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ABSTRACT

Government Purchases and the Real Exchange Rate

Recent empirical research documents that an exogenous rise in government purchases in a given country triggers a persistent *depreciation* of its real exchange rate - which raises an important puzzle, as standard macro models predict an *appreciation* of the real exchange rate. This paper presents a simple model with limited international risk sharing that can account for the empirical real exchange rate response. When faced with a country-specific rise in government purchases, local households experience a negative wealth effect; they thus work harder, and domestic output increases. Under balanced trade (financial autarky) this supply-side effect is so strong that the terms of trade worsen, and the real exchange rate depreciates. In a bonds-only economy, an increase in government purchases triggers a real exchange rate depreciation, if the rise in government purchases is sufficiently persistent and/or labor supply is highly elastic.

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1. Introduction

Much recent research has provided empirical estimates of the macroeconomic effect of fiscal policy shocks, based on structural vector-autoregressions (VARs). That work suggests that an exogenous increase in government purchases in a given country raises output and employment in that country, and that it triggers a persistent *depreciation* of its real exchange rate; see, e.g., Kollmann (1998), Dellas, Neusser and Wältli (2005), Corsetti and Müller (2006), Monacelli and Perotti (2006, 2009), Ravn, Schmitt-Grohé and Uribe (2007), Kim and Roubini (2008), Enders, Müller and Scholl (2008) and Corsetti, Meier and Müller (2009a,b).

That empirical response of the real exchange rate raises an important puzzle, as standard macroeconomic models predict that a rise in government purchases triggers a real exchange rate *appreciation*. For example, in the canonical international RBC model of Backus, Kehoe and Kydland (1994) a country-specific rise in government purchases triggers a fall in domestic private consumption, which is accompanied by an appreciation of the real exchange rate, as the model postulates that consumption risk is efficiently shared across countries. A real exchange rate appreciation is also predicted by traditional Keynesian models (Mundell-Fleming); in those models, an increase in government purchases raises aggregate demand — goods market clearing requires an appreciation of the nominal exchange rate, which leads to a real exchange rate appreciation, given the assumption that prices are sticky.

The paper here presents a simple micro-based model that can generate a real exchange rate *depreciation*, in response to a rise in government purchases. The key ingredient of the model is the assumption that international financial markets are incomplete--a setting with balanced trade (financial autarky) is considered, as well as a setting in which only an unconditional bond can be traded internationally. When faced with a country-specific rise in government purchases, local households experience a negative wealth effect; they thus work harder and domestic output rises. Limited risk sharing exacerbates this negative wealth effect and the resulting country-specific output increase. I show that, under balanced trade, this supply effect is so strong that the country's terms of trade deteriorate, and its real exchange rate depreciates. This supply-side effect is shown to operate also when prices or wages are sticky—provided that (as seems plausible) monetary policy does not completely offset the stimulative effect of the rise in government purchases on output. In the bonds-only economy, an increase in (relative) government purchases triggers a real exchange rate depreciation, if the rise in government purchases is sufficiently persistent and/or labor supply is highly elastic.

Section 2 discusses the basic mechanism, using a static model. A dynamic model is discussed in Section 3. Section 4 concludes.

2. A static model

2.1. Technologies, preferences and markets

There are two ex-ante symmetric countries, Home (H) and Foreign (F). Each country is inhabited by a representative household and a government. Country *i*=H,F produces Y_i units of a tradable intermediate good *i*, using local labor and the linear technology $Y_i = L_i$, where L_i is the labor input. In addition, country *i* uses local and imported intermediate goods to produce Z_i units of a non-traded final good that is used for private and government consumption. Country *i*'s final-good production function is given by:

$$Z_i = [\alpha^{1/\phi}(y_i^i)^{(\phi-1)/\phi} + (1-\alpha)^{1/\phi}(y_j^i)^{(\phi-1)/\phi}]^{\phi/(\phi-1)} \quad \text{with} \quad j \neq i\,,$$

where y_j^i is the amount of intermediate good *j* used in the production of final good *i*; $\phi > 0$ is the substitution elasticity between the intermediate goods. I assume $0.5 < \alpha < 1$, i.e. there is a technological bias in favor of the use of the local input in final good production.

Country *i* production technologies are operated by competitive firms owned by the local household. The labor market is likewise competitive. Prices and wages are flexible. Prices thus equal marginal costs. The price of the country *i* intermediate good, denoted p_i, is hence given by $p_i = W_i$, where W_i is the country *i* wage rate. The price of the country *i* final good is:

$$P_i \equiv [\alpha(p_i)^{1-\phi} + (1-\alpha)(p_j)^{(1-\phi)}]^{1/(1-\phi)}, \quad j \neq i\,. \tag{1}$$

Final good producers use a mix of local and foreign intermediates such that the marginal rate of substitution between those inputs is equated to the relative price. This implies:

$$y_i^i = \alpha (p_i/P_i)^{-\phi} Z_i,\ y_j^i = (1-\alpha)(p_j/P_i)^{-\phi} Z_i \text{ for } j \neq i. \tag{2}$$

The country *i* household has utility $U_i = \frac{1}{1-\sigma}\{(C_i)^{1-\sigma} - 1\} - \frac{1}{1+1/\eta}(L_i)^{1+1/\eta}$, where C_i is her final good consumption. $\sigma, \eta > 0$ are the risk aversion coefficient and the (Frisch) labor supply elasticity, respectively. The household's budget constraint is: $P_i C_i = p_i Y_i - T_i$, where $T_i = P_i G_i$ is a lump sum tax levied by the government to finance exogenous stochastic real public purchases G_i. Thus, the budget constraint can be written as

$$P_i (C_i + G_i) = p_i Y_i. \tag{3}$$

The household equates her marginal rate of substitution between consumption and leisure to the real wage rate, $W_i/P_i = (p_i/P_i)$. Hence,

$$(C_i)^{-\sigma}(p_i/P_i) = (L_i)^{1/\eta}. \tag{4}$$

Market clearing requires $Y_i = y_i^H + y_i^F$ and $Z_i = C_i + G_i$ for *i*=H,F. Note that, in this static model, trade is balanced (net imports are zero), as initial external financial claims are zero. Y_i represents the real GDP of country *i*. The Home terms of trade are $q \equiv p_H / p_F$; I define the Home real exchange rate as the price of final good H in units of final good F: $rer \equiv P_H/P_F$ (an increase in rer is thus an appreciation of the Home real exchange rate).

