Currency Wars, Trade Wars and Global Demand

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Preliminary

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Abstract

I present a tractable model of a global economy in which countries attempt to boost their employment and welfare by depreciating their currencies and making their goods more competitive—a "currency war"—or by imposing a tariff on imports—a "trade war." Because of downward rigidity in nominal wages the global economy may be in a liquidity trap with less than full employment. In such a situation a trade war further depresses global demand and leads to large welfare losses (amounting to about 10 percent of potential GDP under our benchmark calibration). By contrast, currency war in which countries depreciate their currencies by raising their inflation targets restores full employment and leads to large welfare gains. The uncoordinated use of capital controls leads to symmetry breaking, with a fraction of countries competitively devaluing their currency and lending their surpluses to deficit countries at a low interest rate.

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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 more

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

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). I characterize the Nash equilibria in exchange rate and trade policies and explore the case for international coordination. 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 main results crucially depend on whether global demand is sufficient to ensure full employment at the global level. If there is full employment at the global there is no need for international monetary cooperation but it is beneficial to agree on not using tariffs. Exchange rate policy is used to achieve full employment and tariffs are used to manipulate the terms of trade. Individual countries are not tempted to engage in a currency war since there is full employment. The temptation, rather, is for each country to manipulate the terms of trade in its favor by appreciating its currency while maintaining full employment with a tariff on imports. The outcome, in general equilibrium, is that international trade is inefficiently low and consumption is distorted towards the home good, like in the textbook model of tariff war. Under plausible calibrations the welfare cost of these trade wars is equivalent to a permanent decrease in consumption of one or two percent (significant but not overwhelming).

The results are different when global demand is insufficient. This scenario is obtained by increasing the discount factor of the representative consumer up to a point where the global economy falls in a liquidity trap. The nominal interest rate is at the zero bound and there is unemployment in all countries. 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. There is no benefit from coordinating conventional monetary policy. There is also no benefit from coordinating unconventional monetary policy that manipulates the inflation target. In fact, the Nash equilibrium in which each country sets its inflation target competitively leads to full employment as it relaxes the zero bound constraint on the real interest rate.

The case for international coordination is the strongest when it comes to prevent a tariff war in a global liquidity trap. In a liquidity trap countries use tariffs in order to reach employment objectives. Each country finds it optimal to impose a tariff in order to switch domestic demand away from imports and towards the home good to increase domestic employment. This makes sense in partial equilibrium but decreases each country's contribution to global demand. 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.

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." I find that under my benchmark calibration a capital war leads 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. The welfare of deficit countries, however, is the same as that os surplus countries because they can borrow at a very low cost while the surplus countries receive a very low return on their external assets. Furthermore, global welfare is slightly increased by the capital war.

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.

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.

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. A two-period version of their model features a Nash equilibrium between advanced economies and emerging market economies where the latter accumulate reserves to depreciate their real exchange rate. This equilibrium is inefficient and 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.

The paper is related to and Korinek (2016). That paper presents a unified framework for analyzing whether international spillovers call for international policy coordination. Korinek gives a set of conditions under which the spillovers 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.

2 Assumptions

The model has two periods $t = 1, 2$ respectively representing the short run and the long run. It represents a world composed of a continuum of atomistic countries indexed by $j \in (0, 1)$. Each country produces its own good and has its own currency. The goods structure is similar to Gali and Monacelli (2005). The nominal wage is rigid downwards as in Schmitt-Grohé and Uribe (2016, 2017). There is no uncertainty. Taxes on imports and exports are introduced as the instruments of trade policy.

Each country is populated by a mass of identical consumers. I first describe the preferences of the representative consumer and drop the country index to alleviate notations.

Preferences. The utility of the representative consumer is defined recursively by,

$$U = u(C) + \beta C', \tag{1}$$

where C and C' denote consumption in the first and second periods respectively. Second-period variables are denoted with primes. 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 period 1 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, whereas in period 2 her utility is a linear function of the two types of goods,

$$C' = C'_H + C'_F.$$

This specification implies that the period-2 terms of trade are equal to 1 independently of the country's net foreign assets, which considerably simplifies the analysis.

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

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

Imports are defined by the same index for all countries. 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

$$L \leq \overline{L}. \tag{3}$$

There is full employment if this constraint is satisfied as an equality. It is assumed that there is full employment in the second period (the long run), $L' = \overline{L}$, but there could be unemployment in period 1 (the short run).

The period-1 nominal wage is denoted by W. Like in Schmitt-Grohé and Uribe (2016) or Eggertsson et al. (2016), downward nominal stickiness in the wage is captured by the constraint,

$$W \geq \underline{W}, \tag{4}$$

where the lower bound $\underline{W}$ is an increasing function of the previous period nominal wage. The economy can be in two regimes: full employment ($L = \overline{L}$), or less than full employment, in which case the nominal wage is at its lowest possible level ($L < \overline{L}$ and $W = \underline{W}$). The constraints on the labor market can be summarized by (3), (4) and

$$\left(\overline{L} - L\right)\left(W - \underline{W}\right) = 0. \tag{5}$$

This leads to a L-shaped Phillips curve where the nominal wage becomes indeterminate once there is full employment.

