Effects of Government Purchases in Open Economies: Empirical Evidence and Predictions of a Dynamic General Equilibrium Model With Nominal Rigidities

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1999

Effects of Government Purchases in Open Economies: Empirical Evidence and Predictions of a Dynamic General Equilibrium Model With Nominal Rigidities (*)

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January 30, 1999

Estimates of effects of changes in government purchases are provided, for the G7 countries, during the post-Bretton Woods era. Empirically, a country-specific increase in government purchases tends to raise domestic and foreign output and consumption; domestic and foreign output multipliers of government purchases exceed unity, in the short to medium run. A quantitative dynamic-optimizing general equilibrium model of a two-country world with money and sticky prices and wages is presented, and that model is examined for its ability to explain the above empirical regularities. Standard RBC models with flexible prices and wages fail to generate large government purchases multipliers, unless labor supplies are highly elastic (with respect to the wage rate). The paper shows that this changes when sticky prices and/or wages are assumed: even when labor supplies are inelastic, the model here generates sizable government purchases multipliers. However, irrespective of the degree of nominal rigidity, the predicted response of *foreign* real activity to country-specific changes in government purchases is weak. The model here predicts that a rise in government purchases, in a given country induces a *depreciation* of that country's exchange rate, as seems consistent with the data.

Keywords: open economies, government purchases, exchange rate, post-Bretton Woods era, DSGE models, nominal rigidities,
JEL code: E3, E6, F3, F4.

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I thank Ellen McGrattan and participants at sessions of the North American Winter Meeting of the Econometric Society and of the Annual Conference of the Society for Economic Dynamics for useful comments. Thanks are also due to Marcelo Bianconi and Fabrizio Perri for suggestions and discussions as well as to the Institute for Quantitative Investment Research Europe for financial support.

1. Introduction

This paper provides estimates of domestic and international dynamic effects of changes in government spending, in the post-Bretton Woods era, and it seeks to interpret these effects, using a dynamic stochastic general equilibrium (DSGE) model of a two-country world.

Several recent papers have used time-series methods to estimate impulse responses of *domestic* macroeconomic variables to changes in government spending.[1] The present paper extends that literature by investigating the *international* repercussions of government purchases shocks, using vector autoregressions (VARs).[2] Specifically, the paper studies the transmission of shocks of this type between the U.S. and an aggregate of the remaining G7 countries (G6, henceforth), during the post-Bretton Woods era. The paper confirms earlier research that showed that an increase in government purchases in a given country raises output in that country. The results here suggest that the effects on *foreign* output are likewise positive. The multiplier of domestic and foreign output to a country-specific shock to government purchases ranges between 1 and 2, eight to twelve quarters after the shock. A country-specific increase in government purchases likewise raises domestic and foreign private consumption (the multiplier of domestic and foreign non-durables and services consumption is smaller than unity), and it tends to *reduce* the domestic and foreign price level and nominal interest rate. The data suggest also that an increase in U.S. government purchases reduces U.S. net exports and that it induces a nominal *depreciation* of the U.S. dollar (against a G6 currency basket), roughly 8 to 12 quarters after the rise in U.S. government purchases.

The theoretical model presented in this paper assumes a flexible nominal exchange rate, full international integration of bond markets, and overlapping price and wage contracts à la Calvo (1983). Physical capital accumulation and endogenous household labor supply are assumed. It builds

[1]E.g., Ramey and Shapiro (1998), Blanchard and Perotti (1998), Fatás and Mihov (1998), Edelberg, Eichenbaum and Fisher (1998), Rotemberg and Woodford (1989, 1992).

[2]There has been little *empirical* research on this issue. Bryant et al. (1988) compare simulation results for international effects of government purchases, obtained from large traditional macroeconometric models. Their results are heavily dependant on the theoretical set-up assumed in their analysis. Ahmed et al. (1993) study international business cycles, using VARs that include government purchases, but they do not report estimates of the international effects of these purchases. Chinn (1999) provides empirical evidence on the relationship between government spending and real exchange rates.

on recent research on quantitative (calibrated) dynamic-optimizing general equilibrium models with money and sticky prices and wages; see, e.g., Beaudry and Devereux (1995), Chari, Kehoe and McGrattan (1998), Betts and Devereux (1997), Kollmann (1997, 1999).[3] That work has abstracted from fiscal policy shocks.[4]

The model predicts that a permanent rise in government purchases in a given country, say the 'home' country, raises output, labor supply and capital investment and the price level, in that country, while private consumption and net exports fall. Also, the home country experiences a nominal and real depreciation of its currency. Foreign output and investment rise likewise, although much less than home output and investment. The intuition for the responses of home output, investment and consumption is that a rise in home government purchases has a negative wealth effect for home country private households (given the increase in taxes required to finance the rise in government purchases), which induces these households to increase their labor supply (provided leisure is a normal good), and to consume less.[5] Hence, home output rises; home investment rises likewise, as the increase in the labor input raises the marginal product of capital. The fact that the supply of foreign goods rises more strongly than that of home goods explains why the relative price

[3]See also the related work by, i.a., Obstfeld and Rogoff (1995), Hau (1998), Zhu (1998), Monacelli (1998), Ghironi (1998).

[4]Fiscal policy shocks, in a dynamic-optimizing setting with nominal rigidities are studied by Obstfeld and Rogoff (1995), Pesenti and Corsetti (1998) and Tille (1998) but their models are more stylized than that developed in the paper here. Related analyses of the effect of fiscal policy shocks are also presented by McKibbin and Sachs (1991) and Laxton et al. (1998) who use multi-country models with nominal inertia that combine elements of dynamic-optimizing behavior with standard Keynesian features; these models do not allow for the endogenous labor supply responses to government spending shocks that play a key role in the model developed below. Frenkel and Razin (1992), Backus et al. (1995), Baxter (1995), Yi (1993), Bianconi (1996), Turnovsky (1997), Kollmann (1991, 1998a), i.a., study two-country dynamic-optimizing trade models with shocks to government purchases, but that work abstracts from money and nominal rigidities (for closely related work on the effect of government purchases shocks in closed economies without nominal rigidities see, i.a., Rotemberg and Woodford (1992), Baxter and King (1993), Braun and McGrattan (1993), Galí (1994); Olivei (1998) analyzes fiscal policy in a closed economy model with nominal rigidities); also, these analyses assume a world with a single good, i.e. these models are not suited for analyzing the response of the exchange rate to government purchases (an exception is Frenkel and Razin (1992) whose analysis focuses on two-period models).

[5]Baxter and King (1993) showed that, in a neo-classical model, an increase in government purchases induces a rise in output, because of the wealth effect of that increase on the labor supply.

of home produced goods falls, which helps understand why the home country experiences a real (and nominal) exchange rate depreciation. The rise in government purchases induces also a rise in foreign output. Qualitatively, the mechanism that was just outlined operates irrespective of whether prices and wages are fully flexible, or whether prices and/or wages are sticky. However, when prices are sticky, home (and foreign) output respond more strongly to a rise in government purchases. Standard RBC models with flexible prices and wages fail to generate large government spending multipliers, unless labor supplies are highly elastic (with respect to the wage rate). The paper shows that this changes when sticky prices and/or wages are assumed: even when labor supplies are inelastic, the model here generates sizable government spending multipliers. However, irrespective of the degree of nominal rigidity, the predicted response of *foreign* real activity to a changes in country-specific changes in government purchases is weak.

The structure of the remainder of the paper is as follows. The empirical results regarding the effects of government purchases shocks are presented in Section 2. Section 3 discusses the theoretical model and Section 4 presents simulation results. Section 5 concludes.