The above equations pin down private consumption and output in both countries, as well as relative goods prices, given G_H, G_F. The distributions of government purchases are symmetric across countries; I denote mean purchases by $\overline{G} \equiv E(G_i)$.

2.2. Model solution

I linearize the model around the equilibrium that obtains when $G_H = G_F = \overline{G}$. $\hat{x} \equiv (x - \overline{x})/\overline{x}$ is the relative deviation of a variable *x* from the point of linearization, $\overline{x}$. Variables without subscripts represent ratios of Home to Foreign variables: $y \equiv Y_H/Y_F$, $z \equiv Z_H/Z_F$, $c \equiv C_H/C_F$, $g \equiv G_H/G_F$.

From equation (1), the real exchange rate obeys: $\widehat{rer} = (2\alpha - 1)\hat{q}$; a Home terms of trade improvement induces thus a Home real exchange rate appreciation (due to the local content bias $\alpha > 0.5$). The demand functions for intermediate goods (2) imply that relative *world* demand for intermediate good H (compared to demand for good F) is:

$$d \equiv \frac{y_H^H + y_H^F}{y_F^H + y_F^F} = q^{-\phi} \frac{\alpha\, rer^{\phi} z + 1 - \alpha}{\alpha + (1-\alpha)\, rer^{\phi} z}, \tag{5}$$

where $z \equiv Z_H / Z_F = (C_H + G_H)/(C_F + G_F)$ is relative country H absorption. Market clearing requires that relative demand equates relative GDP: $d = y$. Linearizing (5) thus gives:

$$\hat{y} = -\phi\hat{q} + (2\alpha - 1)(\phi\widehat{rer} + \hat{z}) = -4\alpha(1-\alpha)\phi\hat{q} + (2\alpha-1)\{(1-\Gamma)\hat{c} + \Gamma\hat{g}\}, \tag{6}$$

as $\hat{z} = (1-\Gamma)\hat{c} + \Gamma\hat{g}$, where $\Gamma \equiv \overline{G_i}/(\overline{C_i} + \overline{G_i})$. [1] (6) shows that relative world demand for the Home intermediate good is decreasing in the Home terms of trade, and increasing in relative Home private and government consumption, as $\alpha > 0.5$.

The budget constraint (3) implies that $P_H Z_H - P_F Z_F = p_H Y_H - p_F Y_F$, and hence:

$$(1-\Gamma)\hat{c} + \Gamma\hat{g} = \hat{y} + 2(1-\alpha)\hat{q}. \tag{7}$$

An increase in relative Home consumption or government purchases thus has to be financed by an increase in relative Home (real) GDP and/or by an improvement of the Home terms of trade.

(6) and (7) allow to express relative Home consumption and GDP as functions of the terms of trade and of relative government purchases:

$$\hat{c} = -\tfrac{1}{1-\Gamma}\{2\alpha\phi - 1\}\hat{q} - \tfrac{1}{1-\Gamma}\hat{g}, \tag{8}$$

$$\hat{y} = -\{1 + 2\alpha(\phi - 1)\}\hat{q}. \tag{9}$$

Holding constant the terms of trade, an increase in (relative) government purchases thus crowds out (relative) consumption. Provided $\phi > 1 - 1/(2\alpha)$, an improvement in the Home terms of trade reduces relative GDP. (9) is an 'effective' relative *demand* function for the Home intermediate good that captures the substitution effect of terms of trade changes, as well as the income effect of terms of trade changes (via the relative budget constraint (7)).

I next discuss the determinants of the (relative) *supply* of Home intermediates. Equation (4) implies that hours worked (and, thus, GDP) in country *i* are increasing in the

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[1] To get (6), I use that fact that $\overline{q} = \overline{rer} = 1$ and $\overline{y} = \overline{z}$ due to symmetry.

country's terms of trade, and decreasing in consumption. Intuitively, a terms of trade improvement raises the value of the marginal product of labor, in units of final consumption, which increases household labor supply; by contrast, an increase in consumption lowers the marginal utility of consumption which lowers labor supply. In relative Home/Foreign terms, (4) implies:

$$\tfrac{1}{\eta}\hat{y} = 2(1-\alpha)\hat{q} - \sigma\hat{c}, \tag{10}$$

as $\hat{y}=\hat{l}$ (production function). Substitution of the expression for relative consumption (8) into (10) gives:

$$\hat{y} = \eta\{2(1-\alpha) + \sigma\tfrac{2\alpha\phi-1}{1-\Gamma}\}\hat{q} + \eta\sigma\tfrac{\Gamma}{1-\Gamma}\hat{g}\,. \tag{11}$$

(11) can be interpreted as a relative supply function of Home intermediates (as (11) is derived from the household's optimal consumption-leisure choice and the production function). A *sufficient* condition under which relative supply is increasing in the terms of trade is $\phi > 1/(2\alpha)$. The substitution elasticity ϕ corresponds to the price elasticity of international trade flows; empirical estimates of that elasticity are mostly in the range of unity or above unity (e.g., Hooper (1995) and Coeurdacier, Kollmann and Martin (2008, 2009)). In medium-sized to large industrialized economies, the ratio of imports (and exports) to GDP is in the range of 10%-20%, which implies that α lies between 0.8 and 0.9, and thus that $1/(2\alpha)$ is in the range 0.55-0.62. $\phi > 1/(2\alpha)$ holds thus for plausible values of ϕ. The subsequent analysis assumes that this condition is met. (Note that $\phi > 1/(2\alpha)$ implies $\phi > 1-1/(2\alpha)$, which ensures that relative demand for Home intermediates is decreasing in the terms of trade; see (9).)

(11) shows also that an increase in relative Home government purchases $\hat{g}$ raises the relative supply of Home intermediates, at given terms of trade: the increase in $\hat{g}$ crowds out private consumption (see (8)), which raises (relative) labor supply and GDP (as discussed above). When relative Home government purchases increase, market clearing thus requires a worsening of the Home terms of trade, and a depreciation of the Home real exchange rate. Solving (9) and (11) for the equilibrium terms of trade gives:

$$\hat{q} = \Psi_g^{BT} \hat{g}\,, \qquad (12)$$

with $\Psi_g^{BT} \equiv -\sigma \frac{\Gamma}{1-\Gamma} / [2(1-\alpha) + \sigma \frac{2\alpha\phi-1}{1-\Gamma} + (1-2\alpha(1-\phi))/\eta]$.