The gross inflation rate in the nominal wage (or home good price) is equal to a target denoted by Π

$$\frac{W'}{W} = \Pi.$$

The inflation target will be taken as exogenous for most of the analysis.

Budget constraints. Consumers can trade one-period bonds denominated in the global good. The budget constraints of the representative consumer are

$$P\frac{B}{1+\tau^b} + WC_H + (1+\tau^m)\,PC_F = WL + Z, \tag{6}$$

$$W'C'_H + P'C'_F = W'L' + P'\,(1+r)\,B, \tag{7}$$

where P denotes the offshore domestic-currency price of the global good, τ^m is a tax on imports, B is the quantity of real bonds accumulated by the representative consumer, τ^b is a tax on foreign borrowing (or capital inflows), r is the real interest rate in terms of the global good and Z is the lump-sum rebate of the proceeds of the taxes. 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. Observe that since there is full employment ($L' = \overline{L}$) and the terms of trade are equal to 1 ($W' = P'$) in the second period, the budget constraint can be rewritten,

$$C' = \overline{L} + (1+r)\,B. \tag{8}$$

In the long run consumption is equal to potential output minus the service of external debt.

Denoting the gross exports of home good by X, the period-1 demand for home labor is,

$$L = C_H + X. \tag{9}$$

The first term is the labor used in the production of home good for home consumption and the second term is the labor used to produce exports. Gross exports are in turn given by,

$$X = \left[(1+\tau^x)\,\frac{W}{P}\right]^{-\gamma} C_F^W,$$

where $C_F^W = \int C_{Fk}dk$ denotes global gross imports and τ^x is a tax on exports.

It will be convenient to define three terms of trade,

$$S \equiv \frac{W}{P},\ \ S^m \equiv \frac{S}{1+\tau^m} \text{ and } S^x \equiv (1+\tau^x)\,S, \tag{10}$$

where S denotes the undistorted terms of trade, and S^m and S^x are the tax-distorted terms of trade that apply to imports and exports respectively. The home demand for the home good and for imports are respectively given by,

$$C_H = \alpha_H\,(S^m)^{-\alpha_F}\,C, \tag{11}$$

$$C_F = \alpha_F\,(S^m)^{\alpha_H}\,C. \tag{12}$$

The demand for home labor (9) can be re-written,

$$L = \alpha_H\,(S^m)^{-\alpha_F}\,C + (S^x)^{-\gamma}\,C_F^W. \tag{13}$$

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

Finally, using $Z = \tau^m P C_F + \tau^x W\,(L - C_H) - \tau^{bP} B/\left(1+\tau^b\right)$ and equations (9), (10), (11), and (12) to substitute out Z, L, C_H, C_F, W and P from the representative consumer's budget constraint (6) gives

$$B = (S^x)^{1-\gamma}\,C_F^W - \alpha_F\,(S^m)^{\alpha_H}\,C. \tag{14}$$

Equation (14) gives net exports B as a function of domestic consumption, C, global consumption, C_F^W, and 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 Policies

We now review the policy instruments that are available to the domestic social planner. There are three policy areas: monetary policy, trade policy, and capital account policy (or capital controls).This section shows that the policy instruments are well-defined in the sense that they determine one unique allocation. The second subsection establishes equivalence results between capital account policy and trade policy and the last subsection looks at the impact of the policy instruments on the allocations.

3.1 Policy instruments

The instrument of monetary policy is the nominal interest rate, denoted by i. The nominal interest rate is the nominal return on onshore domestic currency bonds. The nominal interest rate can be set freely subject to the zero lower bound (ZLB) constraint $i \geq 0$.

The onshore real interest rate in terms of global good being equal to $(1+r)(1+\tau_b)$, arbitrage between real bonds and nominal bonds implies,

$$1 + i = (1 + r)\left(1 + \tau^b\right)\frac{P'}{P}.$$

Then using $P' = W'$ and $W'/W = \Pi$ this can be written as an expression for the first-period terms of trade,

$$S = \frac{1+i}{1+\tau^b}\frac{1}{(1+r)\,\Pi}. \tag{15}$$

The terms of trade can be reduced (the currency depreciated) either by a decrease in the nominal interest rate or by an increase in the tax on capital flows. Thus, the interest rate and capital controls can be viewed as two alternative instruments of exchange rate policy.

The instrument of capital account policy could instead be specified as foreign exchange interventions (Jeanne, 2013). Assume that the government (including the central bank) monopolizes financial transactions with the rest of the world and accumulates foreign reserves.[2] With a closed capital account there generally is a wedge between the onshore and offshore real rates of interest and this wedge is affected by reserves interventions. Other things equal, an accumulation of reserves reduces domestic consumption and increases the onshore real interest rate. The allocation corresponding to a certain level of reserves can be achieved by a tax on capital inflows that is equal to the wedge between the onshore and offshore interest rates. That is, taxing capital flows and reserves interventions are two different ways of achieving the same allocations.

