Currency Wars, Trade Wars and Global Demand

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Abstract

I present a tractable model of a global economy with downward nominal wage rigidity in which national social planners have access to various policy instruments—the nominal interest rate, taxes on imports and exports, and taxes on capital flows. The economy can fall in a global liquidity trap with unemployment if social planners use only monetary policy. In this context, trade wars involving tariffs on imports aggravate unemployment and lead to large welfare losses. By contrast, there is full employment, and no need for international coordination, if national planners use export subsidies. Capital wars may lead to endogenous symmetry breaking, with a fraction of countries competitively devaluing their currencies to achieve full employment.

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1 Introduction

Countries have regularly accused each other of being aggressors in a currency war since the global financial crisis. Guido Mantega, Brazil's finance minister, in 2010 accused the US of launching "currency wars" through quantitative easing and a lower dollar. "We're in the midst of an international currency war, a general weakening of currency. This threatens us because it takes away our competitiveness."[1] At the time Brazil itself was trying to hold its currency down by accumulating reserves and by imposing a tax on capital inflows. Many countries, including advanced economies such as Switzerland, have depreciated or resisted the appreciation of their currency by resorting to foreign exchange interventions. The phrase "currency war" was again used when the Japanese yen depreciated in 2013 after the Bank of Japan increased its inflation target (and more recently when it reduced the interest rate to a negative level). Bergsten and Gagnon (2012) propose that the US undertake countervailing currency intervention against countries that manipulate their currencies, or tax the earnings on the dollar assets of these countries. The election of Donald Trump added to these concerns that of a tariff war initiated by the US.

While G20 countries have regularly renewed their pledge to avoid depreciating their currencies to gain a competitive trading advantage, they have also implemented stimulatives policies that often led to depreciation. Bernanke (2015) argues that this situation should not raise concerns about currency wars as long as the depreciations are the by-product, rather than the main objective, of monetary stimulus (see also Blanchard (2016)). Mishra and Rajan (2016) find the international spillovers from monetary and exchange rate policies less benign and advocate enhanced international coordination to limit the effects of these spillovers.

The concepts of currency war and trade war are old ones but we do not have many models to analyze these wars, separately or as concurrent phenomena (more on this in the discussion of the literature below). In this paper I present a simple model in which an open economy can increase its employment and welfare by depreciating its currency and making its goods

[1] Reported by Martin Wolf in "Currencies Clash in New Age of Beggar-thy-Neighbor," Financial Times September 28, 2010.

more competitive in exports markets. I consider a symmetric world with many identical countries, each one producing its own good like in Gali and Monacelli (2005). There is downward nominal stickiness in wages like in Schmitt-Grohé and Uribe (2016). Because of the zero lower bound (ZLB) on the nominal interest rate the global economy may fall in a liquidity trap with unemployment if global demand is low. I characterize the Nash equilibria in exchange rate and trade policies and explore the case for international coordination. Countries cannot commit to policy paths and the equilibrium is time-consistent. The main qualities that I look for in the model are tractability and analytical transparency but the model can be used to quantify the size of the effects, and in particular the welfare cost of currency and trade wars.

The economy falls in a global liquidity trap when the discount factor of the representative household exceeds a threshold. The nominal interest rate is at the zero bound and there is unemployment in all countries. I show that there is no benefit from international coordination of monetary policies in this situation and focus on the other policy instruments. Each country is tempted to boost its own employment by increasing its share in global demand but the collective implications of such beggar-thy-neighbor policies crucially depend on which policy instrument is used. The lack of international policy coordination is particularly damaging when countries use tariffs on imports. The equilibrium tariff is higher when there is unemployment. Because the liquidity trap is a transitory state, the tariffs act as an intertemporal tax on consumption which further reduce demand. Thus, global demand and employment are lower in the Nash equilibrium with tariffs. The welfare impact of a tariff war can be substantial: under my benchmark calibration the unemployment rate is increased from 10 percent to about 18 percent.

The outcome of a trade war is quite different when countries use a subsidy on exports. An export subsidy acts as an intertemporal subsidy on consumption and so stimulates consumption. In the Nash equilibrium in export subsidies full employment is achieved, The trade war actually increases welfare and there is no benefit from international coordination. This result holds whether or not countries use tariffs on top of the export subsidies.

I also look at the case where countries can depreciate their currencies by restricting capital inflows and accumulating reserves (still in the case of a global liquidity trap), a situation that has been called a "capital war." Setting a tax on capital flows is a zero-sum game that simply transfers welfare from the rest of the world to the country imposing capital controls. Thus a capital wars leading to a symmetric Nash equilibrium leaves welfare unchanged and there is no need for international coordination. However if the elasticity of substitution between exported goods is large enough (but within the range of typical calibrations), I find that a capital war may lead to endogenous symmetry-breaking. A fraction of countries accumulate foreign assets to achieve a trade surplus and full employment, whereas the other countries accept a trade deficit and less than full employment.

Literature. There is a long line of literature on international monetary coordination—see e.g. Engel (2016) for a review. The case for international monetary cooperation in New Open Macro models was studied by Obstfeld and Rogoff (2002), Benigno and Benigno (2006), Canzoneri, Cumby and Diba (2005) among others. This line of literature has concluded that the welfare cost of domestically-oriented rules is small. The paper is related to and Korinek (2016). Korinek gives a set of conditions under which the international spillovers associated with various policies are efficient and coordination is uncalled for. The model in this paper does not satisfy these conditions—in particular the fact that countries do not have monopoly power.

A more recent group of papers has explored the international spillovers associated with monetary policy when low natural rates of interest lead to insufficient global demand and liquidity traps: Eggertsson et al. (2016), Caballero, Farhi and Gourinchas (2015), Fujiwara et al. (2013), Devereux and Yetman (2014), Cook and Devereux (2013), and Acharya and Bengui (2016). This paper shares some themes with that literature, in particular the international contagion in the conditions leading to a liquidity trap. Eggertsson et al. (2016) and Caballero, Farhi and Gourinchas (2015) study the international transmission of liquidity traps using a model that shares several features with this paper, in p articular the downward nominal stickiness a la Schmitt-Grohé and Uribe (2016).

This paper is related to the recent literature that looks at the macroeconomic impact of trade policy.Barbiero et al. (2017) study the macroeconomic consequences of a border adjustment tax in the context of a dynamic general equilibrium model with nominal stickiness and a monetary policy conducted according to a conventional Taylor rule. Lindé and Pescatori (2017) study the robustness of the Lerner symmetry result in an open economy New Keynesian model with price rigidities and find that the macroeconomic costs of a trade war can be substantial. Erceg, Prestipino and Raffo (2017) study the short-run macroeconomic effects of trade policies a dynamic New Keynesian open-economy framework. One difference between my paper and these contributions is that I solve for optimal policies (instead of assuming for example Taylor rules).

In our model the social planner uses capital controls to affect the exchange rate, a form of intervention that can be interpreted as foreign exchange interventions. Fanelli and Straub (2016) present a model in which countries can use foreign exchange interventions to affect their terms of trade. They find that there is scope for international coordination to reduce reserve accumulation. Amador et al. (2017) study the use of foreign exchange interventions at the zero lower bound.

2 Assumptions

The model represents a world composed of a continuum of atomistic countries indexed by $j \in (0,1)$ over a finite number of periods $t = 1, 2..., T$. The goods structure is similar to Gali and Monacelli (2005). Each country produces its own good and has its own currency. The nominal wage is rigid downwards as in Schmitt-Grohé and Uribe (2016, 2017). There is no uncertainty.

Each country is populated by a mass of identical consumers. I first describe the preferences of the representative consumer. The country index j is omitted to alleviate notations until section 4 (when global equilibria are considered).

Preferences. In all periods except the final one, the utility of the representative consumer is defined recursively by,

$$U_t = u(C_t) + \beta_t U_{t+1}. \tag{1}$$

Time variation in the discount factor β_t will be used to affect domestic demand. The utility function has a constant relative risk aversion

$$u(C) = C^{1-1/\sigma} / (1 - 1/\sigma).$$

The consumer consumes the good that is produced domestically (the home good) as well as a basket of foreign goods. In all periods except the final one the consumer cares about the Cobb-Douglas index,

$$C = \left(\frac{C_H}{\alpha_H}\right)^{\alpha_H} \left(\frac{C_F}{\alpha_F}\right)^{\alpha_F}, \tag{2}$$

(with $\alpha_H + \alpha_F = 1$) where C_H is the consumption of home good, and C_F is the consumption of foreign good.

Utility in the final period is linear in the consumption of the two goods,

$$U_T = C_{HT} + C_{FT}. \tag{3}$$

This specification implies that the final period terms of trade are equal to 1 independently of the country's net foreign assets, which makes the model quite tractable. Without this assumption, the final terms of trade would be an increasing function of the country's foreign assets, an effect that is known to be very small and would not significantly affect the qualitative or quantitative properties of the model.

The consumption of foreign good is a CES index of the goods produced in all the countries,

$$C_F = \left[\int_0^1 C_k^{(\gamma-1)/\gamma} dk\right]^{\gamma/(\gamma-1)}.$$

The composite good defined by this index will be called the "global good" in the following. The elasticity of substitution between foreign goods is assumed to be larger than one, $\gamma > 1$.

Production and labor market. The home good is produced with a linear production function that transforms one unit of labor into one unit of good, $Y = L$. The representative consumer is endowed with a fixed quantity of labor $\overline{L}$ and the quantity of employed labor satisfies

$$L \leq \overline{L}. \tag{4}$$

There is full employment if this constraint is satisfied as an equality. It is assumed that there is full employment in the final period, $L_T = \overline{L}$, but there could be unemployment in earlier periods. We normalize $\overline{L}$ to 1.