Note that $\Psi_g^{BT} < 0$ holds (if $\phi > 1/(2\alpha)$). (The 'BT' superscript stands for 'Balanced Trade', a key feature of the present structure; see discussion below.)

The response of the terms of trade to government purchases shocks is more pronounced, the greater are the risk aversion coefficient and the labor supply elasticity: for higher values of σ and η, the (relative) supply of Home intermediates increases more strongly in response to a rise in government purchases (see (11)), and thus market clearing requires a stronger terms of trade worsening (and real exchange rate depreciation).

Note also that an increase in relative Home government purchases $\hat{g}$ raises relative GDP, but that it lowers relative consumption (as can be seen by substituting (12) into (8) and (9)). It can also be shown that an increase in Home government purchases G_H raises Home output and lowers Home consumption in levels (not just in relative terms).

As mentioned in the Introduction, recent empirical research suggests that an exogenous increase in government purchases raises output and depreciates the real exchange rate. The model here reproduces these facts. There is no consensus in the empirical literature on the response of consumption: some empirical studies (e.g. Ramey (2008) and Edelberg, Eichenbaum and Fischer (1999)) report that consumption falls, in response to a rise in government purchases, while other studies report an increase (e.g, Monacelli and Perotti (2009)) or find that the response of consumption is not significant (Mountford and Uhlig (2008)).

To generate a positive response of private consumption to a rise in government spending, one could assume that country i government consumption increases the productivity of local intermediate goods firms, and/or that it raises the local household's marginal utility of private consumption (see Kollmann (1998)). It seems plausible that, in the real world, government spending has a positive effect on private sector productivity, and on households' enjoyment from private consumption (e.g. if public spending is used to maintain law and order, or to provide other vital public goods). These additional channels would strengthen the supply-side effect of an increase in government purchases, and hence reinforce the real exchange rate depreciation.

2.3. Complete asset markets

The baseline model assumes balanced trade, and thus limited international risk sharing. Compared to a setting with full risk sharing, this strengthens the negative effect of a rise in government purchases on private consumption, and thus induces a rise in relative labor supply and output that is sufficiently strong to worsen the terms of trade. To highlight the role of risk sharing, assume that before government purchases are realized, the households trade in a complete set of Arrow-Debreu securities. The existence of complete markets implies that, in equilibrium, the ratio of Home to Foreign households' marginal utilities of final consumption is proportional to the real exchange rate (e.g. Kollmann (1991, 1995), Backus and Smith (1993)): $(C_H)^{-\sigma}/(C_F)^{-\sigma}=rer$. Efficient risk sharing implies thus that a fall in Home relative consumption has to be accompanied by an appreciation of the Home real exchange rate:

$$\hat{c} = -\tfrac{1}{\sigma}(2\alpha - 1)\hat{q}. \tag{13}$$

Of course, (6) (relative demand for Home intermediates as a function of the terms of trade and relative absorption) and the (relative) optimal labor (output) supply condition (10) continue to hold, under complete markets. (The relative budget constraint (7) does *not* hold anymore; (7) is replaced by (13).) Substitution of (13) into (6) and (10) gives:

$$\hat{y} = -\left[4\alpha(1-\alpha)\phi + (2\alpha-1)^2(1-\Gamma)/\sigma\right]\hat{q} + (2\alpha-1)\Gamma\hat{g}\ , \tag{14}$$

$$\text{and } \hat{y} = \eta\,\hat{q}\,. \tag{15}$$

(14) is an 'effective' relative demand function for the Home intermediate good, under complete markets ((14) captures the substitution effect of terms of trade changes, as well as the effect of the terms of trade on relative consumption due to the risk sharing condition (13)). (15) is a relative supply function for the Home intermediate. The key insight (compared to the setting with balanced trade) is that, when markets are complete, a positive shock to Home government purchases *raises* relative demand for the Home intermediate good (see (14)), but has no effect on the relative supply, at unchanged terms

of trade (as relative consumption only depends on the terms of trade, under full risk sharing; see (13)). At unchanged terms of trade, an increase in Home government purchases creates an excess demand for the Home intermediate, when markets are complete; market clearing requires therefore an *improvement* in the Home terms of trade.

Solving (14) and (15) for $\hat{q}$ shows that, under complete markets (CM), the equilibrium Home terms of trade are *increasing* in relative Home government purchases:

$$\hat{q} = \Psi_g^{CM}\,\hat{g}, \tag{16}$$

with $\Psi_g^{CM} \equiv (2\alpha-1)\Gamma/\{4\alpha(1-\alpha)\phi+(2\alpha-1)^2(1-\Gamma)/\sigma+\eta\} > 0$.

2.4. Nominal rigidities

Do the previous results go through when prices or wages are sticky? With nominal rigidities, the effect of a fiscal policy shock is influenced by the response of monetary policy (see e.g. Betts and Devereux (2000), Lombardo and Sutherland (2004), Canzoneri, Collard, Dellas, Diba (2007), Dellas, Neusser and Wältli (2005), Erceg, Guerrieri and Gust (2005) and Erceg, Gust and Lopez-Salido (2007) for discussions of this point, in an open economy context). However, I show next that, in the setting with limited risk sharing (balanced trade), the Home real exchange rate continues to depreciate in response to a positive shock to Home government purchases, if monetary policy does not fully off-set the stimulative effect of the fiscal shock on Home output. [2] The econometric evidence (see Introduction) shows that output rises in response to a positive shock to government purchases--which suggests that, in the real world, monetary policy does not fully off-set the fiscal policy stimulus.

This Subsection again considers a world with balanced trade. I assume now that each country has its own currency. Let '*e*' denote the nominal exchange rate, defined as the Foreign currency price of one unit of Home currency, and let p_j^i be the price of

[2] In a world with nominal rigidities and complete financial markets, the real exchange rate continues to *appreciate* in response to a rise in relative government purchases, unless monetary policy significantly strengthens the stimulus effect on output (beyond the stimulus that exists with flexible prices and wages).

intermediate good *j*, in country *i* (in currency *i*). The real exchange rate and the terms of trade are now defined as: $rer \equiv P_H e/P_F$ and $q \equiv (p_H^F/e)/p_F^H$, respectively.