2. Empirical evidence on domestic and international effects of changes in government purchases

In what follows, the following three measures of government purchases of goods and services are considered: real U.S. military defense spending (series GDFDEC from Citibase) and total real government consumption (as defined in National Accounts Statistics), in G7 countries (source: OECD Main Economic Indicators, MEI). Interest centers on the effect of changes in these variables on economic variables in the U.S. and in an aggregate of the remaining G7 countries (G6), during the post-Bretton Woods era. G6 time series are weighted averages of series for the individual G6 countries.[6] All series used below are quarterly; the sample period is 1973:Q1-1997:Q1.

Discussion of the econometric methodology

Much research on the effect of government purchases has focused on military spending, based on the view that changes in (U.S.) military spending are

[6]The weights are the shares of these countries in total G6 output, in 1980. For interest rates, a weighted arithmetic average is used; for the remaining variables, a geometric average is used.

exogenous with respect to the state of the economy. As pointed out by Rotemberg and Woodford (1989), given exogeneity of government purchases, the response of an endogenous variable to an innovation in government purchases can be computed by regressing government purchases on lagged government purchases and by regressing the endogenous variable on lagged values of that variable and on current and lagged values of government purchases. Based on this idea, I computed impulse responses to shocks to military purchases by estimating the following equations:

$$\ln(\mathfrak{G}_t) = \alpha_0 + \alpha_1 \cdot t + \sum_{i=1}^{i=2} a_i \cdot \ln(\mathfrak{G}_{t-i}) + \varphi_t^g;$$

$$z_t = \beta_0 + \beta_1 \cdot t + \sum_{i=1}^{i=2} b_i \cdot z_{t-i} + \sum_{i=0}^{i=2} d_i \cdot \mathfrak{G}_{t-i} + \varphi_t^z,$$

where $\mathfrak{G}$ denotes government purchases and z is an endogenous variable.

Panel (a) of Table 2 applies this method to compute the effect of a shock to U.S. military purchases (Panel (d) in Table 2 and Panel (a) in Table 3 also use this method to compute responses to shocks to U.S. and G6 government consumption). Responses of the following variables are considered: U.S. and G6 GDP, private consumption (non-durables plus services), physical investment, price level (CPI), short term nominal interest rates, the U.S.-G6 bilateral nominal exchange rate and U.S. net exports (the exchange rate is defined as the U.S. dollar price of a basket of G6 currencies). (The Appendix provides detailed information on the data.) The estimating equations use all variables in log form, with the exception of interest rates and net exports.[7]

In addition, I computed impulse responses using vector autoregressions (VARs) of the form

$$X_t = \gamma_0 + \gamma_1 \cdot t + \sum_{i=1}^{i=2} A_i X_{t-1} + \varepsilon_t^X,$$

where X_t is a vector of variables that includes one of the three measures of government purchases, as well as the 12 endogenous variables that were just listed.[8] Wold causal orderings are assumed to generate impulse responses to government spending shocks. I experiment with two Wold orderings: one uses government purchases as the first variable, in the vector X_t (see Panels (b) and (e) in Table 2 and Panel (b) in Table 3),

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[7]In the regression equations, two lags of the exogenous and endogenous variables were used (the VARs discussed below also use two lags), as it appears that two lags are sufficient to obtain regression residuals that do not exhibit serial correlation. The empirical results are robust to changes in the number of lags.

[8]The VAR approach for generating impulse responses is valid even when government purchases are *not* exogenous, but that approach is less efficient, if government purchases are exogenous. The exogeneity assumption seems harder to defend for general government consumption than for military purchases.

while the other uses government purchases as the last variable.

All impulse responses are computed for an innovation to government purchases that corresponds to 1% of domestic GDP. To save space, responses are only shown 0, 4, 8 and 12 quarters after the shock, provided that these response are statistically significant at the 20% level (p-value for two-sided significance test used).[9] (When the response is not significant, the Table merely reports the *sign* of the response.). Responses of GDP, consumption and investment are expressed in multiplier form (e.g., the response of output, Y, is expressed as $\Delta Y/\Delta\mathfrak{G}$);[10] the responses of the price level and the exchange rate are expressed as percentage changes, relative to the "unshocked" paths of these variables, while responses of interest rates and net exports are expressed as percentage point differences compared to the "baseline" path (interest rates are expressed in % per annum).

Discussion of estimation results

The impact responses of U.S. and G6 output to shocks to U.S. and G6 government spending are generally statistically insignificant.[11] However, country-specific government purchases shocks have a significant positive *lagged* effect on domestic *and* foreign output. The multiplier of domestic and foreign output to a country-specific shock to government purchases mostly range between 1 and 2, eight or twelve quarters after the shock. A country-specific increase in government purchases likewise induces a statistically significant lagged rise in domestic and foreign private consumption (of non-durables and services), but consumption rises less than output--the consumption multipliers are smaller than unity (interestingly, the responses of G6 consumption, to a rise in U.S. government purchases, are more significant than those of U.S. consumption). The responses of U.S. investment (to U.S. and G6 government spending shocks) are almost all insignificant, but G6 investment shows a significant positive response to increases in U.S. and in G6 government purchases.

[9] Significance based on 80% confidence bands for impulse responses (confidence bands for impulse responses based on bivariate model are asymptotic bands, constructed using estimated covariance matrix of regression coefficients of; confidence bands for VARs are based on Monte Carlo with 250 replications).

[10] The Appendix explains how these multipliers are constructed.

[11] Note that when the government spending variable is assumed to be ordered *last* in the Wold causal chain, then the impact effect of a shock to government spending on the remaining variables in the VAR is zero, by construction.

A positive shock to U.S. government purchases induces a depreciation of the U.S. dollar (18 of the 22 responses to a U.S. government purchases shock show a depreciation of the U.S. dollar), although it can be noted that this response is only statistically significant with a delay of 8 or 12 quarters. The response of the U.S. dollar to a positive G6 government purchases shock is more mixed: such a shock induces a significant *appreciation* of the U.S. dollar, 4 quarters after the shock, but it triggers a significant *depreciation* of the U.S. dollar 8 quarters after the shock.

The U.S. and G6 price levels both respond *negatively* to a positive shock to domestic or foreign government purchases. Finally, it can be noted that the U.S. nominal interest rate responds *negatively* to a positive shock to U.S. or G6 government purchases (the G6 nominal interest rate likewise responds *negatively* to a rise in U.S. or G6 government purchases, but the responses of the G6 interest rate are less significant, statistically).

The next section develops a two-country dynamic general equilibrium models. That model will be examined for its ability to explain the empirical regularities that have just been discussed.

3. The Model[12]

A world with two countries, called home and foreign, is considered. In each country there are firms, a representative household and a government. *Domestic* physical capital and *domestic* labor are used to produce tradable intermediate goods (labor and physical capital are immobile internationally). Each country uses domestic and imported intermediate inputs to produce a single non-tradable final good that can be used as a private or government consumption good, or as a capital good. Each country's government issues a national currency, and it purchases the country's final good. Government purchases are exogenous. These purchases are financed using a lump sum tax. The government consumption good does not enter the households' utility function or the firms' production functions.

The following description focuses on the home country. The foreign country is a complete mirror image of the home country (preferences and technologies are symmetric across the two countries). Foreign country variables are denoted by an asterisk.