The period-t nominal wage is denoted by W_t and the inflation rate in the nominal wage is denoted by π_t,

$$1 + \pi_t = \frac{W_t}{W_{t-1}}.$$

Like in Schmitt-Grohé and Uribe (2016) or Eggertsson et al. (2016), downward nominal stickiness in the wage is captured by the constraint,

$$\pi_t \geq \underline{\pi}, \tag{5}$$

where the lower bound on the inflation rate $\underline{\pi}$ is nonpositive. In any period t the economy can be in two regimes: full employment ($L_t = \overline{L}$), or less than full employment, in which case the nominal wage is at its lower bound ($L_t < \overline{L}$ and $\pi_t = \underline{\pi}$). The constraints on the labor market can be summarized by (4), (5) and

$$\left(\overline{L} - L_t\right)(\pi_t - \underline{\pi}) = 0. \tag{6}$$

This leads to a L-shaped Phillips curve where the nominal wage can be set independently of employment once there is full employment.

Budget constraints. Consumers trade one-period bonds denominated in the global good. In any period $t < T$ the budget constraint of the representative consumer is

$$P_t \frac{B_{t+1}}{R_t\left(1+\tau_t^b\right)} + W_t C_{Ht} + (1+\tau_t^m) P_t C_{Ft} = W_t L_t + Z_t + P_t B_t, \tag{7}$$

where P_t denotes the offshore domestic-currency price of the global good, τ_t^m is a tax on imports, τ_t^b is a gross tax on foreign borrowing, B_t is the quantity of real bonds held by the representative consumer at the beginning of period t, R_t is the offshore gross real interest rate in terms of the global good and Z_t is a lump-sum transfer from the government. I have used the fact that the price of the home good is equal to the wage because of the linearity in the production function.

In the final period the budget constraint is given by,

$$W_T C_{HT} + P_T C_{FT} = W_T \overline{L} + P_T B_T. \tag{8}$$

There is full employment and no trade tax in the final period. As a result the terms of trade are equal to 1 ($W_T = P_T$), and welfare is given by,

$$U_T = \overline{L} + B_T. \tag{9}$$

The period-t demand for home labor is,

$$L_t = C_{Ht} + \left[(1+\tau_t^x)\frac{W_t}{P_t}\right]^{-\gamma} C_{Ft}^W, \tag{10}$$

where $C_F^W = \int C_{Fk} dk$ denotes global gross imports and τ^x is the tax on exports. The first term on the right-hand side of (10) is the labor used to serve home demand for the home good and the second term is the labor used to produce exports.

It will be convenient to define three terms of trade,

$$S_t \equiv \frac{W_t}{P_t},\ S_t^m \equiv \frac{S_t}{1+\tau_t^m} \text{ and } S_t^x \equiv (1+\tau_t^x)\, S_t, \tag{11}$$

where S_t denotes the undistorted terms of trade, and S_t^m and S_t^x are the tax-distorted terms of trade that apply to imports and exports respectively. Given the Cobb-Douglas specification (2) the home demand for the home good and for imports are respectively given by,

$$C_{Ht} = \alpha_H \left(S_t^m\right)^{-\alpha_F} C_t, \tag{12}$$

$$C_{Ft} = \alpha_F \left(S_t^m\right)^{\alpha_H} C_t. \tag{13}$$

The demand for home labor (10) can thus be re-written,

$$L_t = \alpha_H \left(S_t^m\right)^{-\alpha_F} C_t + \left(S_t^x\right)^{-\gamma} C_{Ft}^W. \tag{14}$$

The demand for home labor increases with home consumption and global consumptions but is reduced by a loss in domestic competitiveness (an increase in S^m or S^x).

The net tax proceeds are rebated in a lump-sum way to the representative consumer. Using $Z_t = \tau_t^m P_t C_{Ft} + \tau_t^x W_t (L_t - C_{Ht}) - \tau_t^b P_t B_{t+1} / \left(1+\tau_t^b\right)$ and equations (10), (11), and (13) to substitute out Z_t, L_t, C_{Ht}, C_{Ft}, W_t and P_t from the representative consumer's budget constraint (7) gives the balance of payments equation

$$\frac{B_{t+1}}{R_t} = B_t + X_t, \tag{15}$$

where net exports in terms of global good are given by

$$X_t = \left(S_t^x\right)^{1-\gamma} C_{Ft}^W - \alpha_F \left(S_t^m\right)^{\alpha_H} C_t. \tag{16}$$

Net exports are a function of domestic and global consumption, and of the terms of trade that are relevant for exports and imports. Note that the value of net exports in terms of global good decreases if the country loses competitiveness in export markets (an increase in S^x) because $\gamma > 1$.

3 National policymaking

This section explains how a national social planner sets the domestic policy instruments to maximize domestic welfare. The first subsection presents our assumptions about commitment and derives some preliminary results about the social planner's optimization problem. The second subsection compares the impact of different policy instruments and the third subsection discusses conditions under which the instruments are equivalent.

3.1 National social planner's problem

This section considers the policies chosen by a benevolent national social planner who maximizes the welfare of the representative consumer taking the global economic conditions $(R_t)_{t=1,\dots,T-1}$ and $\left(C_{Ft}^W\right)_{t=1,\dots,T}$ as given.

The national social planner can potentially uses three policies: monetary policy, trade policy, and capital account policy (or capital controls).[2] The instrument of monetary policy is the nominal interest rate, denoted by i_t, which is set subject to the zero lower bound (ZLB) constraint $i_t \geq 0$. The instruments of trade policy are the taxes on imports and on exports τ_t^m and τ_t^x. The instrument of capital account policy is the tax on capital inflows (or subsidy on outflows) τ_t^b.[3]

We will sometimes assume that the set of usable policy instruments is restricted. National monetary sovereignty is a maintained assumption of our analysis so that the interest rate i can always be used (subject to the ZLB constraint) but this may not be the case for the other instruments, for example if they are ruled out by international agreements (e.g., the WTO for trade taxes or the OECD for capital controls).

The inflation rate can be set at any level higher than $\underline{\pi}$ when there is full employment. This decision is irrelevant for welfare since the inflation rate is unrelated to real allocations conditional on full employment. We assume

[2] We do not introduce taxes or subsidies on labor, which can be used to ensure full employment in this model.

[3] As we show at the end of this section, the instrument of capital account policy could instead be specified as foreign exchange interventions when the capital account is closed.

that when there is full employment the inflation rate is set to a target π^*,[4]

$$
\begin{aligned}
\pi_t &= \pi^* \text{ if } L_t = \overline{L}, & (17)\\
&= \underline{\pi} \text{ if } L_t < \overline{L}. & (18)
\end{aligned}
$$

In line with most of the literature we assume that the social planner cannot commit to her future policies so that policies must be time-consistent. The rest of this section shows how the social planner's problem can be solved by backward induction, starting from period T. We rely on two equilibrium conditions. First, arbitrage between real and nominal bonds implies

$$1 + i_t = R_t \left(1 + \tau_t^b\right) \frac{P_{t+1}}{P_t},$$

which, using $P_t = W_t/S_t$ and $W_{t+1}/W_t = 1 + \pi_{t+1}$, gives

$$S_t = \frac{1 + i_t}{R_t \left(1 + \tau_t^b\right)\left(1 + \pi_{t+1}\right)} S_{t+1}. \tag{19}$$

Given the next-period terms of trade and inflation, the current-period terms of trade can be increased (the currency appreciated in real terms) by an increase in the nominal interest rate or a decrease in the tax on capital flows. Thus, the interest rate and capital controls can be viewed as alternative instruments of exchange rate policy.

The second equilibrium condition is the Euler equation for consumption, which can be written

$$u'\left(C_t\right)\left(S_t^m\right)^{\alpha_F} = \beta_t \frac{1 + i_t}{1 + \pi_{t+1}} u'\left(C_{t+1}\right)\left(S_{t+1}^m\right)^{\alpha_F} \tag{20}$$

for any period $t < T - 1$ and

$$u'\left(C_{T-1}\right)\left(S_{T-1}^m\right)^{\alpha_F} = \beta_{T-1} \frac{1 + i_{T-1}}{1 + \pi_T} \tag{21}$$

in period $T - 1$.

Policies can then be mapped into allocations as follows. Given the linearity in the last-period utility function and full employment, the terms of trade are equal to one and the inflation rate is equal to the target in the last

[4] Appendix A, which presents the model with money and nominal bonds, shows how the inflation rate can be set to the target using money supply.

period, $S_T = 1$ and $\pi_T = \pi^*$. Consider period $T-1$. The social planner sets policy $\left(i_{T-1}, \tau^m_{T-1}, \tau^x_{T-1}, \tau^b_{T-1}\right)$. The terms of trade S_{T-1} are determined by equation (19) and consumption C_{T-1} is determined by (21). The demand for labor L_{T-1} is derived from (14) and must be lower than $\overline{L}$ for the policy to be admissible. The inflation rate π_{T-1} is then equal to $\underline{\pi}$ or π^* depending on whether there is full employment or not.

The social planner sets policy so as to maximize domestic welfare. Given (9) and (15) welfare can be written

$$U_{T-1} = u\left(C_{T-1}\right) + R_{T-1}\left(B_{T-1} + X_{T-1}\right) + \beta_{T-1}\overline{L},$$

where the trade surplus X_{T-1} is given by (16). This problem will be solved under various assumptions about the available policy instruments in the rest of the paper but the important point to note is that (because of the linearity in the last-period utility) the optimal policy does not depend on the country's net foreign assets B_{T-1}. It depends only on the global conditions, as summarized by R_{T-1} and C^W_{FT-1}.

The iterations for periods $t < T-1$ are similar, except that the Euler equation is (20) instead of (21). In the iteration for period t, the $t+1$-variables, including inflation π_{t+1}, have been determined in the previous step of the backward iteration. Period–t policy then determines a unique allocation and the social planner maximizes

$$V_t \equiv u\left(C_t\right) + \left(\prod_{t'=t}^{T-1} \beta_{t'} R_{t'}\right) X_t. \tag{22}$$

That is, the social planner maximizes the flow utility resulting from the period-t levels of consumption and trade balance. The social planner's problem, thus, can be decomposed in a sequence of period-t problems that are all independent of the country's net foreign assets.