Sticky wages

Suppose that nominal wages are set before government purchases are realized, while prices are fully flexible. If (as assumed so far) the Law of one price holds, then intermediate goods prices obey $\widehat{p_H^H}+\hat{e}=\widehat{p_H^F}$ and $\widehat{p_F^H}+\hat{e}=\widehat{p_F^F}$. This implies that the real exchange rate is again given by: $\widehat{rer}=(2\alpha-1)\hat{q}$. Also, (6) and (7) continue to hold, so that the effective relative demand for Home intermediate goods is still given by (9): $\hat{y}=-\{1+2\alpha(\phi-1)\}\hat{q}$.

Sticky prices—producer currency price setting (PCP)

Assume next that wages are flexible, but that prices are set in advance, in producer currency. Then the terms of trade are given by $\hat{q}=\hat{e}$ and $\widehat{rer}=(2\alpha-1)\hat{e}$. [3] Thus, it remains true that $\widehat{rer}=(2\alpha-1)\hat{q}$. (6) and (7) continue to hold, and thus the relative demand for Home intermediates is again given by (9): $\hat{y}=-\{1+2\alpha(\phi-1)\}\hat{q}$.

Sticky prices—local currency price setting (LCP)

Alternatively, assume that prices are set in advance, in local (buyer) currency. Then the real exchange rate and the terms of trade are given by $\widehat{rer}=\hat{e}$ and $\hat{q}=-\hat{e}$, respectively.[4] With LCP, equation (6) implies $\hat{y}=(2\alpha-1)\{(1-\Gamma)\hat{c}+\Gamma\hat{g}\}$, while the relative budget constraint (7) is replaced by: $\hat{y}+2(1-\alpha)\hat{e}=(1-\Gamma)\hat{c}+\Gamma\hat{g}$. [5] Under LCP, a depreciation of the

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[3] To see this, note that under PCP, p_H^H and p_F^F cannot respond to shocks; thus $\widehat{p_H^H}=0$, $\widehat{p_F^F}=0$, and $\widehat{p_H^F}=\hat{e}$, $\widehat{p_F^H}=-\hat{e}$.

[4] LCP implies $\widehat{p_H^H}=\widehat{p_H^F}=\widehat{p_F^F}=\widehat{p_F^H}=\widehat{P_H}=\widehat{P_F}=0$.

[5] Under LCP the Law of one prices does *not* hold. The budget constraints of the country H and F household are now $p_H^H y_H^H + p_H^F y_H^F/e = P_H(C_H+G_H)$ and $p_F^F y_F^F + p_F^H y_F^H e = P_F(C_F+G_F)$, respectively. Take the difference between these constraints and linearize; this gives $2(1-\alpha)\hat{e}+\hat{y}=(1-\Gamma)\hat{c}+\Gamma\hat{g}$.

Home nominal exchange rate *improves* the Home terms of trade; for a given value of relative Home GDP, $\hat{y}$, this raises relative Home absorption. It follows from the preceding two equations (and $\widehat{rer}=\hat{e}$) that $\hat{y}=-(2\alpha-1)\widehat{rer}$ holds, under LCP.

Note that under all three types of nominal rigidities, relative Home output $\hat{y}$ is inversely related to the Home real exchange rate. Thus, if a rise in $\hat{g}$ leads to an increase in $\hat{y}$-- which is the case if monetary policy fails to fully off-set the stimulative effect of the fiscal shock-- then the real exchange rate depreciates.

3. A dynamic model with incomplete financial markets

Do the main results go through in a multi-period world? In this Section, I discuss an infinite-horizon version of the model, assuming flexible prices and wages.[6] In period t, the expected lifetime utility of the (infinitely lived) country *i* representative household is

$$E_t \sum_{s=0}^{\infty} \beta^s \left(\tfrac{1}{1-\sigma}\{(C_{i,t+s})^{1-\sigma}-1\} - \tfrac{1}{1+1/\eta}(L_{i,t+s})^{1+1/\eta} \right),$$

where $0<\beta<1$ is the subjective discount factor. If balanced trade (financial autarky) or complete financial market were assumed, the response of the real exchange rate to government spending shocks would be the same as in the static model of Section 2. [7] To obtain a setting in which the multi-period dimension matters, I assume that there is international asset trade, but that the financial market is incomplete. Specifically, I postulate that only a one-period bond can be traded.[8]

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[6] Kollmann (1998) reports simulations of a dynamic two-country model with incomplete financial markets and Calvo-style price/wage stickiness; in that model, a persistent rise in relative government purchases leads to a real exchange rate depreciation.

[7] Under these two asset structures, the date *t* terms of trade in the multi-period economy are determined by equations that only feature date *t* endogenous variables and date *t* government purchases; these equations are identical to the ones that govern the terms of trade in the static model: namely (6), (7) and (10) under balanced trade; (6), (13) and (10) under complete markets.

[8] Models with a bonds-only structure have a long tradition in international economics (e.g. Obstfeld and Rogoff (1996), Kollmann (1991, 1996), Baxter and Crucini (1995)). Up to a first order approximation, it does not matter whether the bond is denominated in the Home good or the Foreign good, or in a basket of goods, if (as in the analysis below) the model is approximated around a deterministic steady state in which net foreign bond holdings are zero.

As Ricardian equivalence holds here, I assume without loss of generality that the government runs a balanced budget. The country *i* household thus faces the following budget constraint in period *t*:

$$A_{i,t+1}+P_{i,t}(C_{i,t}+G_{i,t})=p_{i,t}Y_{i,t}+A_{i,t}(1+r_t), \tag{17}$$

where $A_{i,t+1}$ is the household's stock of bonds at the end of t; r_t is the interest rate between *t*-1 and *t*. Market clearing for bonds requires $A_{H,t}+A_{F,t}=0$ for all t. Subtract the Foreign budget constraint from the Home constraint, and linearize the resulting expression around a symmetric deterministic steady state.[9] This gives:

$$2\widetilde{A_{t+1}}+\widehat{rer_t}+(1-\Gamma)\widehat{c_t}+\Gamma\widehat{g_t}=\widehat{q_t}+\widehat{y_t}+2\widetilde{A_t}\frac{1}{\beta}, \tag{18}$$

where $\widetilde{A_{t+1}}\equiv A_{H,t+1}/(\overline{p_H}\,\overline{Y_H})$ is the country H bond position at the end of period *t*, normalized by steady state GDP; $1/\beta$ is the steady state gross interest rate.