3.1. Household preferences

The preferences of the home country household are described by:

[12] The model here extends Kollmann (1999), by considering a more general utility function and adding government purchases to the structure.

$$E_0 \sum_{t=0}^{\infty} \beta^t \, U(C_t, \mathcal{M}_t/P_t, L_t). \tag{1a}$$

E_0 denotes the mathematical expectation conditional on information available in period t=0. $0<\beta<1$ is a subjective discount factor and U(.) is an instantaneous utility function. C_t and L_t represent the household's consumption of the home country final good and her labor effort, respectively, in period t. $\mathcal{M}_t$ denotes the household's stock of home country money, at the beginning of period t, while P_t is the price of the final good. The household can provide labor services of different types that are indexed by $h\in[0,1]$. L_t is defined as $L_t \equiv \int_0^1 l_t(h)\, dh$, where $l_t(h)$ denote the amount of type h labor. The utility function U is given by:

$$U(C,\mathcal{M}/P,L) = (1/(1-\Psi))\,\{([C^{\sigma} + \kappa\,(\mathcal{M}/P)^{\Gamma}\,]^{1/\sigma})^{1-\Psi}-1\} - L^{1+1/\eta}, \tag{1b}$$

where $\Psi>0$, $\sigma<1$, $\Gamma<1$, $\kappa>0$ and $\eta\geq 0$ are parameters.

3.2. Technologies, firms and the structure of goods markets

There are three types of firms in the each country: (i) intermediate good producers; (ii) final good producers; (iii) capital rental firms. There is a continuum of intermediate goods indexed by $s\in[0,1]$ produced in the home country and a continuum of intermediate goods, also indexed by $s\in[0,1]$, produced in the foreign country. The intermediate goods are imperfect substitutes for one another. Each intermediate good is produced by a single firm--monopolistic competition is, hence, assumed in intermediate goods markets. In contrast, the final good sector and the rental market for capital are perfectly competitive, in each country. Firms are price takers in the markets for their inputs.

3.2.1. Final good production

The home country final good is produced using the aggregate technology

$$Q_t = (D_t)^{1-\alpha}(Z_t)^{\alpha}\ , \text{ with } 0<\alpha<1, \tag{2}$$

where Q_t is the home final good production level, while D_t and Z_t are indexes of domestically produced and imported intermediate goods:

$$D_t=\{\int_0^1 d_t(s)^{1/(1+\nu)}\}^{1+\nu} \text{ and } Z_t=\{\int_0^1 z_t(s)^{1/(1+\nu)}\}^{1+\nu}, \text{ with } \nu>0,$$

where $d_t(s)$ and $z_t(s)$ denote, respectively, the quantities of domestically produced and of imported intermediate (type s) goods that are purchased by home country final good producers. Let $pd_t(s)$ and $pz_t(s)$ denote the purchase prices paid by home country final good producers for these intermediate goods. These prices are expressed in home currency (throughout the paper, all prices are expressed in the buyer's currency).

Cost minimization conditions for final good producers can be written as:

$$d_t(s)= D_t\cdot(pd_t(s)/\mathcal{PD}_t)^{-(1+\nu)/\nu}, \tag{3a}$$

$$z_t(s)= Z_t\cdot(pz_t(s)/\mathcal{PZ}_t)^{-(1+\nu)/\nu}, \tag{3b}$$

and $$D_t/Z_t=(\alpha/(1-\alpha))\mathcal{PD}_t/\mathcal{PZ}_t, \tag{3c}$$

with $$\mathcal{PD}_t\equiv\{\int_0^1(pd_t(s))^{-1/\nu}\,ds\}^{-\nu} \text{ and } \mathcal{PZ}_t\equiv\{\int_0^1(pz_t(s))^{-1/\nu}\,ds\}^{-\nu}.\text{[13]} \tag{3d}$$

Perfect competition in the market of the final good implies that the date t home country final good price, P_t, is:

$$P_t = (\alpha)^{-\alpha}\ (1-\alpha)^{1-\alpha}\ (\mathcal{PD}_t)^{1-\alpha}\ (\mathcal{PZ}_t)^{\alpha}, \tag{4}$$

where the term on the right-hand side is the marginal cost of producing the final good.

3.2.2. Intermediate goods producers

The production function of the firm producing intermediate good 's', in the home country, is:

$$y_t(s) = \theta_t\ (\mathcal{K}_t(s))^{\psi}\ (\mathcal{L}_t(s))^{1-\psi}, \tag{5}$$

at date t, where $y_t(s)$ is the firm's output. θ_t is an exogenous productivity parameter (productivity is identical for all intermediate goods locates in the same country). $\mathcal{K}_t(s)$ is the physical capital stock used by the 's' firm at date t, while $\mathcal{L}_t(s)$ is an index of the different types of labor used by the firm: $\mathcal{L}_t(s)=\{\int_0^1\ell_t(h;s)^{1/(1+\gamma)}dh\}^{(1+\gamma)}$, with $\gamma>0$.

Let R_t and $w_t(h)$ be the date t nominal rental rate of capital and the nominal wage rate for type h labor, respectively, in the home country. The cost function of a home intermediate good producer is:

$$\mathfrak{S}_t(y)\equiv \underset{\mathcal{K},\ell(h)}{\mathrm{Min}}\ R_t\cdot\mathcal{K} + \int_0^1 w_t(h)\ell(h)\ dh \quad \text{s.t. } y = \theta_t\ \mathcal{K}^{\psi}\ \{\int_0^1\ell(h)^{1/(1+\gamma)}dh\}^{(1+\gamma)(1-\psi)}.$$

Cost minimization implies:

$$\ell_t(h;s) = \mathcal{L}_t(s)\ [w_t(h)/W_t]^{-(1+\gamma)/\gamma},\quad \mathcal{L}_t(s) = ((1-\psi)/\psi)\ R_t\ \mathcal{K}_t(s)/W_t, \tag{6}$$

where $W_t\equiv\{\int_0^1 w_t(h)^{-1/\gamma}dh\}^{-\gamma}$ is an aggregate wage index.[14]

As the production function exhibits constant returns to scale, $\mathfrak{S}_t(y)=y\cdot\mathfrak{S}_t'$ holds, where $\mathfrak{S}_t'$ is the firm's marginal cost function:

$$\mathfrak{S}_t'=(1/\theta_t)\ (R_t)^{\psi}\ (W_t)^{1-\psi}\ \psi^{-\psi}\ (1-\psi)^{-(1-\psi)} \tag{7}$$

The home country producer of intermediate good s faces the demand function (3a) in her domestic market. A condition analogous to (3b) holds in the foreign country, which implies that the firm's export demand function is: $z_t^*(s)=Z_t^*\cdot(pz_t^*(s)/\mathcal{PZ}_t^*)^{-(1+\nu)/\nu}$, where $z_t^*(s)$ denotes foreign country purchases of the home produced intermediate good of type s, while

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[13] $\mathcal{PD}_t$ and $\mathcal{PZ}_t$ are price index that represents the minimal expenditure, in home currency, needed to purchase one unit of the composite intermediate inputs D_t and Z_t, respectively. ($\mathcal{PD}_tD_t=\int pd_t(s)d_t(s)$, $\mathcal{PZ}_tZ_t=\int pz_t(s)z_t(s)ds$, when (3a), (3b) hold.)

[14] W_t represents the minimal expenditure, in home country currency, needed to purchase one unit of the composite labor input $\mathcal{L}$ in period t.

$p\mathfrak{z}^*_t(s)$ is the export price of the good, in terms of foreign currency.[15] The firm's output equals the demand for its good:

$$y_t(s) = d_t(s) + z^*_t(s). \tag{8}$$

At t, the profit of the home country producer of intermediate good s is: $pd_t(s)\, d_t(s) + e_t\, p\mathfrak{z}^*_t(s)\, z^*_t(s) - \mathfrak{S}^{i,}_t{}' \cdot (d^i_t(s)+z^*_t(s))$, where e_t is the nominal exchange rate between the two countries, defined as the home currency price of foreign currency.