To summarize, the policy mix of the country is characterized by a set $(i, \tau^m, \tau^x, \tau^b)$. Monetary policy is characterized by i, trade policy by τ^m and τ^x, and capital account policy by τ^b.

The next step is to check that policy is well specified in the sense that a given policy mix leads to one unique allocation. The terms or trade S being determined by (15), the trade taxes then pin down the distorted terms of trade S^m and S^x. Domestic demand C then results from the Euler equation,

$$u'(C) = \beta \frac{1+i}{\Pi} (S^m)^{-\alpha_F} . \tag{16}$$

Finally, employment L and net exports B are then given by (13) and (14).

Proposition 1 *For any policy mix $(i, \tau^m, \tau^x, \tau^b)$ there is at most one allocation C, S, L, and B satisfying the equilibrium conditions (13), (14), (15) and (16).*

Proof. See discussion above. ■

Although the allocation is unique, it may not correspond to an equilibrium because the constraint $L \leq \overline{L}$ is not necessarily satisfied. In the following we consider admissible policy mixes that satisfy this constraint. In addition the nominal W is not determinate if there is full employment ($L = \overline{L}$). This results from the L-shape of the Phillips curve. The indeterminacy of W is

[2]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.

not a problem since the nominal wage is irrelevant for period-1 welfare. This feature could be remedied by assuming that the slope of the Phillips curve is very large but not infinite for $L > \overline{L}$, i.e., overemployment is possible at the cost of high inflation.

3.2 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, L, and B achieved by policy $(i, \tau^m, \tau^x, \tau^b)$ can also be achieved without export tax by policy $(i, \widetilde{\tau}^m, 0, \widetilde{\tau}^b)$ with $1 + \widetilde{\tau}^m = (1 + \tau^m)(1 + \tau^x)$ and $1 + \widetilde{\tau}^b = \left(1 + \tau^b\right) / (1 + \tau^x)$.*

Proof. We denote with tilde the allocation under the alternative policy mix $(i, \widetilde{\tau}^m, 0, \widetilde{\tau}^b)$. Using (15) the undistorted terms of trade are $\widetilde{S} = S(1 + \tau^x)$,and it follows from $\widetilde{\tau}^x = 0$ and $1 + \widetilde{\tau}^m = (1 + \tau^m)(1 + \tau^x)$ that $\widetilde{S}^m = S^m$ and $\widetilde{S}^x = S^x$. Equation (16) then implies $\widetilde{C} = C$. Equations (11), (12), (13) and (14) then imply $\widetilde{C}_H = C_H$, $\widetilde{C}_F = C_F$, $\widetilde{L} = L$ and $\widetilde{B} = B$. ■

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).[3] Real allocations are determined by the tax-distorted prices of the home good in terms of global good both in export markets and in the domestic market. Gross exports are left unchanged if a decrease in the export tax is perfectly offset by an increase in the terms of trade (a real appreciation). For consumption and imports to remain the same the real appreciation must be neutralized by an increase in the import tax of the same amount. The real appreciation is achieved by a fall in the tax on inflows, which also offsets the depressing impact of the transitory tariff on consumption. The real appreciation should not come from a monetary restriction (an increase in i) because this would reinforce the fall in consumption caused by the traiff.

[3] Costinot and Werning (2017) provide a number of generalizations and qualifications of the Lerner symmetry theorem.

The proposition allows us to identify the conditions under which trade policy and exchange rate policy are equivalent (Meade, 1955). Consider the trade policies that subsidize exports at the same rate as they tax imports, that is

$$(1+\tau^m)(1+\tau^x)=1. \tag{17}$$

This implies that $S^m = S^x$, i.e., the trade taxes induce the same distortion for imports and exports. Then Proposition 2 implies that the real allocations achieved by trade policy can be replicated, without any trade tax, by a tax on capital inflows that depreciates the exchange rate.[4] That is, there is an equivalence between exchange rate policy and trade policy provided that (i) trade policy introduce the same price distortion in domestic and exports markets; and (ii) the instrument of exchange rate policy is the tax on capital flows rather than the interest rate.

Another implication of Proposition 2 is that one of the policy instruments is redundant. If the country does not peg the exchange rate it does not need to have taxes on both imports and exports. Hereafter I will assume that the social planner does not tax exports[5]

$$\tau^x = 0.$$

From now on policy will be defined as a set of three instruments (i, τ^m, τ^b).

3.3 Comparative statics

This section furthers our understanding of how policy instruments impact allocations. Table 1 shows how the terms of trade, consumption, employment, net exports and welfare are affected by a change in any given policy instrument taking the other policy instruments as given. The table reports the elasticity of the terms of trade S, consumption C and employment L with respect to the row variable. For the net exports B and the country's welfare U the table reports the semi-elasticities normalized by the level of consumption: for example in the case of the nominal interest rate, $\frac{1+i}{C}\frac{\partial B}{\partial(1+i)}$ and $\frac{1+i}{C}\frac{\partial U}{\partial(1+i)}$. The elasticities are computed in a symmetric undistorted allocation in which $S=1$, $C=L$, $C_F^W=\alpha_F C$ and $B=0$. There could be

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

[5]Real-world policymakers seem more inclined to impose taxes on imports than on exports.

full employment or not (if there is full employment then the policies that increase employment are not possible).