Solving (18) forward (ruling out Ponzi schemes) yields the intertemporal budget constraint $\widetilde{A_t}\frac{1}{\beta}=E_t\sum_{s=0}^{\infty}\beta^s\chi_{t+s}$, where $\chi_{t+s}\equiv\frac{1}{2}(1-\Gamma)\widehat{c_{t+s}}+\frac{1}{2}\Gamma\widehat{g_{t+s}}-\frac{1}{2}\widehat{y_{t+s}}-(1-\alpha)\widehat{q_{t+s}}$ are Home country net imports at *t*+*s* (normalized by steady state GDP). Thus, country H external financial wealth at the beginning of period *t* equals the expected present value of H's net imports in $t, t+1, t+2,...$ (normalized by GDP).

In the dynamic model, the relative demand condition (6) and the household's optimal labor (output) supply decision (10) (reproduced here for convenience, with time subscripts) have to hold in all periods:

$$\widehat{y_t}=-4\alpha(1-\alpha)\phi\widehat{q_t}+(2\alpha-1)\{(1-\Gamma)\widehat{c_t}+\Gamma\widehat{g_t}\}, \tag{6}$$

$$\text{and} \quad \frac{1}{\eta}\widehat{y_t}=2(1-\alpha)\widehat{q_t}-\sigma\widehat{c_t}. \tag{10}$$

(6) and (10) allow to express $\widehat{c_t}$ and $\widehat{y_t}$ as functions of $\widehat{g_t}$ and $\widehat{q_t}$. Thus, net imports too can be written as a function of $\widehat{g_t}$ and $\widehat{q_t}$: $\chi_t=b_g\widehat{g_t}+b_q\widehat{q_t}$, for coefficients $b_g>0$ and b_q;

[9] As market clearing requires $A_{H,t}=-A_{F,t}$, the differences between (17) for *i*=H and F can be written as: $2A_{H,t+1}+P_{H,t}(C_{H,t}+G_{H,t})-P_{F,t}(C_{F,t}+G_{F,t})=p_{H,t}Y_{H,t}-p_{F,t}Y_{F,t}+2A_{H,t}(1+r_t)$. Note that in a symmetric steady state, bond holdings are zero: $\overline{A_H}=\overline{A_F}=0$.

$b_q>0$ holds when $\phi>1-1/(2\alpha)$. [10] Interestingly, $b_g/b_q=-\Psi_g^{BT}$, where Ψ_g^{BT} is the elasticity of the terms of trade with respect to $\hat{g}$ under balanced trade (see (12)). [11] The intertemporal budget constraint can thus be expressed as

$$\widetilde{A}_t \frac{1}{\beta} = b_q E_t \sum_{s=0}^{\infty} \beta^s \{\widehat{q_{t+s}} - \Psi_g^{BT} \widehat{g_{t+s}}\}. \quad (19)$$

The bond position $\widetilde{A}_t$ is set in period t-1. Hence, a date t fiscal shock that raises the expected present value of relative Home government purchases induces a fall in the *expected present value* of the Home terms of trade at $t, t+1, t+2, \ldots$.

A more precise characterization of the terms of trade response can be obtained from the Home and Foreign households' intertemporal Euler equations:

$$(1+R_{t+1})E_t\beta(C_{H,t+1}/C_{H,t})^{-\sigma}(P_{H,t}/P_{H,t+1})=1 \text{ and } (1+R_{t+1})E_t\beta(C_{F,t+1}/C_{F,t})^{-\sigma}(P_{F,t}/P_{F,t+1})=1.$$

In linearized form, these equations imply:

$$E_t \Delta\widehat{c_{t+1}} = -\frac{1}{\sigma}(2\alpha-1)E_t\Delta\widehat{q_{t+1}}, \quad (20)$$

where $\Delta x_{t+1} \equiv x_{t+1} - x_t$. Thus, a 'conditional' version of the complete-markets risk sharing condition (13) holds in the dynamic bonds-only economy: the expected *future* growth rate of relative Home consumption is perfectly negatively correlated with the expected rate of appreciation of the Home real exchange rate.

As (6) and (10) allow to express $\hat{c}_t$ as a function of $\hat{g}_t$ and $\hat{q}_t$, it follows from (20) that $E_t\Delta\widehat{q_{t+1}}$ can be expressed as a function of $E_t\Delta\widehat{g_{t+1}}$. In fact,

$$E_t\Delta\widehat{q_{t+1}} = \Psi_g^{CM} E_t\Delta\widehat{g_{t+1}}, \quad (21)$$

where Ψ_g^{CM} is the elasticity of the terms of trade with respect to relative government purchases under *complete* markets (see (16)). [12] As $\Psi_g^{CM}>0$, the expected rate of change

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[10] $b_q = \{(1-\alpha)/(2\alpha-1)\}\{[2(2\alpha-1)(1-\alpha)(1-\Gamma)-4\alpha(1-\alpha)\sigma\phi]/[\sigma+(2\alpha-1)(1-\Gamma)/\eta]+2\alpha(\phi-1)+1\}$ and $b_g=(1-\alpha)\Gamma\sigma/\{(\sigma+(2\alpha-1)(1-\Gamma)/\eta\}$.

[11] Under balanced trade $\chi=b_g\hat{g}+b_q\hat{q}=0$ holds, i.e. then $\hat{q}=-(b_g/b_q)\hat{q}$. Thus $\Psi_g^{BT}=-b_g/b_q$.

[12] Recall that (16) is derived from (6), (10) and (13). In the dynamic bonds-only economy, (6) and (10) continue to hold; (13) is replaced by the conditional version of that equation, (20). Hence, a conditional expected version of (16) holds in the dynamic model, namely (21).

of the Home terms of trade is positive, iff the expected growth rate of relative Home government purchases is positive.

