is the widely-studied one-good version of the two-country business cycle model. In this case, the incentive to tax capital flows derives solely from the incentive to manipulate the interest rate, since the terms of trade is fixed. Again in this case we find larger welfare gains from imposing capital controls than under our baseline parameterization. Our intuition for this finding is that in a one-good model, international capital flows tend to be much larger, 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, and net foreign asset positions are larger, countries have more to gain from

- Background motivation (to come earlier in paper)
- If a country is large in the sense that its choices impact the world interest rate or terms of trade, then can potentially expand its share of world output by manipulating these prices.
- Example: a country has low output (relative to desired consumption) today and high expected output tomorrow and wants to borrow. The more country 1 consumes in aggregate today, the higher is the price of consumption today relative to tomorrow (ie the higher is the interest rate) and the worse the terms at which the country borrows. Individual agents do not internalize the impact of their borrowing on the interest rate, but a planner can do so, and would want to restrict consumption in period 1 in order to lower the world interest rate. One way to restrict consumption is to tax borrowing so that on the margin agents want to borrow less.
- This is really just the familiar optimal tarriff logic
- Costinot et al. explored this idea from a theoretical perspective in a simple endowment model.

- We want to know how important this logic for capital controls is quantitatively in a standard international business cycle model with production, investment, and when a country's aggregate decisions impact both the inter-temporal relative price of consumption (the interest rate), and the intra-temporal relative price at which imports are exchanged for domestically-produced goods (the terms of trade).

- Fully optimal capital controls difficult to compute and to communicate to policy makers. Instead look at a simpler policy in the Ramsey tradition: a tax on foreign saving that is increasing in the NFA to GDP ratio. Qualitatively this policy will nudge interest rates in the desired direction, reducing world saving and raising interest rates when a country is a net creditor, and increasing world saving and lowering interest rates when a country is a net debtor.

- Key question: does this logic for capital controls imply only marginal deviations from free trade in bonds? Or does it justify large taxes on international borrowing and lending?

- There are two ways to measure whether the logic implies small or large deviations from free capital mobility: (i) what is the tax rate, (ii) at the optimal tax rate, by how much is borrowing and lending reduced. We find that the argument justifies substantial deviation from capital mobility: tax rates are large, and average absolute net foreign asset positions are much lower.

5.1 Risk Aversion and the Persistence of Shocks

We now perform sensitivity analysis with respect to two parameters that are important for determining the price and quantity of country-specific risk.

First, our baseline utility function assumes that utility is logarithmic in the consumption composite. We now consider the effect of increasing risk aversion. To preserve the balanced growth feature of preferences, we switch to the Cobb-Douglas specification for period utility (eq. **??**). We set $\gamma = 2$ and set μ such that in steady state agents work one third of the time endowment.

Second, our baseline productivity process assumed highly persistent country-specific shocks ($\rho = 0.995$). This near-unit-root process implies that country-specific shocks lead to large changes in relative permanent income, and that country productivities tend to diverge over time. We now revisit our welfare calculations with much less persistent shocks, setting $\rho = 0.91$ (as in BKK, 1994 and Heathcote and Perri, 2013).

We report unconditional welfare gains for both these experiments in Table 4. Here we focus throughout on the baseline import share, $is = 0.25$.

Table 4. Welfare Gains Sensitivity

	Elasticity of Substitution			
	$\sigma = 0.5$	$\sigma = 1$	$\sigma = 2$	$\sigma = 5$
Baseline Model				
$\gamma = 1$	1.108	0.003	0.153	0.491
$\rho = 0.995$	**0.059**	-0.006	-0.029	-0.068
High Risk Aversion (Cobb-Douglas prefs)				
$\gamma = 2$	1.222	0.001	0.261	0.714
$\rho = 0.995$	**0.146**	-0.009	-0.041	-0.091
Low Persistence				
$\gamma = 1$	0.064	0.001	0.003	0.011
$\rho = 0.91$	-0.012	-0.015	-0.009	-0.019

In each cell the top number is the gain from completing markets,
the bottom the gain from moving to financial autarky.
Both gains are relative to the bond economy model.
$is = 0.25$ in each case

Consider, first, the effect of assuming higher risk aversion. The welfare gains from completing markets are now generally larger than in the baseline specification. Because households are more averse to consumption fluctuations, perfect consumption risk sharing would imply smaller fluctuations in relative consumption. Recall that when $\sigma = 0.5$ shocks to relative productivity have such a large impact on the path for the terms of trade that a positive shock in country 1 increases the relative value of income and consumption in country 2. Financial autarky dampens the terms of trade response, improving insurance, and stabilizing relative consumption. Since consumption smoothing is more valued here, the welfare gains in moving to financial autarky are larger. In fact, the unconditional gains in moving to financial autarky remain positive as the elasticity is increased up to a value of $\sigma = 0.82$.

Finally, we turn to the case with less persistent shocks (the last row of Table 4). The first thing to note here is that the welfare gains from completing markets are now very small, around

20 times smaller than in the baseline calibration. This is in part a manifestation of Lucas' (1987) observation that small and relatively transitory fluctuations have very small welfare costs, and in part reflects the fact that self-insurance via non-contingent borrowing and lending effectively delivers near perfect insurance when shocks are not too persistent (Baxter and Crucini, 1995). The second thing to note is that there are now no cases in which moving to financial autarky is welfare improving. This again is because trade in a bond delivers allocations that are close to complete markets, and it is therefore hard to beat the bond economy. Another way to understand why financial autarky is not attractive is that when shocks are not very persistent, they imply small changes in relative permanent income. This reduces the value of insurance against changes in permanent income, whether that insurance comes from explicit financial markets or from more attrative cyclical dynamics for the terms of trade.

6 Conclusion

We have explored the welfare effects of imposing capital controls within a textbook international business cycle model. We found that when countries differ with respect to initial productivity they also differ with respect to expected welfare losses from ruling out capital flows. In particular, the more productive country – which attracts inward investment in the near term under the bond trade equilibrium – would often do better under financial autarky. 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). In the context of the model we explored, restricting capital inflows in such countries both restrains the increase the relative supply of locally produced goods, and also supports future demand for those goods (by preventing the accumulation of a negative net foreign asset position). Both effects translate into a more favorable time path for the terms of trade.

More susprisingly, 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 sufficiently improves insurance that both countries prefer permannet 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 over-borrowing in environments with default risk. However, abstracting from these features has allowed us to focus on a channel that turns out to be quantitatively important for welfare: the impact of the international asset market structure on the dynamics of international relative prices.

The asset market structures we compared were two standard benchmarks in the literature: free trade in a bond versus financial autarky. In practice it is likely that in some cases an intermediate market structure – perhaps featuring taxes on bond trade, or limits on debt positions – would offer higher expected welfare than either of these two extremes. In addition, introducing trade in additional assets would likely strengthen the case for free trade in bonds, since a sufficiently rich menu of assets should ultimately complete markets, obviating the scope for Pareto improving capital controls.

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TO DO

- Abstract

- intro

- change calibaration with new variance

- pics in the unilateral capital controls (rerun with higher variance)

- add sensitivity section after unilatearl capital controls (persistence 0.9, 0.99, variance (0.01,0.04), elasticity (0.5,5), trade share (0.15, 0.75)

- finsish up condition capital controls

- finish interest rate v/s exchange rate section, $\sigma = 200$

- Pareto improving capital controls (figure from slides with 4 lines, the new line being the high persistence case)

- conclusion