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

	$1+i$	$1+\tau^m$	$1+\tau^b$
S	1	0	-1
C	$-\sigma\alpha_H$	$-\sigma\alpha_F$	$-\sigma\alpha_F$
L	$-\gamma\alpha_F-\alpha_H\left(\alpha_F+\sigma\alpha_H\right)$	$\alpha_H\alpha_F\left(1-\sigma\right)$	$\alpha_F\left[\gamma+\alpha_H\left(1-\sigma\right)\right]$
B	$-\alpha_F\left[\gamma-1+\alpha_H\left(1-\sigma\right)\right]$	$\alpha_F\left(\alpha_H+\alpha_F\sigma\right)$	$\alpha_F\left(\gamma-1+\alpha_H+\alpha_F\sigma\right)$
U	$-\alpha_H\sigma-\alpha_F\left[\gamma-1+\alpha_H\left(1-\sigma\right)\right]$	$\alpha_H\alpha_F\left(1-\sigma\right)$	$\alpha_F\left[\gamma-1+\alpha_H\left(1-\sigma\right)\right]$

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 it has on other variables. 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 welfare-maximizing social planners do not always seek full employment.

Second, the impact of the import tariff on employment and welfare depends on how the elasticity of substitution between the two goods compares with the elasticity of intertemporal substitution of consumption. 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,

$$\sigma<1.$$

We will assume that this condition is satisfied in the following.

Third, a tariff on imports and a tax on capital inflows have similar effects with one importance exception: the tax on capital inflows reduces the relative price of the home good in export markets whereas the tariff on imports does not.[6] This implies that the tax on capital inflows has a larger impact than the tariff on employment, net exports and welfare.

The parameter values that will be used in quantitative illustrations are reported in Table 2. 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 values for the elasticity of substitution between home and foreign goods, η, and between foreign goods, γ, are 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. Home goods amount to 60 percent of total consumption. Finally the labor endowment is normalized to 1.

Table 2. Benchmark calibration

σ	γ	α_H	$\overline{L}$
0.5	3	0.6	1

With these parameter values the elasticities are reported in Table 3. A one-percent decrease in the nominal interest and a one-percent increase in the capital inflow tax have very similar impact, both in signs and magnitude (except for consumption). The impact of a tariff on imports is significantly smaller because, as noted above, it does not affect exports.

Table 3. Benchmark elasticities

	$1+i$	$1+\tau^m$	$1+\tau^b$
S	$+1$	$+0.0$	-1
C	-0.3	-0.2	-0.2
L	-1.6	$+0.1$	$+1.3$
B	-0.9	$+0.3$	$+1.1$
U	-0.9	$+0.1$	$+0.9$

4 The benefits of international policy coordination when global demand is high

In the remainder of the paper we look at equilibria of the global economy in which national social planners coordinate their policies or not. All countries

[6]This is why the export elasticity γ does not appear in the expressions for the elasticities with respect to the import tax.

j are assumed to have the same discount factor β. The equilibria crucially depend on whether the global propensity to save, as captured by β, puts the economy in a liquidity trap where the ZLB constraint on the nominal interest rate is binding. In this section we focus on the case where global demand is high enough that the ZLB is not binding. For simplicity the ZLB constraint is ignored in the rest of this section and will be taken into consideration in the next section. We derive in the next section the conditions on β that determine whether the ZLB is binding.

There are two global market clearing conditions. The countries net foreign assets sum up to zero,

$$\int B_j dj = 0, \tag{18}$$

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

$$C_F^W = \alpha_F \int \left(S_j^m\right)^{\alpha_H} C_{jt} dj. \tag{19}$$

The global markets clearing conditions and integrating $B_j = \left(S_j\right)^{1-\gamma} C_F^W - \alpha_F (S_j^m)^{\alpha_H} C_j$ over all countries j imply

$$\int S_j^{1-\gamma} dj = 1. \tag{20}$$

Changing the terms of trade of a given country changes the terms of trade of the rest of the world in the opposite direction.

We look at a Nash equilibrium between national social planners (NSP) who do not coordinate and compare it 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 equilibrium can also be interpreted as arising from international coordination between the national social planners. In a Nash equilibrium all social planners solve the following problem,

$$(P_j) \begin{cases} \max U_{r,C_F^W}\left(i_j, \tau_j^n, \tau_j^b\right), \\ L_{r,C_F^W}\left(i_j, \tau_j^n, \tau_j^b\right) \leq \overline{L}, \end{cases}$$

where $U_{r,C_F^W}\left(i_j, \tau_j^n, \tau_j^b\right)$ and $L_{r,C_F^W}\left(i_j, \tau_j^n, \tau_j^b\right)$ denote respectively welfare and demand for domestic labor when global economic conditions are given by r, C_F^W and domestic policies are given by $\left(i_j, \tau_j^n, \tau_j^b\right)$. We have shown in the previous section that these functions are well defined.