Using (21), the present value budget constraint (19) can be solved for $\widehat{q_t}$:

$$\widehat{q_t} = \Psi_g^{BT}\widehat{g_t} + (\Psi_g^{BT} - \Psi_g^{CM})E_t\sum_{s=1}^{\infty}\beta^s\Delta\widehat{g_{t+s}} + (1-\beta)\tfrac{1}{b_q}\widetilde{A}_t\frac{1}{\beta}, \qquad (22)$$

where $\Psi_g^{BT}<0$ and $\Psi_g^{BT} - \Psi_g^{CM} < 0$ (under the assumption that $\phi>1/(2\alpha)$). Ceteris paribus, an increase in date *t* relative Home government purchases, and an increase in the expected present value of future *growth rates* of relative government purchases, worsen thus the Home terms of trade at t.

Permanent shocks to relative government purchases

The response of the terms of trade is stronger, the greater the persistence of government purchases. Assume for example that $\Delta\widehat{g_t}$ follows the AR(1) process $\Delta\widehat{g_{t+1}}=\lambda\Delta\widehat{g_t}+\varepsilon_{t+1}$, with $\lambda\geq0$, where ε_{t+1} is a white noise, so that relative government purchases have a unit root. Then an unexpected increase in $\widehat{g_t}$ unambiguously triggers a real exchange rate depreciation, on impact. When relative government purchases follow a random walk $(\lambda=0)$, then $\widehat{q_t}=\Psi_g^{BT}\widehat{g_t}+(1-\beta)\frac{1}{b_q}\widetilde{A}_t\frac{1}{\beta}$, and thus the elasticity of the terms of trade (and of the real exchange rate) to government purchases is the same as in the balanced-trade economy.

Transitory shocks to relative government purchases

When faced with transitory fluctuations in relative government purchases, households borrow/lend in the international bond market to smoothen their consumption path. As a result, the output supply response is weaker than under balanced trade, and the real exchange rate may appreciate on impact.

Assume e.g. that $\widehat{g_t}$ follows the AR(1) process $\widehat{g_t}=\rho\widehat{g_{t-1}}+\varepsilon_t$, with $0\leq\rho<1$. Then

$$\widehat{q_t}=\left\{\Psi_g^{BT}-(\Psi_g^{BT}-\Psi_g^{CM})\frac{1-\rho}{1-\beta\rho}\beta\right\}\widehat{g_t}+(1-\beta)\frac{1}{b_q}\widetilde{A}_t\frac{1}{\beta}. \qquad (23)$$

Now, a rise in relative Home government purchases triggers a Home terms of trade deterioration (and real exchange rate depreciation) if $\rho > \frac{1-\beta}{\beta}\Psi_g^{BT}/\Psi_g^{CM}+1$. When $\rho < \frac{1-\beta}{\beta}\Psi_g^{BT}/\Psi_g^{CM}+1$, the terms of trade *improves* on impact; but note that the terms of trade worsen *after* the shock (because of (21)). In the long-run, the Home terms of trade (and the real exchange rate) converge to a value that is below the value without shock; thus Home net imports and bond holdings are likewise permanently lowered by the shock.

Special case: infinitely elastic labor supply

As is well known, neoclassical business cycle models require high (Frisch) labor supply elasticities to match the empirical volatility of hours worked and output (e.g., King and Rebelo (1999)); following Hansen (1985), an infinite labor supply elasticity is frequently assumed in macroeconomics, $\eta=\infty$. Baxter and King (1993) point out that RBC models also require highly elastic labor supply to generate significant output responses to government purchases shocks. A sufficiently elastic labor supply is likewise key for the ability of the bonds-only model here to generate a real exchange rate depreciation, on impact, in response to a *transitory* rise in government purchases.

Consider the special case where $\eta=\infty$. Then $\Psi_g^{CM}=0$ (see (16)), and thus $E_t\Delta\widehat{q_{t+s}}=0$ for $s\geq 0$, i.e. the terms of trade follow a random walk. Hence, (19) implies: $\widehat{q}_t=(1-\beta)\Psi_g^{BT}E_t\sum_{s=0}^{\infty}\beta^s\widehat{g_{t+s}}+(1-\beta)\frac{1}{b_q}\widetilde{A}_t\frac{1}{\beta}$, when $\eta=\infty$. Plausible time series processes for government purchases imply that a positive shock to $\widehat{g}_t$ raises the expected present value $E_t\sum_{s=0}^{\infty}\beta^s\widehat{g_{t+s}}$. Thus, even a very short-lived rise in Home relative government purchases is likely to depreciate the Home real exchange rate, when the labor supply elasticity is infinite, or sufficiently large (recall that $\Psi_g^{BT}<0$, if $\phi>1/(2\alpha)$). (The same prediction holds for $\alpha=0.5$, i.e. when Home and Foreign final goods are identical; then too $\Psi_g^{CM}=0$).

Numerical simulations of the bonds-only model

To give a feel for the quantitative properties of the bonds-only model, the Table below reports impulse responses of key endogenous variables. The parameter values used here are standard in the business cycle literature. I calibrate the model so that one period represents one quarter in calendar time; accordingly, I set $\beta=0.99,$ which implies an annual interest rate of 4.04%, a value that corresponds roughly to the long-run average real return on capital observed empirically (in steady state, $(1+\bar{r})\beta=1$ holds, where $\bar{r}$ is the steady state interest rate). Consistent with data for large OECD economies, the steady state ratios of government purchases and of imports to GDP are set at 20%, i.e. $\bar{G}=0.2, \alpha=0.8.$ In the quantitative experiments, the risk aversion coefficient is set at $\sigma=5$ (estimates of σ in the range of 4-5 are common for industrialized countries; e.g., Barrionuevo (1992)).

As mentioned above, the substitution elasticity ϕ corresponds to the price elasticity of international trade flows. Hooper and Marquez (1995) survey a large number of time-series studies that estimated (long run) price elasticities of aggregate trade flows, for the US, Japan, Germany, the UK and Canada; the median estimates (post-Bretton Woods era) for those countries are 0.97, 0.80, 0.57, 0.6, and 1.01, respectively; the median estimate across the five countries is 0.88. Accordingly, I set $\phi=0.88,$ in the simulations.