The following proposition summarizes the properties derived so far and adds the result that the social planner never finds it optimal to accept unemployment if this can be avoided with monetary policy.

Proposition 1 *The optimal policy path $(i_t, \tau^m_t, \tau^x_t, \tau^b_t)_{t=1,\ldots,T-1}$ set by a benevolent time-consistent national social planner depends on the global conditions $(R_t)_{t=1,\ldots,T-1}$ and $(C^W_{Ft})_{t=1,\ldots,T-1}$ and not on the country's level of foreign assets B_1. If $\sigma \leq 1$, either there is full employment or the economy is in a liquidity trap,*

$$\forall t,\ L_t = \overline{L} \text{ or } i_t = 0.$$

Proof. See Appendix C. ■

The instrument of capital account policy could instead be specified as foreign exchange interventions (Jeanne, 2013). To see this, assume that the capital account is closed, i.e., that the government monopolizes financial transactions with the rest of the world and holds all the country's foreign assets B_t (which could be interpreted as foreign exchange reserves).[5] Then the social planner sets $(i_t, \tau_t^m, \tau_t^x, B_{t+1})$ in each period t and the Euler equations (20) and (21) no longer apply. As shown in Appendix C (proof of Proposition 1), the social planner's problem is the same as when when she uses a tax on capital inflows. Taxing capital flows and reserves interventions are two different ways of achieving the same allocations. For example, the impact of increasing the tax on capital flows in a given period t can be replicated, with a closed capital account, by increasing the foreign exchange reserves B_{t+1}.

3.2 Comparative statics

As shown in the previous section, the mapping from period-t policies into period-t allocations does not depend on the policies implemented in the subsequent periods. This section explains how policy instruments map into allocations.

Table 1 shows how the terms of trade, consumption, employment, net exports and welfare are contemporaneously affected by a change in any given policy instrument (the formulas are derived in Appendix B). The table reports the elasticity of the terms of trade S, consumption C, employment L, the trade balance X and welfare U with respect to the row policy variable. For employment and net exports the elasticities are normalized by C, i.e., the elasticities with respect to policy instrument $n = i, \tau^m, \tau^x, \tau^b$ are given by $\frac{1+n}{C}\frac{\partial L}{\partial n}$ and $\frac{1+n}{C}\frac{\partial X}{\partial n}$. For welfare the elasticity is further normalized by $u'(C)$, i.e., it is given by $\frac{1+n}{Cu'(C)}\frac{\partial U}{\partial n}$. For L, X and U the elasticities are computed in a symmetric allocation with zero taxes and assuming less than full employment. To alleviate the expressions we introduce a new notation

$$\eta = \alpha_F (\gamma - \alpha_H \sigma - \alpha_F),$$

[5]The assumption that there are no private capital flows is extreme but the insights remain true if frictions prevent economic agents from arbitraging the wedge between onshore and offshore interest rates.

for the elasticity of the trade deficit with respect to the nominal interest rate.

Table 1. Elasticities of macroeconomic variables and welfare with respect to policy instruments

	i_t	τ_t^m	τ_t^x	τ_t^b
S_t	1	0	0	-1
C_t	$-\alpha_H\sigma$	$-\alpha_F\sigma$	0	$-\alpha_F\sigma$
L_t	$-\alpha_H\sigma-\alpha_F-\eta$	$\alpha_H\alpha_F(1-\sigma)$	$-\alpha_F\gamma$	$\eta+\alpha_F$
X_t	$-\eta$	$\alpha_F(\alpha_H+\alpha_F\sigma)$	$-\alpha_F(\gamma-1)$	$\eta+\alpha_F\sigma$
U_t	$-\alpha_H\sigma-\eta$	$\alpha_H\alpha_F(1-\sigma)$	$-\alpha_F(\gamma-1)$	η

Several observations are in order. First, the elasticities of employment and welfare with respect to all policy instruments have the same signs. This means that any policy that raise employment also raises welfare independently of the impact that it has on the other variables.[6]

Second, the import tariff raises employment and welfare if and only if $\sigma < 1$. The tariff has an ambiguous effect on employment because it reduces total consumption at the same time as it shifts consumption towards the home good. The tariff raises employment if the second effect dominates, that is if the elasticity of intertemporal substitution of consumption is smaller than the elasticity of substitution between the two goods. We assume that this is the case in the following,

$$\sigma < 1.$$

Third, a tariff on imports and a tax on capital inflows have similar effects except that the tax on capital inflows reduces the terms of trade whereas the tariff on imports does not.

The elasticities reported in Table 1 assume less than full employment. When there is full employment the policy changes considered in Table 1 are not always feasible. For example, it is not possible to increase the tax on imports because this would increase employment above $\overline{L}$. The increase in the tax on imports must be associated with other adjustments that ensure

[6]One should not infer from this result that maximizing welfare is always equivalent to reaching full employment because the elasticities reported in Table 1 apply only around a symmetric undistorted allocation. We will indeed see that under some circumstances welfare-maximizing social planners do not seek full employment.

that employment does not exceed $\overline{L}$, for example an increase in the nominal interest rate or an increase in inflation above the target that appreciates the currency in real terms. In the full employment regime, policies that would increase employment must be perfectly offset by exchange rate changes.

Numerical illustration. We illustrate the properties of the model based on numerical values. We assume the following parameter values in quantitative illustrations of the model. The elasticity of intertemporal substitution of consumption, σ, is set to 0.5, which corresponds to a risk aversion of 2, a standard value in the literature. The elasticity of substitution between foreign goods, γ, is set to 3, which is consistent with the recent estimates of Feenstra et al. (2018). Note in particular that the "microelasticity" between the differentiated imported goods is substantially larger than the "macroelasticity" between the home good and imports (which is 1 because of the Cobb-Douglas specification). Finally, we assume $\alpha_H = 0.6$, i.e., home goods amount to 60 percent of total consumption.

Table 2. Elasticities of macroeconomic variables and welfare with respect to policy instruments under benchmark calibration

	i_t	τ_t^m	τ_t^x	τ_t^b
S_t	$+1.0$	0.0	0.0	-1.0
C_t	-0.3	-0.2	0.0	-0.2
L_t	-1.6	$+0.1$	-1.2	$+1.3$
X_t	-0.9	$+0.3$	-0.8	$+1.1$
U_t	-0.9	$+0.1$	-0.8	$+0.9$

3.3 Equivalence between exchange rate policy and trade policy

A long-standing question in the macroeconomic and trade literature is that of the conditions under which exchange rate manipulation can replicate the impact of tariffs. The relationship between trade policy and exchange rate policy is clarified in the following proposition.

Proposition 2 *Any allocation $(C_{Ht}, C_{Ft}, L_t, \pi_t)_{t=1,\ldots,T}$ achieved by policy path $(i_t, \tau_t^m, \tau_t^x, \tau_t^b)_{t=1,\ldots,T-1}$ can also be achieved without export tax by policy path*

$(i_t, \widetilde{\tau}_t^m, 0, \widetilde{\tau}_{jt}^b)_{t=1,\ldots,T-1}$. *with*

$$\begin{aligned} 1+\widetilde{\tau}_t^m &= (1+\tau_t^m)(1+\tau_t^x), \\ 1+\widetilde{\tau}_t^b &= \frac{1+\tau_{t+1}^x}{1+\tau_t^x}\left(1+\tau_t^b\right). \end{aligned} \tag{23}$$

Proof. See Appendix C. ■

In words, the allocation is unchanged if the social planner shifts the tax on exports to imports and at the same time increase the tax on capital inflows by the one-period-ahead change in the tax on exports.[7] For the gross exports to be left unchanged, the decrease in the export tax must be perfectly offset by an increase in the terms of trade (a real appreciation). The real appreciation must in turn be offset by an equivalent increase in the tax on imports to keep the domestic price of imports the same. The real appreciation results from a decrease in the tax on capital inflows that is cumulatively of the same size as the tax on exports but distributed over time so as to offset the impact of the tax on imports on the domestic intertemporal consumption-saving choice. The domestic Euler equation (20) implies that the nominal interest rate stays the same.

The proposition allows us to identify the conditions under which trade policy and exchange rate policy are equivalent (Meade, 1955). Let us denote by E_t the nominal exchange rate between the small open economy and a given foreign country, defined as the price of the foreign currency in terms of domestic currency. The law of one price implies

$$P_t = E_t P_t^*,$$

where P_t^* is the (offshore) price of the global good in terms of foreign currency. The policies and allocations are consistent with a fixed exchange rate regime if they satisfy $E_t = \overline{E}$. The following result states a condition under which the allocations achievable with a fixed exchange rate regime and trade taxes are the same as the allocations achievable with a floating exchange rate and free trade.

[7] The fact that a tax on imports has the same impact as a tax on exports is known as Lerner's symmetry theorem in the trade literature (Lerner, 1936). Costinot and Werning (2017) provide a number of generalizations and qualifications of the Lerner symmetry theorem in a dynamic environment.

Corollary 3 *The allocations achievable with a fixed exchange rate* $E_t = \overline{E}$ *and trade taxes* τ_t^m *and* τ_t^x *can be replicated with a floating exchange rate and zero trade taxes if and only if*

$$(1 + \tau_t^m)(1 + \tau_t^x) = 1, \tag{24}$$

for all times t.

Proof. See Appendix C. ■

If condition (24) is satisfied then the allocations achievable with a fixed exchange rate $\overline{E}$ and trade taxes can also be achieved without trade tax by the floating exchange rate

$$\widetilde{E}_t = (1 + \tau_t^m)\, \overline{E},$$

i.e., the social planner depreciates the domestic currency relative to the fixed exchange rate as a substitute to the tariff on imports. Importantly, the social planner must be able to tax capital flows for the equivalence between trade taxes and exchange rate flexibility to hold.[8] The exchange rate adjustments required by the removal of trade taxes are achieved by capital controls rather than the nominal interest rate, which again is pinned down by the domestic Euler equation (20). To summarize, there is an equivalence between exchange rate policy and trade policy provided that (i) trade policy introduces the same terms of trade distortion in domestic and foreign markets; and (ii) the instrument of exchange rate policy is the tax on capital flows rather than the interest rate.