A Nash equilibrium is composed of (i) global economic conditions $\left(r, C_F^W\right)$; (ii) policies $(i_j, \tau_j^m, \tau_j^b)$ and terms of trade and allocations (S_j, C_j, L_j, B_j) for all countries $j \in [0,1]$ such that:

- country policies maximize domestic welfare given the global economic conditions,
- country allocations satisfy the equilibrium conditions given country policies and global conditions;
- the global markets clearing conditions (18) and (19) are satisfied.

The NSP and GSP equilibria are characterized and compared in the following proposition.

Proposition 3 *Assume the ZLB constraint does not hold. In the Nash equilibrium between national social planners all countries set the tariff on import to* $\tau^m = 1/(\gamma - 1)$*, the tax on capital inflows to* $\tau^b = -1/\gamma$ *and the nominal interest rate* i *so as to reach full employment. In the global social planner equilibrium all countries set the tariff on imports to zero, the tax on capital inflows to an arbitrary level, and the nominal interest rate so as to reach full employment. The welfare gain from international policy coordination is equivalent to a first-period consumption gain by the factor* $(1 - 1/\gamma)^{\alpha_F} / (1 - \alpha_F/\gamma)$*.*

Proof. See Appendix. ■

A social planner who does not coordinate his policies with the rest of the world taxes imports so as to manipulate the terms of trade like in the classical optimal tariff literature.[7] The tariff depresses consumption and this must be counteracted by subsidizing capital inflows. Given this, the only task left for monetary policy is to ensure full employment. If there is unemployment, lowering the interest rate raises welfare since it increases consumption in both periods.

The terms of trade manipulation cannot be successful since by equation (20) the terms of trade must be equal to 1 in all countries in a symmetric

[7] The formula for the optimal tax rate was originally derived by Johnson (1953) in a static model with balanced trade.

equilibrium. The benefit of international coordination is to avoid a textbook tariff war in which all countries try to manipulate the terms of trade in their favor, and in general equilibrium end up distorting production and consumption. The tax subsidy on capital inflows raises the real interest rate r and has no impact in general equilibrium.

Under our benchmark calibration the equilibrium tariff is τ is equal to 50 percent. In a tariff war the consumption of home good increases from $0.6\overline{L}$ to $0.69\overline{L}$, the consumption of global good shrinks from $0.4\overline{L}$ to $0.31\overline{L}$, and total consumption falls from $\overline{L}$ to $0.98\overline{L}$. Thus the welfare loss from a tariff war (and the welfare gains from international coordination of trade policies) is equivalent to a two percent gain in consumption.

5 The benefits of coordination when global demand is low

In this section we take the ZLB constraint $i_j \geq 0$ into account. Full employment may be impossible to achieve if the ZLB is binding. Then the economy finds itself in a liquidity trap with some unemployment. This changes the nature of the national social planners' problem because the trade and capital flow taxes can be used to stimulate employment. Increasing the tariff τ^m raises employment by shifting domestic demand towards the home good, whereas raising the capital tax τ^b depreciates the exchange rate and stimulates exports. This section studies the multilateral implications of these policies.

In a symmetric equilibrium with no trade taxes one has $S = S^m = 1$ and $C = \overline{L}$ so that by (16) the nominal interest rate is given by,

$$1 + i = \frac{\Pi}{\beta} u'\left(\overline{L}\right).$$

If $\beta > \Pi u'\left(\overline{L}\right)$, the ZLB constraint is not consistent with full employment. All countries fall in a liquidity trap with some unemployment. In this context we assess the impact of a trade war in which all countries use tariffs. Next we assess the impact of a capital war in which all countries use a tax on capital inflows to depreciate their currencies. Finally, we consider a Nash equilibrium in which all countries may increase their inflation targets.

5.1 Trade wars

We now assume that all countries can tax imports at rate τ_j^m in a global liquidity trap. The nominal interest rate is set to zero in all countries and there is free capital mobility. implying that in a symmetric equilibrium the real interest rate is given by $1 + r = 1/\Pi$. In a symmetric allocation the problem of country j is

$$\begin{cases} \max_{S_j^m} U_j = u(C_j) + \frac{\beta}{\Pi} B_j \\ u'(C_j) = \frac{\beta}{\Pi} \left(S_j^m\right)^{-\alpha_F} \\ B_j = C_F^W - \alpha_F \left(S_j^m\right)^{\alpha_H} C_j \\ L_j = C_F^W + \alpha_H \left(S_j^m\right)^{-\alpha_F} C_j \leq \overline{L}. \end{cases}$$

In a symmetric equilibrium one has $S_j = 1$ and $S_j^m = 1/\left(1 + \tau_j^m\right)$. The benefit of taxing imports (lowering S_j^m) is that this raises the demand for labor and national income, but the tax also depresses domestic consumption. We know that the equilibrium tariff must be strictly positive since welfare increases with τ_j^m for $\tau_j^m = 0$ as shown in Table 1. In general equilibrium the tariffs reduce the welfare of the representative country, $u(C_j)$, since C_j decreases with τ_j^m. This is because the tariffs reduce the global demand for imports, C_F^W, which countries take as given when they choose their own tariff.