Following Obstfeld and Rogoff (1995), it is assumed that there are no costs to trade between the countries, which implies that the price of each intermediate goods is the same in *both* markets, i.e.

$$p\mathfrak{z}^*_t(s) = pd_t(s)/e_t \tag{9a}$$

which implies

$$\mathcal{PZ}^*_t = \mathcal{PD}_t/e_t. \tag{9b}$$

Equations (9a), (9b) and the demand functions for intermediate goods (3) imply that the nominal profit of the producer of intermediate good s in the home country can be expressed as the following function of the home currency price of that good, $pd_t(s)$:

$$\pi_t(pd_t(s)) \equiv (pd_t(s)-\mathfrak{S}_t{}')\cdot(d_t+z^*_t)\cdot[pd_t(s)/\mathcal{PD}_t]^{-(1+\nu)/\nu}. \tag{10}$$

Determination of intermediate goods prices

Prices for intermediate goods, are set in a staggered fashion, à la Calvo (1983): producers of these goods are not allowed to change the *domestic currency* prices of their goods, unless they receive a random "price-change" signal. The probability that the price of an intermediate good of a given type, in terms of the currency of its producer, can be changed in any particular period is $1-\mathfrak{D}_p$, a constant (hence, a fraction $1-\mathfrak{D}_p$ of all domestic currency prices are changed each period and the average time between price changes is $1/(1-\mathfrak{D}_p)$). Consider a producer of an intermediate good in the home country that is "allowed" at date t to set a new home currency price and let $pd_{t,t}$ denote this new price. With probability $(\mathfrak{D}_p)^\tau$, $pd_{t,t}$ is still in effect at date $t+\tau$. Hence, the firm sets $pd_{t,t}$ at

$$pd_{t,t} = \operatorname*{Arg\,Max}_{pd} \sum_{\tau=0}^{\tau=\infty}(\mathfrak{D}_p)^\tau E_t\rho_{t,t+\tau}\, \pi_{t+\tau}(pd\,)/P_{t+\tau}, \tag{11}$$

where $\rho_{t,t+\tau}$ is the pricing kernel used by the firm at date t to value random date $t+\tau$ pay-offs (that are expressed in units of the composite consumption good). As home country firms are owned by that country's

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[15] $\mathcal{PZ}^*_t \equiv \{\int (p\mathfrak{z}^*_t(s))^{-1/\nu}ds\}^{-\nu}$. The foreign country's final good technology is: $Q^*_t = (D^*_t)^{1-\alpha}(Z^*_t)^\alpha$, with $D^*_t \equiv \{\int d^*_t(s)^{1/(1+\nu)}\}^{1+\nu}$, $Z^*_t \equiv \{\int z^*_t(s)^{1/(1+\nu)}\}^{1+\nu}$, where $d^*_t(s)$ denotes intermediate inputs produced in the foreign country.

representative household (see discussion below) it is assumed that $\rho_{t,t+\tau}$ equals the intertemporal marginal rate of substitution in consumption of that household: $\rho_{t,t+\tau}=\beta^{\tau}\cdot U_{C,t+\tau}/U_{C,t}$, where $U_{C,t+\tau}$ is the household's marginal utility of consumption at date $t+\tau$.

The solution of the maximization problem in (11) is:

$$pd_{t,t} = (1+\nu)\left\{\sum_{\tau=0}^{\tau=\infty}(\mathfrak{D}_p)^{\tau}E_t\{\Xi_{t,t+\tau}\,\mathfrak{G}'_{t+\tau}\}\right\}\Big/\left\{\sum_{\tau=0}^{\tau=\infty}(\mathfrak{D}_p)^{\tau}E_t\Xi_{t,t+\tau}\right\}, \qquad (12)$$

where $\Xi_{t,t+\tau}\equiv\rho_{t,t+\tau}\cdot(1/P_{t+\tau})\cdot(D_{t+\tau}+D^{*}_{t+\tau})\cdot(\mathcal{PD}_{t+\tau})^{(1+\nu)/\nu}$.

Note that the analysis here presupposes that firms that set a new price at date t satisfy the demand for their good, at that price, as long as the price remains in effect (see (8)).[16] In other words, firms with predetermined prices (prices that were set in previous periods) have an infinitely elastic output supply schedule.

As, at date t, a fraction $(1-\mathfrak{D}_p)(\mathfrak{D}_p)^{\tau}$ of producers of intermediate goods are posting home currency prices that were set $\tau\geq0$ periods ago, (3d) implies that the law of motion of the price index $\mathcal{PD}_t$ is:

$$(\mathcal{PD}_t)^{-1/\nu} = \mathfrak{D}_p\,(\mathcal{PD}_{t-1})^{-1/\nu} + (1-\mathfrak{D}_p)\,(pd_{t,t})^{-1/\nu}.$$

For future reference, note that (6) implies that the total wage bill of home country intermediate goods producers is

$$\int_0^1\int_0^1 w_t(h)\,\ell_t(h;s)\,dh\,ds = ((1-\psi)/\psi)\,R_t\,\mathcal{K}_t, \qquad (13)$$

while (3), (10) and (13) imply that total profits of home producers of intermediate goods can be expressed as:

$$\Pi_t\equiv\int_0^1 \pi_t(pd_t(s))\,ds = \mathcal{PD}_t\cdot(D_t + Z^{*}_t) - (1/\psi)\,R_t\mathcal{K}_t. \qquad (14)$$

3.2.3. The supply and demand of physical capital

Physical capital in a given country is a homogeneous factor of production that is owned by firms that rent capital to that country's producers of intermediate goods. The law of motion of the home country capital stock is:

$$K_{t+1} + \phi(K_{t+1},K_t) = K_t\,(1-d) + I_t, \qquad (15a)$$

where I_t, gross investment, denotes what quantity of home final output is

[16] This assumption is standard in models with price rigidities (e.g., Mankiw (1997, ch.8)). When prices are fully flexible ($\mathfrak{D}_p$=0), then (12) implies that the price $pd_{t,t}$ is set at the current marginal cost, multiplied by the mark-up factor $1+\nu>1$ ($pd_{t,t}=(1+\nu)\cdot\mathfrak{G}'_{t+\tau}$). When $\mathfrak{D}_p>0$, then up to a certainty equivalent approximation, $pd_{t,t}$ equals a weighted sum of current and expected *future* marginal production costs, multiplied by $1+\nu$, i.e. then $pd_{t,t}$ depends on *future* marginal costs as well. As long as $pd_{t,t}$ exceeds the firm's marginal (=average) cost, it is not in its interest to ration its customers.

required to change the capital stock from K_t to K_{t+1}. $0<d<1$ is the depreciation rate of the capital stock and $\phi(.,.)$ is a convex adjustment cost function that is homogeneous of degree one in K_{t+1} and K_t:

$$\phi(K_{t+1},K_t) = 0.5\ \Phi\ \{K_{t+1} - K_t\}^2/K_t,\quad \Phi>0. \qquad (15b)$$

Home country capital rental firms maximize

$$\sum_{\tau=0}^{\tau=\infty} E_t\rho_{t,t+\tau}\ (R_{t+\tau}\ K_{t+\tau} - P_{t+\tau}\ I_{t+\tau})/P_{t+\tau},$$

where $R_{t+\tau}\ K_{t+\tau} - P_{t+\tau}\ I_{t+\tau}$ is the nominal cash flow of these firms, in period $t+\tau$. Optimal investment decisions by capital rental firms can be characterized by the following Euler equation:

$$1 = \beta\ E_t\{\rho_{t,t+1} \cdot [R_{t+1}/P_{t+1} + 1-d + \phi_{2,t+1}]/[1 + \phi_{1,t}]\}, \qquad (16)$$

where $\phi_{1,t}=\partial\phi\ (K_{t+1},K_t)/\partial K_{t+1}$ and $\phi_{2,t+1}=\partial\phi\ (K_{t+2},K_{t+1})/\partial K_{t+1}$.