The simulations focus on the role of two parameters that are key for the response of the real exchange rate to government purchases shocks: the labor supply elasticity and the persistence of relative government purchases. I report results for $\eta=\infty,$ and for two lower values of the labor supply elasticity: $\eta=5$ and $\eta=2$.

Government purchases in each country follow an AR(1) process: $\widehat{G_{i,t}}=\rho\widehat{G_{i,t-1}}+\varepsilon_{i,t}$ for i=H,F. Empirically, government consumption undergoes highly persistent fluctuations. The detrended logged ratio of real government consumption in the US divided by real government consumption in an aggregate of the remaining G7 countries (‘G6’) has an autocorrelation of 0.92 at an *annual* frequency (sample period: 1970-2004). An Augmented Dickey-Fuller test fails to reject the null hypothesis that relative US/G6 government consumption has a unit root. Of course, the high persistence of government consumption might be due to the fact that government spending exhibits a systematic (endogenous) response to other macroeconomic variables that are themselves highly persistent (e.g. output or demographic variables). However, empirical studies that control for the partial endogeneity of government purchases, report that autonomous public spending is highly persistent (e.g., Forni and Pisani (2009) estimate that the autocorrelation of exogenous government purchases is 0.98, at a quarterly frequency). It seems easier to defend the idea that military spending is exogenous (Rotemberg and Woodford (1989)). As reported by Kollmann (1998), US real defense spending is highly persistent (autocorrelation of linearly detrended US real defense spending: 0.96 at a quarterly frequency during the period 1973Q1-1997Q1). In the simulations, I thus consider persistent processes for government purchases. I report results for $\rho=1$, $\rho=0.95$ and for $\rho=0.9$.

The Table shows responses of the Home real exchange rate, Home and Foreign output and consumption, and the Home bond position (end-of-period) to an innovation that raises Home government purchases by 1% of steady state GDP.

The simulations underscore the fact that persistent government purchases and/or an elastic labor supply are key for the ability of the bonds-only model to generate a real exchange rate depreciation, in response to a rise in government purchases.

Consider first the random walk case, $\rho=1$: in that case, the fiscal shock triggers a real exchange rate depreciation of 1.27% when $\eta=\infty$, and of 1.20% [1.12%] when $\eta=5$ [$\eta=2$]; Home output rises by roughly 1.3%, while Foreign output falls by about 0.3%; Home consumption falls slightly (e.g., by 0.07% of steady state GDP, when $\eta=\infty$), while Foreign consumption rises slightly (intuitively, the improvement in *Foreign* terms of trade raises Foreign wealth).

When the persistence of government purchases is lowered to $\rho=0.95$ or $\rho=0.90$ the negative (relative) wealth effect of a rise in government purchases becomes much weaker. [13] Accordingly, the responses of consumption, output and the real exchange rate become weaker too. E.g., for ρ=0.95, the real exchange rate depreciates by 0.21%, on impact, when η=∞ (initial depreciation when η=5 [η=2]: 0.15% [0.07%]). For ρ=0.9, the real exchange *appreciates* on impact, when η=2, but there is a *delayed* depreciation: in the second period after the shock, the real exchange rate falls below its pre-shock value, and it stays below the pre-shock value thereafter. In the long run, the real exchange rate is about 0.22% [0.12%] below its pre-shock value when ρ=0.95 [ρ=0.90]. (Interestingly, the long run value of the real exchange rate does not depend very much on the labor supply elasticity).

On impact, Home output increases by about 0.8%-0.9% in response to a rise in Home government purchases when ρ=0.95 and ρ=0.90; Foreign output now rises too (by between 0.1% and 0.2%). Home consumption falls, by rather modest amounts (e.g. by only 0.03% of steady state GDP, on impact when ρ=0.95, η=5). The Home household borrows from Foreign when the rise in government purchases is transitory (which together with the increase in her work effort explains the weak fall in Home consumption) -- the fiscal shock has a sizable negative long run effect on the Home net bond position (about -3.4% [-1.9%] of steady state GDP when ρ=0.95 [ρ=0.90]).

4. Conclusion

Recent empirical research based on structural VARs suggests that an exogenous increase in government purchases in a given country triggers a *depreciation* of its real exchange rate. This paper has presented a simple general equilibrium model that can reproduce this empirical regularity. The key ingredient for the success of the model is the assumption that international financial markets are incomplete--a setting with balanced trade (financial autarky) was considered, as well as a setting in which only an unconditional bond can be traded internationally. When faced with a country-specific rise in government purchases, local households experience a negative wealth effect; they thus

[13] When ρ=1, a 1% rise in g_t rises the expected present value of (relative) government purchases, $E_t\sum_{s=0}^{\infty}\beta^s g_{t+s}$ by 1%. When ρ=0.95 [ρ=0.90], the present value rises only by 0.168% [0.092%].

work harder and domestic output rises. Limited risk sharing exacerbates this wealth effect and the ensuing country-specific output increase. I showed that under balanced trade, this supply-side effect is so strong that the country's terms of trade deteriorate, and its real exchange rate depreciates. In a bonds-only economy, an increase in (relative) government purchases triggers a real exchange rate depreciation, if the rise in government purchases is sufficiently persistent and/or labor supply is highly elastic.

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Bonds-only model: responses to a shock to Home government purchases (1% of GDP)

(a) % Responses of Home real exchange rate

	$\eta=\infty$			$\eta=5$			$\eta=2$		
	ρ=1	ρ=.95	ρ=.90	ρ=1	ρ=.95	ρ=.90	ρ=1	ρ=.95	ρ=.90
s=0	-1.27	-0.21	-0.12	-1.20	-0.15	-0.05	-1.12	-0.07	0.02
s=1	1.27	-0.21	-0.12	-1.20	-0.15	-0.06	-1.12	-0.08	0.01
s=2	-1.27	-0.21	-0.12	-1.20	-0.16	-0.06	-1.12	-0.09	-0.00
s=3	-1.27	-0.21	-0.12	-1.20	-0.16	-0.07	-1.12	-0.09	-0.02
s=4	-1.27	-0.21	-0.12	-1.20	-0.16	-0.07	-1.12	-0.10	-0.02
s=8	-1.27	-0.21	-0.12	-1.20	-0.17	-0.09	-1.12	-0.12	-0.06
s=20	-1.27	-0.21	-0.12	-1.20	-0.19	-0.11	-1.12	-0.16	-0.10