The following proposition states a closed-form expression for the equilibrium tariff.

Proposition 4 *Assume countries can use monetary policy and trade policy in a global liquidity trap. A symmetric Nash equilibrium involves a strictly positive tariff*

$$\tau^m = \alpha_H (1/\sigma - 1).$$

and the welfare gain from international policy coordination is equivalent to a first-period consumption gain by the factor $(\alpha_F + \alpha_H/\sigma)^{\alpha_F \sigma}$.

Proof. See discussion above. We have

$$C_j = (\beta/\Pi)^{-\sigma} \left(S_j^m\right)^{\alpha_F \sigma},$$

and domestic welfare can be written as the following function of S_j^m

$$U_j = (\beta/\Pi)^{1-\sigma} \left[(S^m)^{-\alpha_F(1-\sigma)} / (1 - 1/\sigma) - \alpha_F (S^m)^{\alpha_H + \alpha_F \sigma} \right],$$

(exports are constant since $S_j = 1$). Maximizing this function over S^m gives $S^m = 1/\left(\alpha_F + \alpha_H/\sigma\right)$. Since $S^m = 1/\left(1+\tau^m\right)$ this gives the expression for τ^m in the Proposition. The expression for the welfare gain comes from the fact that C is proportional to $\left(S_j^m\right)^{\alpha_F \sigma}$ ■

With our benchmark calibration the gain from international policy coordination is close to 10 percent of consumption. This gain is much larger than in the full employment case, where it was closer to 2 percent of consumption. The reason is that the trade war reduces global employment by reducing the global demand for imports. For example, if β is set at a level such that $L = 0.9\overline{L}$ (a 10 percent unemployment rate), the trade war reduces employment to $0.82\overline{L}$ (increases unemployment from 10 percent to 18 percent). The welfare cost of a trade war comes mostly from the reduction in production rather than the consumption distortion.

5.2 Capital wars

I now assume that there is no tariff but relax the assumption of free capital mobility. Countries may now use a tax on capital flows to depreciate their currencies. The resulting Nash equilibrium can be interpreted as an "unconventional currency war" in which countries depreciate their currencies through unconventional means (capital controls or reserve accumulation) rather than the interest rate.

The problem of country j (assuming $i_j = 0$) is

$$\left\{ \begin{array}{c} \max_{S_j} U_j = u\left(C_j\right) + \beta\left(1+r\right) B_j \\ u'\left(C_j\right) = \frac{\beta}{\Pi}\left(S_j\right)^{-\alpha_F}, \\ B_j = \left(S_j\right)^{1-\gamma} C_F^W - \alpha_F \left(S_j\right)^{\alpha_H} C_j, \\ L_j = S_j^{-\gamma} C_F^W + \alpha_H \left(S_j\right)^{-\alpha_F} C_j \leq \overline{L}. \end{array} \right.$$

The country sets its terms of trade S_j using the tax on capital inflows τ_j^b by equation (15).

If there is a symmetric Nash equilibrium in which all countries apply the same tax τ^b to capital inflows, the allocation is the same as in the Nash equilibrium where countries do not use capital controls. In a SNE where $S_j = 1$ for all j, consumption for all countries is given by

$$u'\left(C_j\right) = \beta/\Pi.$$

This pins down the welfare of the representative country, $u(C_j)$, independently of τ^b. What capital controls do is reduce the equilibrium real interest rate,

$$1 + r = \frac{1}{\Pi(1 + \tau^b)}.$$

The real interest rate must be reduced until the point where countries do not find it profitable to stimulate employment through exports because the return on foreign assets is too low.

Proposition 5 *Assume countries can use monetary policy and capital account policy but not trade policy. If $\beta > \Pi u'\left(\overline{L}\right)$ there is a global liquidity trap. If a symmetric Nash equilibrium exists, it involves a strictly positive tax on capital inflows $\tau^b > 0$ but the allocations and welfare are the same as in the Nash equilibrium without capital controls.*

Proof. See discussion above. One must have $\tau^b > 0$ because welfare strictly increases with τ^b at $\tau^b = 0$, as shown in Table 1. ■

However, a symmetric Nash equilibrium does not always exist, and in fact does not exist under our benchmark calibration.[8] Figure 1 shows how welfare varies with domestic consumption for an individual country, under the benchmark calibration, and assuming that the rest of the world is in a symmetric allocation such that the first-order condition $\partial U/\partial S = 0$ for $S = 1$ is satisfied. The symmetric allocation corresponds to point A. It appears that A corresponds not to a maximum but to a minimum of the individual country's welfare function. Countries strictly benefit from deviating from the symmetric allocation and for example going to point B, which corresponds to a strategy of taxing inflows more than the average country to depreciate the currency and reach full employment. This escalation in the currency war naturally reaches its limits. As countries move from point A to point B, the real interest rate falls, which reduces the welfare gain from accumulating foreign assets. The shape of the welfare function is changed in equilibrium to become the dashed line in Figure 2, where countries are indifferent between points B', corresponding to full employment, and point A', corresponding to less employment but more consumption.