Total *demand* for physical capital, by home country intermediate good firms is:

$$\mathcal{K}_t\equiv\int\mathcal{K}_t(s)ds= (D_t+Z_t^*)\ (\mathcal{PD}_t/\overline{\mathcal{PD}}_t)^{-(1+\nu)/\nu}\ (1/\theta_t)((\psi/(1-\psi))(W_t/R_t)^{1-\psi}, \quad (17)$$

where $\overline{\mathcal{PD}}_t\equiv\{\int(pd_t(s))^{-(1+\nu)/\nu}ds\}^{-\nu/(1+\nu)}$ is a price index that evolves according to: $(\overline{\mathcal{PD}}_t)^{-(1+\nu)/\nu}=\mathfrak{D}_p(\overline{\mathcal{PD}}_{t-1})^{-(1+\nu)/\nu}+(1-\mathfrak{D}_p)\ (pd_{t,t})^{-(1+\nu)/\nu}$. (18)

3.3. Asset markets, household consumption and investment decisions

Each country's representative household owns that country's firms. It can also hold the following assets: local money; risk-free nominal one-period bonds denominated in local and in foreign currency.[17] The period t budget constraint of the home country household is, hence:

$$\mathcal{M}_{t+1} + A_{t+1} + e_t\ B_{t+1} + P_t\ C_t + \mathcal{T}_t = \mathcal{M}_t + A_t(1+r_t) +$$
$$e_t\ B_t\ (1+r_t^*)+ (\Pi_t + R_t\ K_t - P_t\ I_t) + \int_0^1 l_t(h)\ w_t(h)\ dh, \qquad (19)$$

Here, $\mathcal{T}_t$ is a lump sum tax paid by the household. A_t and B_t are, respectively, the home country household's (net) stocks of home currency bonds and of foreign currency bonds that become due in period t. r_t and r_t^* are the nominal interest rates on these two types of bonds. $\Pi_t+R_tK_t-P_tI_t$ is the total cash flow generated by all home country firms. The last term on the right-hand side of (19) is the household's wage income.

The home country household seeks to maximize her expected life-time utility (1a) subject to the restriction that the budget constraint (19)

[17] The household's financial transactions are, thus, restricted to trade in bonds. This asset market structure is consistent with the well documented home-country bias in investors' equity portfolios (e.g., French and Poterba (1991)). Kollmann (1995, 1996, 1998a) compares models of the international economy in which bonds only are traded internationally (as assumed in the present paper) to models that also allow for international trade in state-contingent assets--it is found that, empirically, the former models capture key international business cycle stylized facts better.

holds for all dates and all states of the world and subject to the demand functions for the household's labor (see (23), below). Ruling out Ponzi games, the following equations are first-order conditions of this decision problem:

$$1 = \beta\ (1+r_{t+1})\ E_t\{\{U_{C,t+1}/U_{C,t}\}\cdot\{P_t/P_{t+1}\}\}, \tag{20}$$

$$1 = \beta\ (1+r^*_{t+1})\ E_t\{\{U_{C,t+1}/U_{C,t}\}\cdot\{P_t/P_{t+1}\}\cdot\{e_{t+1}/e_t\}\},\ j\neq i, \tag{21}$$

$$\kappa\ (\Gamma/\sigma)E_t\{U_{C,t+1}\cdot(C_{t+1})^{1-\sigma}(\mathcal{M}_{t+1}/P_{t+1})^{\Gamma-1}/P_{t+1}\}= r_{t+1}\ E_t\{U_{C,t+1}/P_{t+1}\}. \tag{22}$$

Equations (20) and (21) are Euler conditions, while equation (22) can be interpreted as a money demand equation.

3.4. Wage determination

(6) implies that, at date t, total demand for type h labor in the home country is:

$$\ell_t(w_t(h))\equiv\int_0^1\ell_t(h,s)ds=((1-\psi)/\psi)\cdot(w_t(h))^{-(1+\gamma)/\gamma}\cdot R_t\cdot\mathcal{K}_t\cdot(W_t)^{-1/\gamma}, \tag{23}$$

where $\mathcal{K}_t=\int_0^1\mathcal{K}_t(s)ds$.

The household acts as a wage setter, subject to the rule that the nominal wage rate for labor of a given type *h* can only be changed when a random "wage-change signal" is received. With an exogenous probability $1-\mathfrak{D}_W$ the wage rate of a given labor type h can be changed in any particular period. Assume that the wage for type h labor is changed at date t, in the home country, and let $w_{t,t}(h)$ be the new wage. The household agrees to meet the demand for type h labor at that wage until the next wage-change signal (for type h labor) is received. The home country household sets the wage $w_{t,t}(h)$ that maximizes her expected lifetime utility subject to (19) and (23) and the restriction that, with probability $(\mathfrak{D}_W)^\tau$, $w_{t,t}(h)$ is still in effect at $t+\tau$. Thus, $w_{t,t}(h)$ has to satisfy the following first-order condition:

$$\begin{aligned}\sum_{\tau=0}^{\tau=\infty}(\beta\mathfrak{D}_W)^\tau E_t\Big\{U_{C,t+\tau}\cdot\partial[w_{t,t}(h)\cdot\ell_{t+\tau}(w_{t,t}(h))/P_{t+\tau}]/\partial w_{t,t}(h)\Big\}\ +\\ \sum_{\tau=0}^{\tau=\infty}(\beta\mathfrak{D}_W)^\tau\ E_t\Big\{U_{L,t+\tau}\cdot\partial\ell_{t+\tau}(w_{t,t}(h))/\partial w_{t,t}(h)\Big\}\ =\ 0\end{aligned} \tag{24a}$$

$$\Rightarrow w_{t,t}=w_{t,t}(h)=-(1+\gamma)\sum_{\tau=0}^{\tau=\infty}(\beta\mathfrak{D}_W)^\tau E_tU_{L,t+\tau}\chi_{t+\tau}\Big/\sum_{\tau=0}^{\tau=\infty}(\beta\mathfrak{D}_W)^\tau E_tU_{C,t+\tau}\chi_{t+\tau}/P_{t+\tau}, \tag{24b}$$

where $U_{L,t+\tau}=-(1+1/\eta)\ (L_{t+\tau})^{1/\eta}$ is the marginal disutility of labor and $\chi_{t+\tau}\equiv((1-\psi/\psi)R_{t+\tau}\mathcal{K}_{t+\tau}(W_{t+\tau})^{-1/\gamma}$.[18] For a fraction $(1-\mathfrak{D}_W)(\mathfrak{D}_W)^\tau$ of labor

[18](23b) implies that the same contract wage is set for all labor types for which a wage change occurs at t. The left hand side of (24a) shows the effect on the household's expected life-time utility of the change in the

types, the wage rate in effect at date t was set in period $t-\tau$. Hence, the law of motion of the home aggregate wage index $W_t=\{\int_0 w_t(h)^{-1/\gamma}dh\}^{-\gamma}$ is:

$$(W_t)^{-1/\gamma} = \mathfrak{D}_w (W_{t-1})^{-1/\gamma} + (1-\mathfrak{D}_w) (w_{t,t})^{-1/\gamma}.^{19} \tag{25}$$

3.5. Government

The government purchases $\mathcal{G}_t$ units of the final good, and it finances these purchases by issuing the local money and by levying a lump sum tax on the household:

$$P_t\cdot\mathcal{G}_t = M_{t+1}-M_t + \mathcal{T}_t, \tag{26}$$

where M_t is the home country money supply, at the beginning of period t, while $\mathcal{T}_t$ is the lump sum tax. Government purchases and the money supply are exogenous (the government makes no attempt to influence the exchange rate, i.e. the exchange rate floats freely).