One might infer from these equivalence results that one of the policy instruments is redundant. Proposition 2 certainly implies that this is true in equilibria where the social planner can commit to the whole policy path in period 1. As we will show, however, this is not true in equilibria where policies are time-consistent.

4 Global Liquidity Traps

The rest of this paper looks at the benefits of international coordination conditional on various assumptions about the policy instruments that national

[8]The equivalence between taxes on trade and taxes on capital flows is studied in Costinot, Lorenzoni and Werning (2014).

social planners can use. A maintained assumption is that social planners can always use the nominal interest rate subject to the ZLB constraint. Thus, as a benchmark for the rest of the analysis, this section focuses on the case where the nominal interest rate is the only usable policy instrument. I characterize the Nash equilibria between national social planners (NSP) and show that even though global liquidity traps with unemployment may arise in equilibrium, there is no gain from international coordination.

We consider symmetric equilibria in which all countries have the same inflation target π^* and the same time-varying discount rate,

$$\forall j, t \ \beta_{jt} = \beta_t. \tag{25}$$

There are two global market clearing conditions. In any period t the countries' trade balances sum up to zero,

$$\int X_{jt} dj = 0, \tag{26}$$

and global imports are the sum of imports across all countries,

$$C^W_{Ft} = \alpha_F \int \left(S^m_{jt}\right)^{\alpha_H} C_{jt} dj. \tag{27}$$

These global markets clearing conditions and integrating $X_{jt} = \left(S^x_{jt}\right)^{1-\gamma} C^W_{Ft} - \alpha_F (S^m_{jt})^{\alpha_H} C_{jt}$ over all countries j imply

$$\int \left(S^x_{jt}\right)^{1-\gamma} dj = 1. \tag{28}$$

This equation captures the fact that the terms of trade in export markets are relative prices that cannot move in the same direction for all exporters. Changing the terms of trade of a given country or group of countries changes the terms of trade of the rest of the world in the opposite direction.

A Nash equilibrium is composed of

(i) global economic conditions $(R_t)_{t=1,\ldots,T-1}$ and $\left(C^W_{Ft}\right)_{t=1,\ldots,T}$;

(ii) monetary policies $(i_{jt})_{j,t=1,\ldots,T-1}$ and allocations $(C_{Hjt}, C_{Fjt}, C_{jt}, L_{jt}, \pi_{jt})_{t=1,\ldots,T}$ for all countries $j \in [0,1]$ such that:

- the monetary policy of any country j is time-consistent and maximizes domestic welfare given the global economic conditions,

- country allocations satisfy the equilibrium conditions given country policies and global economic conditions;

- the global markets clearing conditions (26) and (27) are satisfied.

The Nash equilibrium can be constructed by iterating backwards as discussed in section 3.1. In the last period there is full employment and inflation is equal to the target in all countries. In the previous period, $T-1$, consumption is given by (21). We know from Proposition 1 that the global economy is either at full employment or in a liquidity trap. If there is full employment then $C_{T-1} = \bar{L} = 1$. Together with $S^m_{t-1} = 1$, this implies $1+i_{T-1} = (1+\pi^*)/\beta_{T-1}$, which is consistent with the ZLB constraint if and only if $\beta_{T-1} \leq 1+\pi^*$. If this condition is violated, there is less than full employment and the nominal interest rate is equal to zero. In general the nominal interest rate is given by

$$i_{T-1} = \left[(1+\pi^*)/\beta_{T-1} - 1\right]^+ .$$

The Nash equilibrium can be derived by continuing these iterations backwards. There is full employment in all periods if and only if the condition $\beta_t \leq 1+\pi^*$ is satisfied for all t. The global economy is in a liquidity trap with less than full employment in any period in which this condition is violated. Note that a liquidity trap in period t lowers inflation to $\underline{\pi}$ so that the condition for a liquidity trap in the previous period, $\beta_t \leq 1+\underline{\pi}$, is weaker. That is, the expectation of a liquidity trap in the next period tends to pull the economy into a liquidity trap in the current period.[9]

The Nash equilibrium can be compared to the equilibrium where national policies are all set by a global social planner (GSP) who maximizes the welfare of the representative country. The GSP allocation can also be interpreted as the result of international coordination between the national social planners. It is easy to see that a time-consistent Global Social Planner chooses the same policies as uncoordinated national social planners. The GSP sets the nominal interest rate so as to maximize the welfare of the representative country. The optimal GSP policy is always to achieve full employment if possible and if not, to maximize demand and employment by setting the nominal interest rate to zero. Thus there are no gains from international coordination of monetary policies.

[9]In some models this leads to self-fulfilling traps that last forever. This is not the case here because the model has a final period in which it is not in a liquidity trap.

Our results so far are summarized in the following Proposition.

Proposition 4 *Assume that the only policy instrument available to national social planners is the nominal interest rate. Then there is a unique Nash equilibrium between national planners. In this equilibrium there is full employment in all periods if and only if* $\beta_t \leq 1+\pi^*$ *for all* t*. The global economy falls in a liquidity trap with the same level of unemployment in all countries in any period* t *that violates this condition. There is no gain from international policy coordination.*

Proof. See discussion above. ■

The Nash equilibrium is no longer symmetric if countries have different inflation targets π_j^*. In a global liquidity trap the countries with higher inflation targets can depreciate their currencies and increase their employment and welfare above those in countries with lower inflation targets. Even in this case, however, there is no Pareto gain from international policy coordination.

This raises the question of the equilibrium when each country can choose its inflation target. To address this question let us assume that each country j sets its inflation target π_j^* before period 1 (say in period 0). The Nash equilibrium from period 1 onwards is then determined as before conditional on the inflation targets. In the period-0 Nash equilibrium each country sets its inflation target so as to maximize domestic welfare taking the other countries' inflation target as given. Then we have the following result.

Proposition 5 *Assume that the national social planners can choose their inflation targets before period* 1*. Then in a symmetric Nash equilibrium social planners set an inflation target* $\pi^* \geq \max_t \beta_t - 1$ *and* $i_{jt} = (1+\pi^*)/\beta_t - 1$*. There is full employment in all countries, and there is no benefit from international coordination.*

Proof. There cannot be unemployment in a symmetric Nash equilibrium, otherwise any social planner could increase domestic welfare by raising the domestic inflation target π_j^*. Hence social planners set an inflation target (it must be the same in all countries in a symmetric equilibrium) such that $\beta_t \leq 1+\pi^*$ for all t or $\pi^* \geq \max \beta_t - 1$. The inflation target is indeterminate as long as it satisfies this condition. A global social planner also increases the inflation target to any level satisfying this condition to maximizes the welfare of the representative country. ■

5 Trade and Capital Wars

In this section the national social planners are allowed to policy instruments other than the interest rate. We explore the multilateral implications of using these policy instruments when global demand is low and there is unemployment, i.e., when the economy is in a global liquidity trap.[10] Section 5.1 describes the international spillovers associated with the different policy instruments. The following sections then consider the benefits of international coordination for, respectively, tariffs on imports, subsidy on exports and taxes on capital inflows.

5.1 Policy spillovers

The international spillovers associated with the different policies are measured as follows. We start from a symmetric equilibrium in which all countries have the same level of employment in a given period t, $L_t < \overline{L}$. Assume that a small group of countries j of mass ε marginally change one policy instrument $n_{jt} = i_{jt}, \tau^m_{jt}, \tau^x_{jt}, \tau^b_{jt}$. We estimate the impact of marginal change in n_{jt} on the welfare of the countries that change their inflation target, U_{jt}, on welfare in the rest of the world, U_{-jt}, as well as global welfare,

$$U^W_t = \varepsilon U_{jt} + (1-\varepsilon) U_{-jt}.$$

The results are derived in Appendix B and reported in Table 3 (with the time index dropped for convenience). The derivatives are normalized by the consumption of each group of countries, for example, the first column reports $\frac{1+i_j}{\varepsilon C}\frac{\partial U_j}{\partial i_j}, \frac{1+i_j}{C}\frac{\partial U_{-j}}{\partial i_j}$ and $\frac{1+i_j}{C}\frac{\partial U^W}{\partial i_j}$. The first row is identical to the last row of Table 1.

Table 3. International spillovers

	i_j	τ^m_j	τ^x_j	τ^b_j
U_j	$-\eta - \alpha_H\sigma$	$\alpha_H\alpha_F(1-\sigma)$	$-\alpha_F(\gamma-1)$	η
U_{-j}	$\eta - \alpha_F\sigma$	$-\alpha_F(\alpha_H + \alpha_F\sigma)$	$\alpha_F(\gamma-1) - \alpha_F\sigma$	$-\eta$
U^W	$-\sigma$	$-\alpha_F\sigma$	$-\alpha_F\sigma$	0

[10] If there is full employment these instruments can be used to manipulate the terms of trade like in a textbook tariff war. This has been studied in a large literature relying on models without nominal stickiness.

Increasing the interest rate in a subset of countries has the standard welfare switching and welfare-reducing effects. The welfare-switching effect comes from the impact of the policy change on trade balances and is captured by the terms in η in Table 3. Welfare is decreased in the countries that raise the interest rate and appreciate their currencies, while it increases in the rest of the world. The welfare-switching effects cancel out in aggregate. The welfare-reducing effect comes from the negative impact of raising the interest rate on demand, both at home (term $\alpha_H \sigma$) and in the rest of the world (term $\alpha_F \sigma$). Increasing the tariff on imports raises the welfare of tariff-raising countries but decreases the welfare of the rest of the world. The impact on total welfare is negative, because tariffs decrease global demand and global employment.

The spillovers are different for export taxes. Subsidizing exports (lowering τ_j^x) raises the welfare of the subsidizing countries and reduces welfare in the rest of the world. But this raises global welfare. The intuition is that an export subsidy makes the global good cheaper and effectively acts as a subsidy on consumption, which tends to stimulate global demand. Export subsidies, thus, give rise to positive sum game.