[8] One can show that a symmetric Nash equilibrium does not exist if γ is too large. Under the benchmark calibration such an equilibrium does not exist if γ exceeds [.].

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. These countries complain about different things: the deficit countries about their unemployment and the surplus countries about the low return that they received on their foreign assets. The cost of one country is the benefit of another: the full employment of surplus countries is made possible by the unemployment in deficit countries, and the deficit countries can find consolation for their lower employment in their ability to borrow abroad at a low interest rate. In equilibrium the welfare of surplus countries and deficit countries is the same.

Furthermore, the figure shows that the welfare of both groups of countries is higher than it was in the symmetric allocation (point A). Since the symmetric allocation yielded the same welfare as without capital controls, this means that the capital war leads to a Pareto improvement when it involves symmetry breaking. The endogenous country heterogeneity increases welfare because of the convexity in the welfare function. The size of the welfare gain is small however.

5.3 Inflation target war

We now assume that all countries can choose their inflation targets Π_j in a global liquidity trap. We have the following proposition.

Proposition 6 *(Endogenous inflation targets) Assume that each country chooses its inflation target Π_j in a global liquidity trap. In a symmetric Nash equilibrium all countries choose an inflation target larger than $\beta/u'\left(\overline{L}\right)$ and there is full employment. There is no benefit from international policy coordination.*

International coordination yields no benefit for inflation targets or for interest rates. When all countries increase their inflation targets by the same amount, there is no expenditure-switching effect, only an expenditure augmenting effect which is efficient at the global level.

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 factors β) 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 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 could have different sizes or home bias.

The model could also be made more dynamics. An infinite-time model would behave similarly to our two-period model if one assumes that the economy is in a full-employment steady state after a finite time. Such a model would make it possible to study the robustness of trigger strategy equilibria in which free trade is supported by the threat of a trade war. An interesting question, in this context, is whether a trade war is made more or less likely by a fall in global demand leading to unemployment.

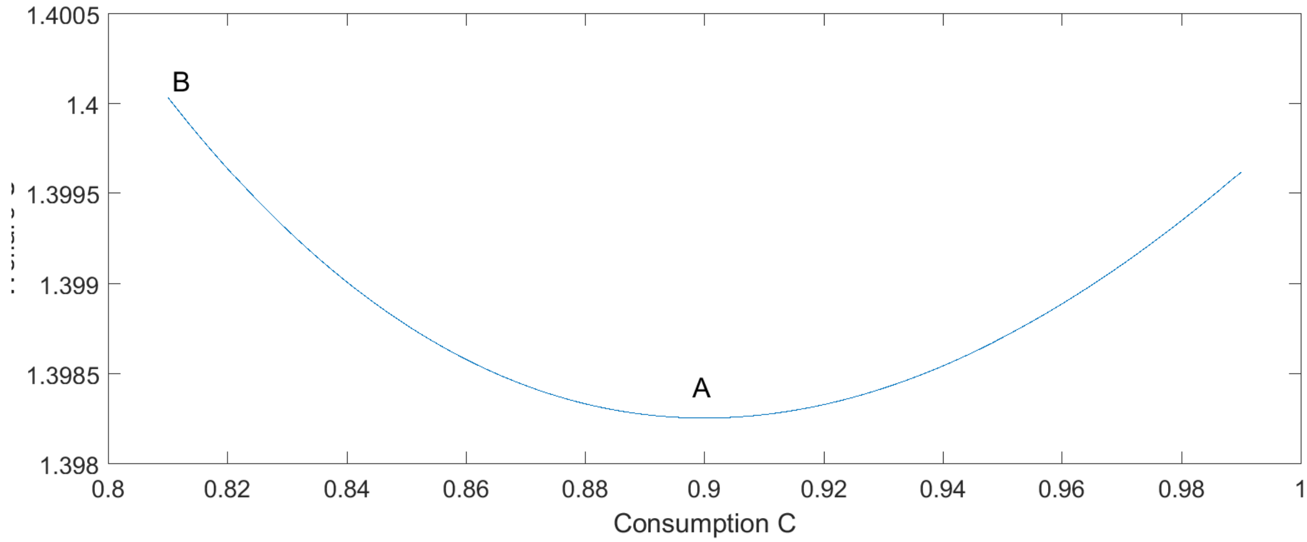

Figure 1: Variation of welfare with consumption (A=symmetric allocation, B= full employment)