3.6. Market clearing conditions

Demand equals supply in labor markets and in the markets for intermediate goods as the household always satisfies the demand for its labor services that she faces and as the producers of intermediate goods likewise meet the demand for their goods that they face.

Market clearing for the final good in the home country requires:

$$C_t + I_t = Q_t. \tag{27}$$

Each country's currency is only held by its residents. Equilibrium in the home country money market requires, thus:

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stream of labor *income* and of the change in current and future labor effort that results from an infinitesimal change in $w_{t,t}(h)$. Here, it is assumed that, when setting $w_{t,t}(h)$, the representative household takes the current and future *average* wage (W) and other economywide variables as given. A note available from the author considers a structure with a continuum of households, where each household monopolistically provides a *single* type of labor. In that structure, an individual household's wage setting decisions have no effect on economywide variables. (23b) holds in that structure and the dynamics of aggregate variables is likewise unchanged (compared to the model in the text), provided there is full risk-pooling among *domestic* households, e.g., if complete financial markets exits *within* each country (the latter implies that consumption and money holdings are equated across all residents of the same country).

[19] N.B. When the wage rate is fully flexible ($\mathfrak{D}_w=0$), and the own-wage elasticity of labor demand is infinitely elastic, $\gamma=0$ (see (23)), then (24b),(25) imply $W_t/P_t=-U_{L,t}/U_{C,t}$, which corresponds to the familiar first-order condition, in models with competitive labor markets, that prescribes the equalization of the marginal rate of substitution between consumption and leisure to the real wage rate.

$$M_{t+1} = \mathcal{M}_{t+1}, \tag{28}$$

where M_{t+1} is the country's money supply, while $\mathcal{M}_{t+1}$ represents the desired money balances of the country's household.

Governments do not issue bonds. Market clearing in the world market for bonds denominated in the currencies of the two countries requires, thus:

$$A_t + A^*_t = 0 \quad \text{and} \quad B_t + B^*_t = 0.^{20} \tag{29}$$

Market clearing in the home country's market for capital requires:

$$\mathcal{K}_t = K_t, \tag{30}$$

where the left hand side is the total demand for physical capital in the country (as given by equation (17)), while the right hand side is the total supply of capital in that country.

3.7. Solution method

Given exogenous processes for productivity, real government purchases and the money supply in the two countries $\{\theta_t, M_t, \mathcal{G}_t, \theta^*_t, M^*_t, \mathcal{G}^*_t\}_{t=0}^{t=\infty}$, and given initial conditions for the predetermined variables $K_0, A_0, B_0, W_{-1}, \mathcal{PD}_{-1}, \mathcal{PZ}_{-1}, \overline{\mathcal{PD}}_{-1}, K^*_0, W^*_{-1}, \mathcal{PD}^*_{-1}, \mathcal{PZ}^*_{-1}, \overline{\mathcal{PD}}^*_{-1}$, the preceding equations for the home country, as well as corresponding conditions for the foreign country, determine the aggregate variables $\{Q_t, C_t, D_t, Z_t, P_t, W_t, R_t, K_{t+1}, I_t, r_t, rs_t, e_t, \sigma_t, Q^*_t, C^*_t, D^*_t, Z^*_t, P^*_t, W^*_t, R^*_t, K^*_{t+1}, I^*_t, r^*_t, rs^*_t, \sigma^*_t\}_{t=0}^{t=\infty}$.

An approximate model solution can be obtained by taking a linear approximation of these equations around a deterministic steady state, i.e. around an equilibrium in which all exogenous and endogenous variables are constant. This approximation yields a system of linear expectational difference equations that was solved using Blanchard and Kahn's (1980) formulae. In the simulations below, the model is linearized around a deterministic steady state that is symmetric across countries (i.e. in which all variables have the same values in both countries), and in which each country's net stock of foreign currency bonds is zero.

3.8. Parameter values

3.8.1. Preference, technology and price and wage adjustment parameters

The coefficient of relative risk aversion and the subjective discount factor are set at $\Psi=1$ and at $\beta=1/1.01$, respectively.[21] These values are in the range of available available estimates of Ψ and β, for the G7 countries

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[20] A^*_t, B^*_t are the foreign household's stock of bonds denominated in the home country's currency and in foreign currency, respectively.

[21] The utility for $\Psi=1$ is taken to be: $U=\ln([C^{\sigma}+\kappa\cdot(M/P)^{\Gamma}]^{1/\sigma})-L^{1+1/\eta}$

(e.g., Braun et al. (1993) and Barrionuevo (1991)). $\beta=1/1.01$ implies that the steady state real interest rate is 1%, a value that corresponds roughly to the long run average return on capital observed empirically (in steady state, $\beta\cdot(1+r)=1$ holds, where r is the steady state interest rate). The preference parameter η is the Frisch elasticity of labor supply. Many studies that use *micro*-level data find labor supply elasticities close to zero (see Pencavel (1986), Mroz (1987) Card (1991)). In contrast, RBC models have often assumed labor supply elasticities in the range of 2 (e.g., King, Plosser and Rebelo (1988)), or even larger elasticities--see, Hansen (1985) who assumes that labor supply is infintitely elastic. In the simulations, I consider a baseline case in which $\eta=2$ (a sensitivity analysis with respect to η is conducted).

The preference parameter κ (see (1b)) is set in such a way that the steady state consumption velocity (ratio of nominal consumption expenditure to the money stock) equals unity.[22] As mentioned above, equation (22) can be interpreted as a money demand equation. Up to a certainty equivalent approximation, (22) implies:

$$M_{t+1}/P_{t+1}=(r_{t+1}\cdot\sigma/(\Gamma\kappa))^{-\varepsilon_r}\cdot(c_{t+1})^{\varepsilon_c}+\upsilon_{t+1}, \tag{31}$$

where υ_{t+1} is a forecast error ($E_t\upsilon_{t+1}=0$) and $\varepsilon_r\equiv-1/(\Gamma-1)$ and $\varepsilon_c\equiv(\sigma-1)/(\Gamma-1)$ are the elasticities of money demand with respect to the nominal interest rate and to consumption, respectively. The baseline simulations assume $\varepsilon_r=0.05$, $\varepsilon_c=1$, consistent with money demand regressions reported in Mankiw and Summers (1988).

The technology parameter α (see (2)) pins down the ratio of the value of imports to the value of final good output. The simulations assume $\alpha=0.1$, as for the US, the ratio of imports to GDP has been approximately 10% during the post-Bretton Woods era.[23]

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[22] The key model predictions discussed below are not sensitive to the assumed steady state velocity (a unit velocity is roughly consistent with data on the M1 consumption velocity in the G7 countries, during the post-Bretton Woods era; e.g., in the U.S. that velocity was 0.93 in 1994).