Increasing the tax on capital inflows raises domestic welfare but reduces foreign welfare, leaving total welfare unchanged. A capital war, thus, is a zero-sum game. The intuition is that a given country country gains from reducing its terms of trade by a tax on capital inflows, but not all countries can gain at the same time because the terms of trade must remain the same in all countries in a symmetric equilibrium. When all countries impose the same tax on capital inflows the equilibrium real interest factor R_t falls so that global demand remains unchanged.

5.2 Tariff wars

In a tariff war the available policy instruments are the nominal interest rate and the tariff on imports. I assume that the economy is in a global liquidity trap. Namely, I consider a period t such that $\beta_t > 1+\pi^*$ and $\beta_{t'} \leq 1+\pi^*$ for all $t' > t$ and allow all national social planners j to use both i_j and τ_j^m in period t. There is full employment and no tariff from period $t+1$ onwards.

Our analysis of the optimal policies at the national level suggests that starting from an allocation with zero tariffs, each national social planner will increase domestic employment and welfare by imposing a positive tariff. The Nash equilibrium level of tariff is given in the following result.

Lemma 6 *Assume that national social planners impose tariffs in a global liquidity trap. The equilibrium tariff in a Nash equilibrium with unemployment is,*

$$\tau^m = \alpha_H \left(\frac{1}{\sigma} - 1 \right). \tag{29}$$

Proof. See Appendix C. ■

The Nash equilibrium tariff is equal to 60% in our benchmark calibration. The equilibrium tariff is decreasing in σ, and equal to zero if $\sigma = 1$, because the marginal impact of the tariff on employment and welfare is proportional to $1 - \sigma$ (see Table 1). The equilibrium tariff does not depend on the export elasticity γ because the tariff does not affect exports in a liquidity trap.

What is the impact of the tariff on global consumption, welfare and employment? Using (20) with $C_{t+1} = S_{t+1}^m = 1$ and $\pi_{t+1} = \pi^*$ (since there is no distortion in period $t + 1$), we have

$$C_t = \left[\frac{\beta_t \left(1 + i_t\right)}{1 + \pi^*} \right]^{-\sigma} \left(S_t^m\right)^{\alpha_F \sigma}, \tag{30}$$

with $S_t^m = 1/\left(1 + \tau_t^m\right)$ since $S_t = 1$ in a symmetric allocation. Thus, global consumption is decreasing with the tariff. Since $V_t = u\left(C_t\right)$ in a symmetric allocation, this is also true for global welfare.

Using $C_{Ft}^W = \alpha_F \left(S_t^m\right)^{\alpha_H} C_t$ and equation (30) to substitute out C_{Ft}^W and C_t from equation (14) gives the following expression for global employment,

$$L_t = \left(\frac{\beta_t \left(1 + i_t\right)}{1 + \pi^*} \right)^{-\sigma} \left(S_t^m\right)^{-\alpha_F (1-\sigma)} \left(\alpha_H + \alpha_F S_t^m\right). \tag{31}$$

Using $S_t^m = 1/\left(1 + \tau_t^m\right)$ and differentiating this expression shows that global employment decreases with the tariff level if and only if,

$$\tau^m \leq \frac{1}{\alpha_H \left(1/\sigma - 1\right)}, \tag{32}$$

that is, if the tariff is not too high. For very distorted economies most of the labor is used to service home consumption rather than exports. Increasing the global tariff level may then increase home consumption more than it reduces exports and thus stimulate the global demand for labor. The tariff war necessarily reduces global employment if the equilibrium tariff level, given by (29), satisfies condition (32), that is, if the equilibrium tariff is lower than 100%, $\alpha_H (1/\sigma - 1) < 1$. We assume that this condition is satisfied from now on (it is satisfied for our benchmark calibration).

By contrast, the global social planner maximizes welfare $u(C_t)$ subject to the constraint $L_t \leq \overline{L}$. It follows from (30) and (31) that this is achieved by setting $i_t = 0$ and S_t^m at the highest possible level subject to $L_t \leq 1$. In a global liquidity trap with $\beta_t > 1 + \pi^*$, this requires $S_t^m > 1$ and $\tau_t^m < 0$, that is, the global social planner subsidizes imports to stimulate global demand. The terms of trade S_t^m must be at the level $S^* \geq 1$ that satisfies $L_t = 1$ when $i_t = 0$, or

$$(S^*)^{-\alpha_F(1-\sigma)} (\alpha_H + \alpha_F S^*) = \left(\frac{\beta_t}{1 + \pi^*} \right)^{\sigma}. \tag{33}$$

Our results so far are summarized in the following proposition.

Proposition 7 *Consider a symmetric Nash equilibrium in which all national social planners use the tariff on imports τ^m in a global liquidity trap. Then the national social planners all set the tariff to the positive level given by (29), which reduces global employment and welfare relative to the equilibrium without tariff. A global social planner would instead subsidize imports so as to ensure full employment at rate $\tau^m = 1/S^* - 1$, where S^* satisfies (33).*

Proof. See discussion above. ■

The impact of a tariff war on welfare and employment is potentially large. As shown by equations (30) and (31), imposing a tariff τ^m reduces consumption by a factor $(1 + \tau^m)^{-\alpha_F \sigma}$ and employment by a factor $(1 + \tau^m)^{\alpha_F(1-\sigma)} (\alpha_H + \alpha_F / (1 + \tau^m))$. Under our benchmark calibration, the Nash equilibrium implies $\tau^m = 60\%$, so that the tariff war implies a fall in consumption by 9.0% and a fall in employment by 6.6%.

Consider, by contrast, the policy of the global social planner. This policy depends on the level of unemployment $U = 1 - L$ that prevails without tariff. The global planner implements $\tau^m = 1/S^* - 1$ where, by equation (33),

$$(S^*)^{-\alpha_F(1-\sigma)} (\alpha_H + \alpha_F S^*) = \frac{1}{1 - U}.$$

For example, if $U = 5\%$, then $S^* = 1.253$, implying that the global social planner subsidizes imports at a rate of 20.2% to achieve full employment.

Using (30) one can see that the social planner increases global consumption by 4.6% relative to the equilibrium without tariffs.

Figure 1 illustrates how the dynamics of unemployment are affected by a trade war. The figure is based on the following parameter values: $\pi^* = 2\%$, $\underline{\pi} = 0$, $T = 4$, $\beta_t = \exp(-3\%)$ for $t < 4$. The equilibrium is constructed by backward induction, taking into account that unemployment reduces inflation and so increases the real interest rate. With or without tariff, unemployment is maximum at the beginning of the liquidity trap and decreases over time. A tariff war increases global unemployment by about 6% because of the depressing effect of the tariff on global demand.

Tariff wars may lead to self-fulfilling liquidity traps. Assume that national social planners use tariffs as soon as there is unemployment, i.e., $L_t < \overline{L} \Rightarrow \tau^m = \alpha_H (1/\sigma - 1)$. Then it is enough, to have a liquidity trap and a tariff war, that the level of consumption implied by (30) be lower than 1 if the equilibrium tariff is put in place, that is for $S^m = 1/(\alpha_H/\sigma + \alpha_F)$. This is true as soon as

$$\beta_t > (\alpha_H/\sigma + \alpha_F)^{-\alpha_F} (1 + \pi^*) . \tag{34}$$

If this condition is satisfied and $\beta_t \leq 1 + \pi^*$ there are two equilibria in period t: one equilibrium with full employment and zero tariff and one equilibrium with less than full employment and a high tariff. The multiplicity comes from the fact that higher tariffs, by lowering demand, pull the economy into a global liquidity trap where all countries have incentives to raise their tariffs in order to boost their employment.

It is easy for condition (34) to be satisfied under plausible calibrations of the model. For our benchmark calibration, and an inflation target $\pi^* = 2\%$, a self-fulfilling tariff war is possible if β_t is between 0.845 and 1.02. Thus, the risk of self-fulfilling trade war becomes chronic once national social planners use tariffs conditional on unemployment.

5.3 Export subsidies

I assume in this section that the national social planners use subsidies on exports in a global liquidity trap. Our small-open-economy analysis suggests that national social planners can increase domestic employment and welfare by subsidizing exports. As stated in the following result the Nash equilibrium leads to full employment.

Proposition 8 *Assume that all national social planners use export subsidies in a global liquidity trap. The Nash equilibrium leads to full employment and a binding ZLB.*

Proof. See Appendix C. ∎

It is possible to see that the Nash equilibrium in export subsidies implements the same allocation as a global social planner using tariffs and/or subsidies. To see this, note that (28) implies $S_t^x = 1$ in a symmetric allocation. Then using (11) we have

$$S_t^m = \frac{1}{\left(1+\tau_t^m\right)\left(1+\tau_t^x\right)}.$$

Given this, equations (30) and (31) still determine the levels of consumption and employment. The global social planner maximizes global welfare by reaching full employment, which requires that $S_t^m = S^*$ or

$$\left(1+\tau_t^m\right)\left(1+\tau_t^x\right) = \frac{1}{S^*} < 1, \tag{35}$$

where S^* is defined by (33). The global social planner must subsidize exports or imports to stimulate consumption, but the allocation of the subsidy between exports and imports does not matter for real allocations and welfare. Hence, the levels of τ_t^m and τ_t^x chosen by the global social planner are indeterminate if she can use both instruments.

The result that the Nash equilibrium leads to the efficient allocation extends to the case where national social planners can use both import tariffs and export subsidies. To see this, observe that there must be full employment if national planners can use export subsidies since it is always optimal for a small open economy to lower τ^x if there is unemployment. Full employment implies that (35) is satisfied, so that the real allocations and welfare are the same as with the global social planner.[11] Our results are summarized below.