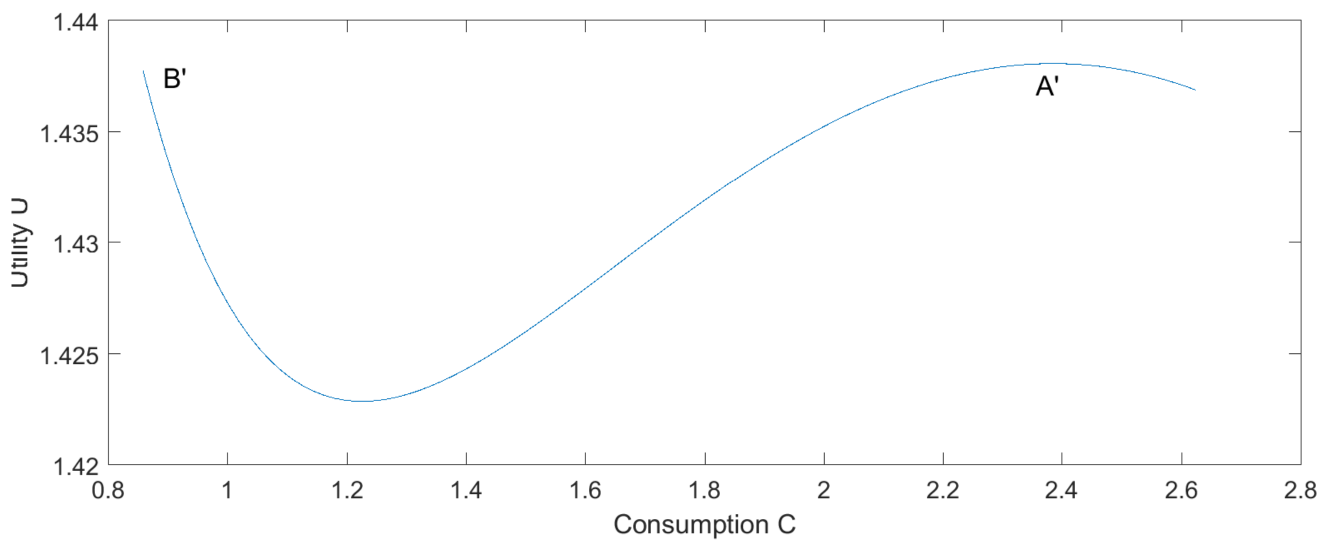

Figure 2: Variation of welfare with consumption in Nash equilibrium

APPENDIX

Proof of Proposition 3

The social planner's problem can be written,

$$\begin{cases} \max_{C_{H_j},C_{F_j},X_j} U_j = u\left(C\left(C_{H_j}, C_{F_j}\right)\right) + \beta\left(1+r\right)B_j, \\ L_j = C_{H_j} + X_j \leq \overline{L}, \\ B_j = \left(C_{F_j}^W\right)^{1/\gamma} X_j^{1-1/\gamma} - C_{F_j}, \end{cases}$$

where $C\left(C_H, C_F\right)$ stands for the CES index given in (2). We simplify the problem by assuming that the social planner sets the endogenous variables C_{H_j}, C_{F_j} and X_j rather than the exogenous policy instruments. The policy instruments can be derived from the allocation using the equilibrium conditions. The expression for welfare substitute out C' from (1) using (8), and leaving aside an unimportant constant. The first constraint combines (3) and (9). The second constraint is (14) where the demand for exports $X = \left(S^x\right)^{-\gamma} C_F^W$ was used to substitute out S^x.The Lagrangian for the social planner's problem is

$$£ = u\left(C\left(C_H, C_F\right)\right) + \beta\left(1+r\right)B + \lambda\left(\overline{L} - C_H - X\right) + \mu\left[\left(C_F^W\right)^{1/\gamma} X^{1-1/\gamma} - C_F - B\right].$$

The first-order conditions for C_H and C_F, and $\frac{\partial C}{\partial C_H} / \frac{\partial C}{\partial C_F} = S^m$ imply

$$\lambda = S^m \mu.$$

The first-order condition for X, and $S = \left(C_F^W\right)^{1/\gamma} X^{-1/\gamma}$ imply

$$\lambda = \left(1 - 1/\gamma\right)\mu S.$$

These two equations imply $S/S^m = \gamma/\left(\gamma - 1\right)$. Then $S/S^m = 1 + \tau^m$ gives the expression for τ^m in the Proposition.

The first-order conditions for B and C_F imply

$$u'\left(C\right)\left(S^m\right)^{-\alpha_H} = \beta\left(1+r\right)$$

whereas (15) and (16) together imply,

$$u'\left(C\right)\left(S^m\right)^{-\alpha_H} = \beta\left(1+r\right)\left(1+\tau^m\right)\left(1+\tau^b\right).$$

The two previous equations imply $(1+\tau^m)\left(1+\tau^b\right) = 1$, which gives the expression for τ^b in the Proposition.

If $\eta = 1$ $p(S) = S^{\alpha_H}$. Conditions $C_H + C_F = \overline{L}$, (11), (12) and $S^m = (\gamma - 1)/\gamma$ imply that first-period consumption is given by $C^{NSP} = (1-\alpha_F/\gamma)\overline{L}/(1-1/\gamma)^{\alpha_F}$.

The global social planner takes into account the fact that $B_j = 0$ in a symmetric equilibrium and maximizes the consumption of the representative consumer $C(C_H, C_F)$ subject to the resource constraint $C_H + C_F \leq \overline{L}$. This gives $C^{GSP} = \overline{L}$. Thus international cooperation increases first-period consumption by the factor $(1-1/\gamma)^{\alpha_F}/(1-\alpha_F/\gamma)$ as stated in the proposition.

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