(b) Responses of Home output (in % of steady state GDP)

	$\eta=\infty$			$\eta=5$			$\eta=2$		
	ρ=1	ρ=.95	ρ=.90	ρ=1	ρ=.95	ρ=.90	ρ=1	ρ=.95	ρ=.90
s=0	1.35	0.89	0.85	1.29	0.84	0.80	1.22	0.78	0.74
s=1	1.35	0.85	0.77	1.29	0.80	0.72	1.22	0.74	0.67
s=2	1.35	0.81	0.69	1.29	0.77	0.65	1.22	0.71	0.61
s=3	1.35	0.78	0.63	1.29	0.73	0.59	1.22	0.68	0.55
s=4	1.35	0.74	0.57	1.29	0.70	0.54	1.22	0.65	0.50
s=8	1.35	0.62	0.39	1.29	0.59	0.37	1.22	0.54	0.35
s=20	1.35	0.38	0.15	1.29	0.36	0.14	1.22	0.33	0.13

(c) Responses of Foreign output (in % of steady state GDP)

	$\eta=\infty$			$\eta=5$			$\eta=2$		
	ρ=1	ρ=.95	ρ=.90	ρ=1	ρ=.95	ρ=.90	ρ=1	ρ=.95	ρ=.90
s=0	-0.35	0.11	0.15	-0.33	0.12	0.17	-0.29	0.15	0.19
s=1	-0.35	0.10	0.13	-0.33	0.11	0.15	-0.29	0.13	0.16
s=2	-0.35	0.09	0.11	-0.33	0.10	0.13	-0.29	0.12	0.14
s=3	-0.35	0.08	0.10	-0.33	0.10	0.10	-0.29	0.11	0.12
s=4	-0.35	0.07	0.08	-0.33	0.09	0.10	-0.29	0.10	0.10
s=8	-0.35	0.04	0.04	-0.33	0.05	0.04	-0.29	0.07	0.05
s=20	-0.35	-0.02	-0.03	-0.33	-0.01	-0.02	-0.29	-0.00	-0.02

(d) Responses of Home consumption (in % of steady state GDP)

	$\eta=\infty$			$\eta=5$			$\eta=2$		
	ρ=1	ρ=.95	ρ=.90	ρ=1	ρ=.95	ρ=.90	ρ=1	ρ=.95	ρ=.90
s=0	-0.07	-0.01	-0.01	-0.11	-0.03	-0.03	-0.16	-0.06	-0.06
s=1	-0.07	-0.01	-0.01	-0.11	-0.03	-0.03	-0.16	-0.06	-0.05
s=2	-0.07	-0.01	-0.01	-0.11	-0.03	-0.03	-0.16	-0.06	-0.05
s=3	-0.07	-0.01	-0.01	-0.11	-0.03	-0.02	-0.16	-0.06	-0.05
s=4	-0.07	-0.01	-0.01	-0.11	-0.03	-0.02	-0.16	-0.06	-0.04
s=8	-0.07	-0.01	-0.01	-0.11	-0.03	-0.02	-0.16	-0.05	-0.03
s=20	-0.07	-0.01	-0.01	-0.11	-0.02	-0.10	-0.16	-0.04	-0.02

Table—ctd.

(e) % Responses of Foreign consumption (in % of steady state GDP)

	$\eta=\infty$			$\eta=5$			$\eta=2$		
	$\rho=1$	$\rho=.95$	$\rho=.90$	$\rho=1$	$\rho=.95$	$\rho=.90$	$\rho=1$	$\rho=.95$	$\rho=.90$
s=0	0.07	0.01	0.01	0.08	0.00	-0.00	0.08	-0.01	-0.02
s=1	0.07	0.01	0.01	0.08	0.00	-0.00	0.08	-0.01	-0.01
s=2	0.07	0.01	0.01	0.08	0.01	-0.00	0.08	-0.01	-0.01
s=3	0.07	0.01	0.01	0.08	0.01	0.00	0.08	-0.00	-0.01
s=4	0.07	0.01	0.01	0.08	0.01	0.00	0.08	-0.00	-0.01
s=8	0.07	0.01	0.01	0.08	0.01	0.00	0.08	0.00	-0.00
s=20	0.07	0.01	0.01	0.08	0.01	0.01	0.08	0.01	0.01

(d) % Response of Home end-of-period bond position (in % of steady state GDP)

	$\eta=\infty$			$\eta=5$			$\eta=2$		
	$\rho=1$	$\rho=.95$	$\rho=.90$	$\rho=1$	$\rho=.95$	$\rho=.90$	$\rho=1$	$\rho=.95$	$\rho=.90$
s=0	0.00	-0.16	-0.18	0.00	-0.17	-0.18	0.00	-0.18	-0.19
s=1	0.00	-0.32	-0.34	0.00	-0.33	-0.35	0.00	-0.35	-0.37
s=2	0.00	-0.47	-0.49	0.00	-0.49	-0.51	0.00	-0.51	-0.52
s=3	0.00	-0.61	-0.62	0.00	-0.63	-0.65	0.00	-0.66	-0.67
s=4	0.00	-0.73	-0.74	0.00	-0.78	-0.77	0.00	-0.81	-0.80
s=8	0.00	-1.23	-1.13	0.00	-1.27	-1.15	0.00	-1.32	-1.19
s=20	0.00	-2.19	-1.62	0.00	-2.26	-1.67	0.00	-2.35	-1.73

Note—The Table shows impulse responses of endogenous variables to a positive innovation to Home government purchases that corresponds to 1% of steady state GDP, for different calibrations. Responses are shown s=0,1,2,3,4,8,20 periods after the shock (see rows labeled s=0,..,s=20).

Panel (a) shows the % response of the Home real exchange rate (NB an increase is an appreciation); Panels (b)–(d) show responses of Home and Foreign output and consumption and of the Home end-of period bond position, all expressed as % of steady state GDP.

Columns labeled $\eta=\infty$, $\eta=5$ and $\eta=2$ assume an infinite (Frisch) labor supply elasticity, and labor supply elasticities of 5 and 2, respectively.

Columns labeled $\rho=1, \rho=.95$ and $\rho=.90$ assume that the AR(1) persistence parameter of government purchases is 1, 0.95 and 0.90 respectively.