[23] In the model, a country's GDP equals its final good production plus its net exports. Denoting home nominal GDP by $\mathcal{Y}$, we have: $\mathcal{Y}_t=P_tQ_t+\mathcal{P}\mathcal{D}_tZ^*_t-\mathcal{P}\mathcal{Z}_tZ_t$. P_tQ_t, the value of the final good sector's output equals its total cost: $P_tQ_t=\mathcal{P}\mathcal{D}_tD_t+\mathcal{P}\mathcal{Z}_tZ_t$ (as the final good sector is competitive). Thus, $\mathcal{Y}_t=\mathcal{P}\mathcal{D}_t(D_t+Z^*_t)$: a country's GDP equals the value of its intermediate goods output. Imported inputs account for a fraction α of the final good sector's cost: $\mathcal{P}\mathcal{Z}_tZ_t=\alpha P_tQ_t$. As described above, the model is linearized around a symmetric deterministic steady state; net exports are zero in that steady state; hence, the ratio of imports to GDP equals α, at

The own-price elasticity of the demand for intermediate goods (see (3)) is set at $(1+\nu)/\nu=6$, which implies that the steady state mark up of price over marginal cost (ν) is 0.20, a value close to the estimates of mark ups (in U.S. manufacturing) reported in Basu and Fernald (1993).[24] In the U.S. and in the remaining G7 countries, the share of total value added going to labor is roughly 0.66. In the model, the steady state share of wage payments to GDP is $(1-\psi)/(1+\nu)$, where ψ is the elasticity of the production function of intermediate goods with respect to capital (see (5)). Hence, ψ is set at $\psi=0.208$.

The capital adjustment cost parameter Φ (see (15b)) is set at $\Phi=6$. Stochastic simulations of the model (with money supply, productivity and government purchases shocks) show that that value of Φ enables the model to match the observed variability of investment (for lower values of Φ, investment is excessively volatile).

The simulations consider a baseline case in which the average time between price changes (in home currency) at the firm level is 4 periods, where 1 period represents one quarter in calendar time (as the model is calibrated to quarterly data). This is motivated by recent empirical studies that suggest average time intervals between price adjustments in the range of 1 year, for a wide range of products (Romer (1996, p.294)). Thus, the parameter $\mathfrak{D}_p$ is set at $\mathfrak{D}_p=0.75$, i.e. a fraction 0.25 ($=1-\mathfrak{D}_p$) of all prices are changed each period. The average interval between wage changes is likewise assumed to be four quarters, i.e. $\mathfrak{D}_w=0.75$ is used (wage contracts typically have a length of 1 year, in the G7 countries; e.g., Taylor (1993, p.77)).

3.8.2. Exogenous variables

The discussions below focus on the effect of shocks to government purchases. Hence, productivity and the money supply will be assumed

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that steady state.

[24]The cyclical properties of aggregate price/quantity variables are invariant to the own-wage elasticity of labor demand, $(1+\gamma)/\gamma$ (see (23)), and hence no specific value needs to be assigned to the parameter γ (the linearized version of the model does not depend on γ).

constant in the baseline simulations considered below. The model is linearized around a deterministic steady state in which the share of government purchases in output is 0.15, which corresponds to the average values of the government consumption-to-GDP ratios in the U.S. and in the G6, during the sample period.

Table 1 reports estimation results for bivariate vector autoregressions (VAR) of order 1 that were fitted to logged U.S. military purchases and logged G6 government consumption, as well as to U.S. and G6 government consumption, for the period 1973:Q1-97:Q1. Government purchases follow a very persistent process: estimates of the diagonal elements of the matrix of autoregressive coefficients of the VAR are close to unity. In contrast, the off-diagonal elements are mostly close to zero. The data are consistent with the hypothesis that an innovation to government consumption in one country has little effect on government consumption in the other country, in subsequent periods.[25]

Based on these findings, the simulations assume that government purchases in the two countries are random walks:

$$\begin{bmatrix} \ln(\mathcal{G}_t) \\ \ln(\mathcal{G}^*_t) \end{bmatrix} = \begin{bmatrix} \ln(\mathcal{G}_{t-1}) \\ \ln(\mathcal{G}^*_{t-1}) \end{bmatrix} + \begin{bmatrix} \zeta_t \\ \zeta^*_t \end{bmatrix}, \tag{32}$$

where ζ_t and ζ^*_t are white noises.

4. Model predictions

Theoretical impulse responses are reported in Tables 4 and 5 (responses $\tau=0$, $\tau=4$ and $\tau=\infty$ periods after the shock are shown). The measures of home and foreign output used in these Tables are

$$Y_t \equiv D_t + Z^*_t, \quad Y^*_t \equiv D^*_t + Z_t.$$ [26]

The theoretical consumption variable is C_t, the price level is P_t. The measure of home country net exports is $NX_t \equiv \mathcal{PZ}^*_t Z^*_t - \mathcal{PZ}_t Z_t)/(\mathcal{PZ}^*_t Z^*_t + \mathcal{PZ}_t Z_t)$, which corresponds to the definition used in the empirical analysis (see Table 2).

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[25] In contrast, Table 1 suggests that a positive innovation to G6 government consumption triggers a significant *lagged* increase in U.S. military purchases.

[26] Y_t, Y^*_t are measures of home and foreign real GDP, respectively. As noted in Section 3.8.1., home *nominal* GDP is $\mathcal{Y}_t = \mathcal{PD}_t \cdot (D_t + Z^*_t)$. *Real* GDP, can be computed by dividing $\mathcal{Y}_t$ by the growth factor of the price index $\mathcal{PD}_t$, compared to some fixed base period, $t=b$: $\mathcal{Y}_t/(\mathcal{PD}_t/\mathcal{PD}_b) = \mathcal{PD}_b \cdot (D_t + Z^*_t)$. Normalizing $\mathcal{PD}_b = 1$ yields $Y_t = D_t + Z^*_t$.

To facilitate the comparison with the empirical responses shown in Tables 2 and 3, the theoretical responses are computed for innovations that increase government consumption in a given country by 1% of its pre-shock output. Also, the theoretical responses of output, consumption and investment are reported in multiplier form, the responses of the price level and the exchange rate are percentage deviations from the "unshocked" baseline.

A simultaneous increase in government purchases in both countries

It is convenient to begin the discussion of model predictions by considering the case where both countries are affected by a simultaneous and identical positive shock to their government purchases. Result for that case are shown in Table 4, where responses of (home) output, consumption, investment and the home price level are reported for three values of the labor supply elasticity (η): η=.1, 2, ∞. In Table 4, versions of the model with flexible prices and wages, with sticky prices (but flexible wages), with sticky wages (but flexible prices), and with sticky prices *and* wages are compared.

An increase in government purchases reduces household wealth, which induces the household to increase her labor supply, and to consume less (consumption and leisure (time not spent working) being normal goods, for the utilty function assumed here). This explains why output rises, when a rise in government purchases occurs.[27] The rise in hours worked increases the marginal product of capital, which induces a rise in the capital stock--investment rises, thus.

Interestingly, (home and foreign) nominal interest rates, and *nominal* consumption expenditures ($P\cdot C$, $P^{*}\cdot C^{*}$) are not affected by changes in government purchases, when the consumption elasticity of money demand and the coefficient of relative risk aversion are set at $\varepsilon_{c}=\Psi=1$ (as is the case in the simulations reported in Table 4).[28] Hence, the fall in

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[27]See Baxter and King (1993) for discussion of this mechanism.