Proposition 9 *Assume that national social planners use export subsidies in a global liquidity trap (with tariffs or not). Then real allocations and welfare are the same as with a global social planner using export subsidies, tariffs, or both.*

Proof. See discussion above. ∎

[11] As shown in the proof of Proposition 8, the levels of τ_t^m and τ_t^x are determinate in a Nash equilibrium where national social planners can use both instruments, and the tariff τ_t^m is positive.

5.4 Capital wars

We now assume that national social planners can use the tax on capital inflows τ_t^b in a global liquidity trap. If there is unemployment national social planners can increase employment and welfare by imposing a tax on capital inflows, which depreciates the domestic currency and stimulates exports, at the cost of distorting consumption. When all national social planners impose the same tax τ^b, the only variable that is affected by the capital inflow tax is the global real interest rate. It follows from (19) and $S_t = 1$ that

$$R_t \left(1 + \tau_t^b\right) = \frac{1 + i_t}{1 + \pi_{t+1}}.$$

Thus, keeping i_t and π_{t+1} constant, the real interest factor R_t adjusts to any change in τ_t^b so as to keep the gross cost of external funds $R_t \left(1 + \tau_t^b\right)$ the same. A symmetric increase in the tax on capital inflows reduces the global rate of interest. This tilts the balance against exporting and accumulating foreign assets. The equilibrium level of τ^b is achieved when the real interest rate is so low that national social planners do not find it profitable to increase their net exports.

The global social planner is indifferent about the level of τ^b since it does not affect welfare. These insights are developed more precisely in the following proposition.

Proposition 10 *Assume all national social planners can use the tax on capital inflows τ^b in a global liquidity trap. There is a symmetric Nash equilibrium if and only if $\gamma \leq 2$. The level of the tax in this equilibrium is given by*

$$\tau^b = \frac{\gamma - \alpha_H \sigma - \alpha_F}{\sigma}. \tag{36}$$

Employment and welfare are the same as in the equilibrium without capital control. The global social planner is indifferent about the level of τ^b, and there is no benefit from international policy coordination.

Proof. See Appendix C. ■

Under our benchmark calibration equation (36) implies $\tau^b = 460\%$ and $R = 0.175$. All countries tax capital inflows at a very high rate, implying that the equilibrium return on foreign assets is very negative—a situation close to financial autarky.[12]

High levels of export elasticity tend to make the symmetric Nash equilibrium unstable. On one hand, a high level of γ implies that exports are highly sensitive to the exchange rate, so that it is possible to achieve full employment at the cost of small increase in capital controls. On the other hand, a high level of γ also implies that the global economy is close to financial autarky and that the return on foreign assets is very low. This increases the benefits of borrowing rather than lending.

When the export elasticity exceeds the threshold $\gamma = 2$, this tension makes the symmetric Nash equilibrium unsustainable. In the symmetric allocation where τ^b is given by (36), countries are better off deviating either by increasing τ^b to increase their employment or decreasing τ^b to finance a larger level of consumption at a low borrowing rate. This is illustrated by Figure 2, which shows how the welfare of an individual country varies with its own tax τ^b in the symmetric allocation as well as in the asymmetric Nash equilibrium (latter to be added). Welfare is a convex function of τ^b in the symmetric allocation, so that countries are better off deviating from the level of τ^b that satisfies the first-order condition in a symmetric allocation.

As a result, the global economy endogenously divides itself into two groups of countries: a group of countries with a more competitive currency, a trade surplus, and full employment, and a group of countries with a less competitive currency, a trade deficit and some unemployment. The Nash equilibrium is reached when countries have the same welfare level in the two groups.

6 Conclusions

The paper opens several directions for further research. Making the model less symmetric would allow us to look at questions that have not been analyzed in this paper. For example, assuming that countries differ in their time preferences (the discount rates ρ) would make it possible to examine how a "global savings glut" in one part of the world may affect the benefits of international policy coordination. Another relevant source of asymmetry

[12]Financial autarky is reached in the limit where τ^b goes to infinity. In this case it is impossible to invest abroad, i.e., countries cannot accumulate their trade surpluses for future consumption ($R = 0$).

is if countries have access to different policy instruments. In the real world some countries are committed not to use certain policy instruments. For example, OECD and EU membership preclude the use of capital controls except in exceptional circumstances. WTO membership also puts restrictions on trade policies (although the limits of these restrictions are increasingly tested). One could also assume that countries have different sizes or home bias.

Another question is the robustness of trigger strategy equilibria in which free trade is supported by the threat of a trade war. It would be interesting to know, in this context, whether a trade war is made more or less likely by a fall in global demand leading to unemployment.

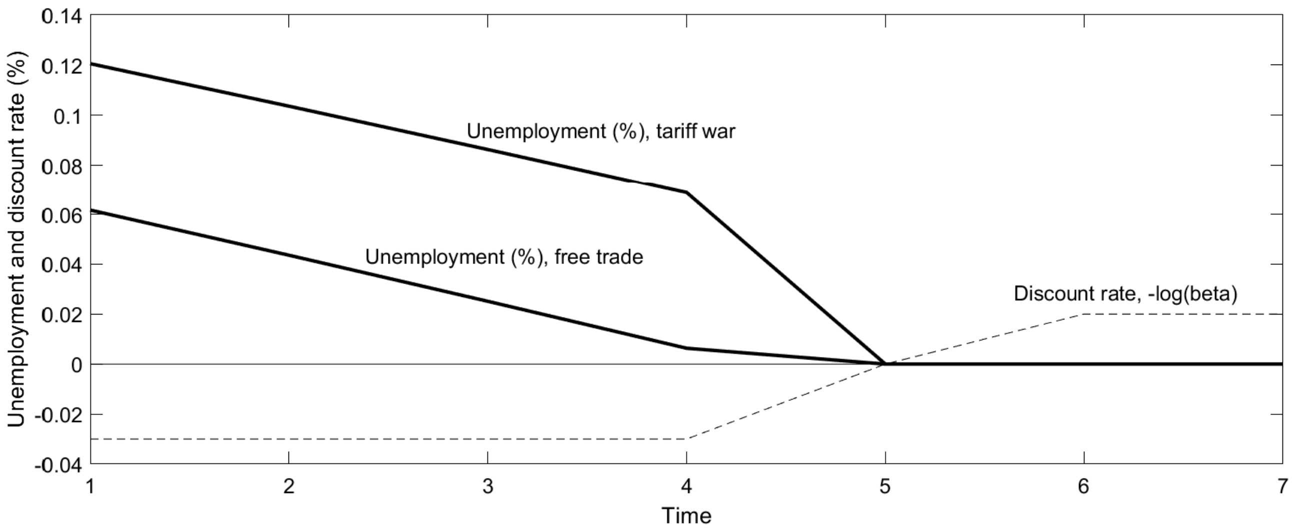

Figure 1: Unemployment rate in a dynamic trade war

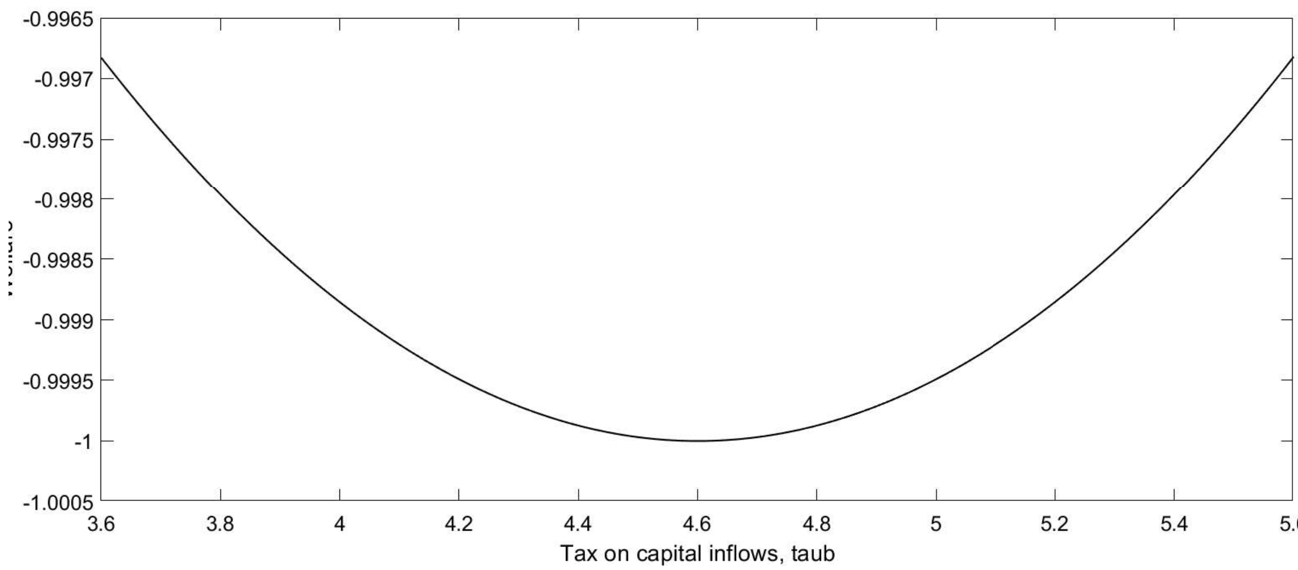

Figure 2: Variation of welfare with tax on capital inflows in symmetric allocation

APPENDICES

APPENDIX A. MODEL WITH MONEY AND NOMINAL BONDS

This appendix derives the first-order conditions in the model with money and nominal bonds. Foreign investors do not hold domestic currency bond or cash (or if they do, the tax τ_t^b applies to these assets). We assume that the representative consumer derives utility $v(M_t/W_t)$ from real money balances. The demand for money is satiated when real money balances reach a level $\overline{m}$, that is, $v'(m) > 0$ for $m < \overline{m}$ and $v'(m) = 0$ for $m \geq \overline{m}$.

For any period $t < T$ the Bellman equation for the representative consumer is

$$U_t\left(B_t, B_t^n, M_{t-1}\right) = \max_{C_{Ht}, C_{Ft}, B_{t+1}, B_{t+1}^n, M_t} u\left(C_t\right) + v\left(\frac{M_t}{W_t}\right) + \beta_t U_{t+1}\left(B_{t+1}, B_{t+1}^n, M_t\right)$$

subject to (2) and the budget constraint

$$P_t \frac{B_{t+1}}{R_t\left(1+\tau_t^b\right)} + \frac{B_{t+1}^n}{1+i_t} + M_t + W_t C_{Ht} + \left(1+\tau_t^m\right) P_t C_{Ft} = W_t L_t + Z_t + P_t B_t + B_t^n + M_{t-1},$$

where i_t is the nominal interest rate and B_t^n is the consumer's holdings of nominal bonds denominated in the domestic currency.

In the final period T the problem becomes

$$\begin{aligned} U_T\left(B_T, B_T^n, M_{T-1}\right) &= \max C_{HT} + C_{FT} + v\left(\frac{M_T}{W_T}\right) \\ \text{s.t. } M_T + W_T C_{HT} + P_T C_{FT} &= W_T L_T + Z_T + P_T B_T + B_T^n + M_{T-1}. \end{aligned}$$

For any period $t < T$ arbitrage between real and nominal bonds implies

$$1 + i_t = R_t\left(1+\tau_t^b\right)\frac{P_{t+1}}{P_t}.$$

The Euler equation can be written

$$u'\left(C_t\right)\left(S_t^m\right)^{\alpha_F} = \beta_t \frac{1+i_t}{1+\pi_{t+1}} u'\left(C_{t+1}\right)\left(S_{t+1}^m\right)^{\alpha_F} \tag{37}$$

for any period $t < T - 1$ and

$$u'\left(C_{T-1}\right)\left(S_{T-1}^{m}\right)^{\alpha_F} = \beta_{T-1}\frac{1+i_{T-1}}{1+\pi_T} \tag{38}$$

in period $T-1$. These equations characterize the intertemporal substitution of home good consumption. Note that $(S_t^m)^{\alpha_F}$ is the onshore price of the home good in terms of home consumption so that $u'(C_t)(S_t^m)^{\alpha_F}$ is the marginal utility gain from consuming an extra unit of home good.

The first-order conditions for money demand are,

$$v'\left(\frac{M_t}{W_t}\right) = u'\left(C_t\right)\left(S_t^m\right)^{\alpha_F}\left(1+1/i_t\right)^{-1} \text{ for } t < T, \tag{39}$$

$$v'\left(\frac{M_T}{W_T}\right) = 1. \tag{40}$$

Equation (40) shows that in period T it is always possible for the social planner to set M_T to a level that ensures $\pi_T = \pi^*$, consistent with full employment in that period.

We now show by backward iteration that in any period $t < T$ there is a unique level of money supply M_t that ensures that inflation is equal to the target, $\pi_t = \pi^*$ if there is full employment.

In any period $t < T$ in which the zero-bound is not binding the social planner can implement the inflation target by setting money supply M_t at the appropriate level. To see this consider a policy path with $i_t > 0$ that pins down C_t, S_t and S_t^m. Then all the variables on the r.h.s. of (39) being fixed, P_t and so W_t (since S_t is fixed) increases proportionately with M_t. It is thus possible for the social planner to set M_t so as to reach the inflation target $\pi_t = \pi^*$. This is not true if $i_t = 0$ because then equation (39) only implies $P_t \leq M_t/\overline{m}$ and raising money supply does not raise the price level.

APPENDIX B. COMPARATIVE STATICS

We derive the elasticities reported in Table 1. To alleviate the algebra we denote by $e(\bullet, n)$ the elasticity of variable $\bullet = S, C, L, X, U$ with respect to instrument $n = i, \tau^m, \tau^x$ and τ^b, that is

$$e\left(S,n\right) = \frac{1+n}{S}\frac{\partial S}{\partial n},\ e\left(C,n\right) = \frac{1+n}{C}\frac{\partial C}{\partial n},$$

$$e\left(L,n\right) = \frac{1+n}{C}\frac{\partial L}{\partial n},\ e\left(X,n\right) = \frac{1+n}{C}\frac{\partial X}{\partial n},\ e\left(U,n\right) = \frac{1+n}{u'\left(C\right)C}\frac{\partial U}{\partial n},$$

(as mentioned in the text the elasticities for L and X are normalized by C and the elasticity for U is normalized by $u'(C)\,C$).

It follows from (19) that S_t can be written

$$S_t = \kappa_t^S \frac{1+i_t}{1+\tau_t^b}, \tag{41}$$

where $\kappa_t^S \equiv \frac{S_{t+1}}{R_t(1+\pi_{t+1})}$ is taken as given by the social planner in period t, because it depends on variables that are either global or determined after t. Future variables are taken as given in a time-consistent equilibrium because the social planner's optimization problem does not depend on net foreign assets. The values of $e(S,n)$ reported in the first row of Table 1 then directly follows from (41).

Similarly, using (19) to substitute out S_t^m from (20) one can write period-t consumption as,

$$C_t = \kappa_t^C (1+i_t)^{-\alpha_H\sigma} (1+\tau_t^m)^{-\alpha_F\sigma} \left(1+\tau_t^b\right)^{-\alpha_F\sigma}, \tag{42}$$

where κ_t^C is taken as given by the national social planner in period t. Differentiating this expression gives the elasticities $e(C,n)$ in the second row of Table 1.

Equations (41) and (42) can be used to differentiate (14) and (16). Using that $C_F^W = C_F$ in a symmetric equilibrium we obtain

$$e(L,n) = [e(C,n) - \alpha_F e(S^m,n)]\frac{C_H}{C} - \gamma e(S^x,n)\frac{C_F}{C}, \tag{43}$$

$$e(X,n) = -[(\gamma-1)e(S^x,n) + e(C,n) + \alpha_H e(S^m,n)]\frac{C_F}{C}. \tag{44}$$

Using the elasticities for C and S given in the first two rows of Table 1 we can use (43) and (44) to derive the expressions in the following table.

Table B1. Elasticities $e(L,n)$ and $e(X,n)$

	i	τ^m	τ^x	τ^b
L	$-(\alpha_H\sigma+\alpha_F)\frac{C_H}{C} - \gamma\frac{C_F}{C}$	$\alpha_F(1-\sigma)\frac{C_H}{C}$	$-\gamma\frac{C_F}{C}$	$\alpha_F(1-\sigma)\frac{C_H}{C} + \gamma\frac{C_F}{C}$
X	$-(\gamma-\alpha_H\sigma-\alpha_F)\frac{C_F}{C}$	$(\alpha_H+\alpha_F\sigma)\frac{C_F}{C}$	$-(\gamma-1)\frac{C_F}{C}$	$[\gamma-\alpha_F(1-\sigma)]\frac{C_F}{C}$

These expressions are valid even if the taxes τ^m and τ^x are not set to zero. The fact that $C_H = \alpha_H C$ and $C_F = \alpha_F C$ in an equilibrium with $\tau^m = 0$ implies the expressions for $e(L, n)$ and $e(X, n)$ given in Table 1.

Next, consider the elasticities of welfare with respect to the policy instruments. Equations (19) and (20) imply

$$\frac{u'(C_t)\,(S_t^m)^{\alpha_F}}{S_t} = \beta_t R_t \left(1 + \tau_t^b\right) \frac{u'(C_{t+1})\left(S_{t+1}^m\right)^{\alpha_F}}{S_{t+1}},$$

and iterating this equation forward gives

$$\frac{u'(C_t)\,(S_t^m)^{\alpha_F}}{S_t} = u'(C_t)\,(1 + \tau_t^x)\,\frac{\alpha_H C_t}{C_{Ht}} = \prod_{t'=t}^{T-1} \beta_{t'} R_{t'} \left(1 + \tau_{t'}^b\right). \tag{45}$$

In a symmetric equilibrium with no taxes,

$$u'(C_t) = \prod_{t'=t}^{T-1} \beta_{t'} R_{t'}. \tag{46}$$

The elasticity for U is the same as the elasticity for V and it can be derived by differentiating (22). It results from (46) that for any instrument $n = i, \tau^m, \tau^x, \tau^b$

$$\frac{1+n}{Cu'(C)}\frac{\partial U}{\partial n} = \frac{1+n}{C}\frac{\partial C}{\partial n} + \frac{1+n}{C}\frac{\partial X}{\partial n}.$$

The elasticities in the bottom row of Table 1 can thus be derived by adding up the elasticities for C and X.

For the spillovers studied in section [.], one should distinguish between the expenditure-switching effect involving X and the expenditure-changing effects involving C. The expenditure-switching effect $\frac{1}{C}\frac{\partial X_j}{\partial n_j}$ has been derived for Table 1, and the impact on the rest of world is

$$\frac{1}{\varepsilon C}\frac{\partial X_{-j}}{\partial n_j} = -\frac{1}{C}\frac{\partial X_j}{\partial n_j},$$

since the trade balances sum up to zero.

The expenditure-changing effects requires endogenizing the real interest rate. It follows from equation (19) and the fact that the next-period terms of trade are equal to 1 in all countries that

$$R_t = \frac{1}{1+\pi_{t+1}} \left\{ (1-\varepsilon) \left[\frac{(1+i_{-jt})\left(1+\tau^x_{-jt}\right)}{1+\tau^b_{-jt}} \right]^{1-\gamma} + \varepsilon \left[\frac{(1+i_{jt})\left(1+\tau^x_{jt}\right)}{1+\tau^b_{jt}} \right]^{1-\gamma} \right\}.$$

It follows (dropping the time index) that

$$\frac{1+i_j}{R}\frac{\partial R}{\partial i_j} = \varepsilon, \quad \frac{1+\tau^m_j}{R}\frac{\partial R}{\partial \tau^m_j} = 0, \quad \frac{1+\tau^x_j}{R}\frac{\partial R}{\partial \tau^x_j} = \varepsilon, \quad \frac{1+\tau^b_j}{R}\frac{\partial R}{\partial \tau^b_j} = -\varepsilon.$$

The impact on welfare can then be computed using equations (41) and (42).

APPENDIX C. PROOFS

Proof of Proposition 1

To prove the first part of the Proposition, observe that period-1 domestic welfare is given by

$$U_1 = \sum_{t=1}^{T} \left(\prod_{t'=1}^{t-1} \beta_{t'} R_{t'} \right) V_t + \left(\prod_{t=1}^{T-1} \beta_t R_t \right) B_1,$$

where V_t is given by (22). In period 1 the social planner maximizes V_1 and this maximization problem is independent of B_1. The same applies to any subsequent period t.

If $L_t < \overline{L}$, lowering the interest rate raises consumption C_t. If $\sigma \leq 1$ this also increases the trade balance X_t and so welfare V_t. Hence the policy cannot be optimal if $L_t < \overline{L}$ and $i_t > 0$.

We now show that as noted after the Proposition, the equilibrium is unchanged if the social planner closes the capital account and sets the level of net foreign assets. We proceed by iteration from period $T-1$ backwards. In period $T-1$ the trade balance is $X_{T-1} = B_{T-1}/R_{T-1} - B_T$. One can derive C_{T-1} from equation (38). Using this expression to substitute out C_{T-1} in equation (16) then gives

$$X_{T-1} = \left(S^x_{T-1}\right)^{1-\gamma} C^W_{FT-1} - \alpha_F \left(\beta_{T-1} \frac{1+i_{T-1}}{1+\pi_{T-1}} \right)^{-\sigma} \left(S^m_{T-1}\right)^{\alpha_H + \alpha_F \sigma}.$$

The r.h.s. of this equation strictly decreases with S_{T-1} given τ^x_{T-1} and τ^m_{T-1} so that the equation has at most one solution S_{T-1}. The values of C_{HT-1} and C_{FT-1} can then be derived from (12) and (13). Employment L_{T-1} is derived from (14). Inflation π_{T-1} then results from (17) and (18). The social planner determines the same allocation as when the instrument is the capital flow tax. Iterations for previous periods are similar.

Proof of Proposition 2

Let us denote with tilde the policy and terms of trade that yield the same allocation as the original policy but with a zero tax on exports. Given the targeting rule (17), the allocation $(C_{Ht}, C_{Ft}, L_t, \pi_t)_{t=1,\dots,T}$ is entirely determined by the terms of trade relevant for imports and exports, $S^m_t = S_t/\left(1+\tau^m_t\right)$ and $S^x_t = S_t\left(1+\tau^x_t\right)$. Thus we must have $S^x_t = \widetilde{S}^x_t$ and $S^m_t = \widetilde{S}^m_t$ for $t = 1, ..., T-1$. Since there is no export tax in the tilde allocation one has $\widetilde{S}^x_t = \widetilde{S}_t$, which together with $\widetilde{S}^x_t = S^x_t$ imply $\widetilde{S}_t = S_t\left(1+\tau^x_t\right)$. Then $\widetilde{S}^m_t = \widetilde{S}_t/\left(1+\widetilde{\tau}^m_t\right) = S_t\left(1+\tau^x_t\right)/\left(1+\widetilde{\tau}^m_t\right)$ and $\widetilde{S}^m_t = S^m_t = S_t/\left(1+\tau^m_t\right)$ imply $1+\widetilde{\tau}^m_t = \left(1+\tau^m_t\right)\left(1+\tau^x_t\right)$ as reported in the Proposition.

The fact that all the variables except i_t in equation (20) are unchanged by the alternative policy implies that i_t is unchanged too, that is, $\widetilde{i}_t = i_t$. Then dividing (19) by the corresponding relationship in the tilde equilibrium,

$$\widetilde{S}_t = \frac{1+\widetilde{i}_t}{R_t\left(1+\widetilde{\tau}^b_t\right)\left(1+\widetilde{\pi}_{t+1}\right)}\widetilde{S}_{t+1},$$

and using $\widetilde{i}_t = i_t$, $\widetilde{\pi}_{t+1} = \pi_{t+1}$, $\widetilde{S}_t = S_t\left(1+\tau^x_t\right)$ and $\widetilde{S}_{t+1} = S_{t+1}\left(1+\tau^x_{t+1}\right)$ gives the expression for $\widetilde{\tau}^b_t$ stated in the Proposition.

Proof of Corollary 3

Condition (24) directly follows from setting $\widetilde{\tau}^m_t = 0$ in equation (23). The nominal exchange rate in the free-trade policy is

$$\widetilde{E}_t = \frac{\widetilde{P}_t}{P^*_t} = \frac{W_t}{\widetilde{S}_t P^*_t} = \frac{W_t}{S_t P^*_t}\frac{1}{1+\tau^x_t} = \frac{P_t}{P^*_t}\left(1+\tau^m_t\right) = \overline{E}\left(1+\tau^m_t\right),$$

where we used $\widetilde{W}_t = W_t$, and $\widetilde{S}_t = S_t\left(1+\tau^x_t\right)$.

National social planner's problem.

We derive the first-order conditions of the national social planner's problem which will be used to prove the following propositions. Dropping the country index, the Lagrangian for the social planner's problem is

$$\pounds = u(C_t) + \beta_t R_t \left[X_t + \lambda\left(\overline{L} - L_t\right)\right] + \mu i_t.$$

Using (45) the first-order condition for instrument $n = i, \tau^m, \tau^x, \tau^b$ can be written

$$\left(1+\tau_t^b\right) e(C,n) + \left(1+\tau_t^x\right) \frac{\alpha_H C_t}{C_{Ht}} \left[e(X,n) - \lambda e(L,n)\right] + \mu 1_{n=i} = 0, \quad (47)$$

for $n = i, \tau^m, \tau^x, \tau^b$.

Proof of Lemma 6.
Assume that the economy is in a global liquidity trap with $i_t = 0$ and $L_t < \overline{L}$. We apply equation (47) with $\tau_t^b = 0$, $\tau_t^x = 0$ and $\lambda_t = 0$, which gives

$$e(C,\tau^m) + \frac{\alpha_H C_t}{C_{Ht}} e(X,\tau^m) = 0.$$

We use the expressions for $e(C,\tau^m)$ and $e(X,\tau^m)$ from Tables 1 and B1 to substitute out the elasticities from this equation, and $1+\tau^m = \frac{\alpha_F}{\alpha_H}\frac{C_H}{C_F}$ to derive (29).

Proof of Proposition 8

The social planner uses the instruments $n = i, \tau^x$. Using equation (47) the first-order condition for i and τ^x can be written

$$\begin{aligned}
\sigma + \gamma(1-\lambda)\frac{\alpha_F}{\alpha_H} &= (\alpha_H\sigma + \alpha_F)\left[\frac{\alpha_F}{\alpha_H} + \lambda(1+\tau^x)\right] + \mu/\alpha_H, \\
\lambda &= \frac{\gamma-1}{\gamma}.
\end{aligned}$$

The second equation implies $\lambda > 0$,which proves that there must be full employment. Using this expression to substitute out λ in the first equation gives,

$$\mu/\alpha_H = (\alpha_H\sigma + \alpha_F)\left[1 - \frac{\gamma-1}{\gamma}(1+\tau^x)\right].$$

Since $\tau^x < 0$ the r.h.s. is strictly positive. That $\mu > 0$ implies that the ZLB is binding.

If τ^m can also be used as an instrument this implies the first-order condition

$$\sigma = \frac{\alpha_H + \alpha_F \sigma}{1 + \tau^m} - \alpha_H \lambda (1 - \sigma)(1 + \tau^x),$$

or

$$\sigma \tau^m = \alpha_H (1 - \sigma) \left[1 - \frac{\gamma - 1}{\gamma} (1 + \tau^x)(1 + \tau^m) \right].$$

The level of $(1 + \tau^x)(1 + \tau^m)$ is determined by the full employment condition, and it is smaller than 1. This equation determines the level of τ^m, which is strictly positive.

Proof of Proposition 10

We assume $\pi^* = 0$, without loss of generality and to alleviate the algebra. We look at equilibria in which there is unemployment and $i_t = 0$. It follows from (19), (20), $C_{t+1} = S_{t+1}^m = 1$ and $S_t^m = S_t$ that

$$C_t = \beta_t^{-\sigma} S_t^{\alpha_F \sigma}.$$

Using this expression, (16) and $C_{Ft}^W = \alpha_F \ \beta_t^{-\sigma}$to substitute out C_t and X_t from $V_t = u(C_t) + \beta_t R_t X_t$ gives

$$V_t = \beta_t^{1-\sigma} \left[\frac{S_t^{-\alpha_F(1-\sigma)}}{1 - 1/\sigma} + \alpha_F R_t \left(S_t^{1-\gamma} - S_t^{\alpha_H + \alpha_F \sigma} \right) \right].$$

Because there is a simple correspondance between the terms of trade and the tax on capital inflows, $S_t = \frac{1}{R_t\left(1+\tau_t^b\right)}$, it is equivalent for the social planner to maximize V_t over τ_t^b or over S_t. Differentiating V_t gives

$$\frac{\partial V_t}{\partial S_t} = \alpha_F \beta_t^{1-\sigma} \left\{ \sigma S_t^{-\alpha_F(1-\sigma)-1} - R_t \left[(\gamma - 1) S_t^{-\gamma} + (\alpha_H + \alpha_F \sigma) S_t^{-\alpha_F(1-\sigma)} \right] \right\}.$$

In a symmetric Nash equilibrium one should have $\partial V_t / \partial S_t = 0$ for $S_t = 1$ and $R_t = 1/\left(1 + \tau_t^b\right)$. Solving for τ_t^b gives equation (36).

Given the equilibrium value of R_t one can compute the second derivative

$$\left. \frac{\partial^2 V_t}{\partial S_t^2} \right|_{S_t=1} = \alpha_F \beta_t^{1-\sigma} \sigma (\gamma - 2).$$

The value of τ_t^b given by equation (36) maximixes domestic welfare if and only if this second derivative is negative, i.e., if and only if $\gamma \leq 2$.

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