[28]Substituting consumption from the linearized version of the money demand equation (31) into the household's (linearized) Euler equation (20) yields a difference equation of the following form, when $\varepsilon_{c}=\Psi=1$ (assuming a constant nominal money supply): $E_t(r_{\tau+1}-r)=\Omega\cdot E_t(r_{\tau}-r)$, for $\tau\geq t$, where $\Omega>1$ is a constant (r is the steady state interest rate). A (non-explosive) model solution requires, hence, that the nominal interest rate is constant ($r_t=r$). Using (20) and (31), it is straightforward to see that this implies that P_tC_t is likewise constant (provided $\varepsilon_{c}=\Psi=1$).

consumption triggered by a rise in government purchases induces a rise in the price level.

The lower the labor supply elasticity, the smaller is the increase in hours, and the bigger is the reduction in consumption. In fact, when prices and wages are flexible, the government purchases multiplier of output is, hence, very small (0.09), when the labor supply elasticity is low; it exceeds unity (1.08), when labor supply is infinitely elastic. This confirms the well-known fact that a flexible price-flexible wage business cycle model cannot generate a significant response of output to government purchases shocks, unless highly elastic labor supplies are assumed (Baxter and King (1993)).

Assuming sticky prices and wages raises significantly the impact multiplier. Intuitively, this is due to the fact that, when prices are sticky, then the price level rises less strongly, in the period of the increase in government purchases--hence, private consumption falls less strongly (recall that the nominal value of consumption, $P \cdot Q$, is constant). However, the rate of increase of the price level is bigger, in the periods that follow the shock, compared to the flexible prices case--hence, the *real* interest rate falls, in the periods that follow the shock (recall that the *nominal* interest rate does not respond to the rise in government purchases); this explains why investment rises more strongly, in the period of the shock. Hence, output rises more strongly too, in that period. The impact multiplier is, hence, bigger when prices are sticky. The same logic explains why the impact multiplier increases when wages are sticky (while prices are flexible), as the stickiness of wages implies that prices rise less, in the period of the shock. When prices *and* wages are sticky, the impact multiplier is significantly bigger than when prices and wages are flexible. The increase in the multiplier is particularly sizable when the labor supply elasticity is small: for $\eta=0.1$, the multiplier increases from 0.09, when prices and wages are flexible, to 1.33, when prices and wages are sticky; when $\eta=\infty$, by contrast, the multiplier increases from 1.08 to 1.39. Hence, it appears that the impact multiplier is, roughly, independent of the labor supply elasticity, when prices and wages are sticky. It is important to note that this remark only applies to the impact multiplier: when the labor supply elasticity is low, the increase in output is quite short-lived, whereas the long-run response of output is sizable, when high labor supply elasticities are assumed.

Permanent rise in home government purchases (foreign government purchases held constant), Table 5

In Table 5, the effect of a permanent rise in home government purchases (by 1% of pre-shock home output) is considered, while foreign government purchases do not change. Panel (a) of the Table reports results for the structure with flexible prices and wages while Panel (b) presents results for the baseline structure with sticky prices and wages (the labor supply elasticity is set at η=2, in Table 5). A country specific rise in home government purchases induces home country responses of output, consumption and investment that are roughly similar to those that obtain when government purchases rise by the same amount in both countries. In contrast to a worldwide rise in government purchases, a country-specific positive shock to home government purchases induces a fall in home net exports, in the initial periods that follow the shock. Also, the substantial rise in home output induces a fall in the relative price of home produced intermediate goods (compared to the price of foreign intermediate goods), and the home country experiences a sizable depreciation of it nominal (and real) and real exchange rate (the nominal exchange rate depreciates by 1.2%, in response to a rise in government purchases by 1% of pre-shock home GDP).

Foreign output is affected through two channels: (i) The fall in the relative price of home goods induces agents to substitute foreign goods with home good. (ii) The rise in home investment and government purchases exceeds the fall in home consumption, i.e. home absorption rises, which stimulates home demand for foreign goods. These two effects roughly off-set each other and, hence, the effect of a rise in home government purchases on foreign output is close to zero; this is so, irrespective of whether fixed or flexible prices/wages are assumed.

A version of the model with Pricing to Market

The baseline model assumes that producers of intermediate goods charge the same price (when expressed in a common currency) in their domestic market and in their export market (see (9a)); this implies that export prices, in terms of foreign currency, are highly responsive to exchange rate movements (ceteris paribus, an exporter responds to a 1% fall in the external value of its home currency by reducing its export price, in foreign currency, by 1%). Recent empirical research on export pricing suggests that, overall, the behavior of U.S. firms is consistent with this prediction, while non-U.S. firms appear to be less likely to pass exchange rate movements through to their foreign customers (e.g., Knetter (1993)).

Therefore, a version of the model is explored that departs from the baseline structure by assuming "pricing to market" (PTM) behavior, in the sense that intermediate goods producers (located in both countries) can set *different* prices in domestic and export markets. In both markets, staggered price setting à la Calvo (1983), in terms of the local currency, is assumed; the average duration between price adjustments is assumed to be 4 periods, in both markets. Results for the PTM case are shown in Panel (c) of Table 5.

PTM behavior strengthens slightly the response of foreign output to a rise in home government purchases (the impact multiplier of foreign output is 0.10, when PTM is assumed, compared to 0.04 in the baseline nominal rigidities structure), as PTM dampens the fall in the relative price of home goods, in the short run.

Discussion of shortcomings of the baseline model

Key shortcomings of the baseline model are: (i) it predicts that consumption falls and that the price level rises, in response of a rise in government purchases; (ii) the model generates cross-country transmission effects of government purchases that seem weak, compared to the estimated transmission effects.

A variant of the model with productive government consumption

Shortcoming (i) can be overcome by assuming that government purchase shocks have a positive effect on private sector productivity, as this generates a positive wealth effect that counteracts the negative wealth effect due to increase in taxes. This is motivated by the plausible idea that, in the real world, governments do have a positive effect on private sector productivity (e.g, by maintaining law and order and by providing other vital goods).

Panel (d) in Table 3 considers a variant of the model in which a 1% increase in home government purchases induces a 0.15% increase in home country total factor productivity: it is assumed there that the productivity index θ_t is linked to government purchases, as follows:

$$\theta_t=\Theta\cdot\mathcal{G}_t^{0.15},$$

where Θ is a constant.[29] In that variant of the model, a positive shock to home government purchases induces an *increase* in home consumption, and a fall in the home price level.

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[29]Experiments with a range of values of the elasticity of productivity with respect to government purchases show that when that elasticity is set at a value smaller than 0.15, then a rise in home country government purchases induces a *fall* in home consumption, as in the baseline structure.

Sensitivity to assumed time-series process of government purchases

Predictions regarding the international transmission of shocks to government purchases are highly sensitive to the assumed time-series process of government purchases. The simulations discussed so far assume that a shock to government purchases in a given country has *no* effect on government purchases in the other country. In Panel (g) of Table 3, the law of motion of government purchases (32) is replaced by:

$$\begin{bmatrix} \ln(\mathcal{G}_t) \\ \ln(\mathcal{G}_t^*) \end{bmatrix} = \begin{bmatrix} 0.99 & 0.01 \\ 0.01 & 0.99 \end{bmatrix} \cdot \begin{bmatrix} \ln(\mathcal{G}_{t-1}) \\ \ln(\mathcal{G}_{t-1}^*) \end{bmatrix} + \begin{bmatrix} \zeta_t \\ \zeta_t^{*}, \end{bmatrix}. \qquad (33)$$

(33) implies that (logged) government purchases have a unit root, but that the (log) difference between home and foreign government purchases is stationary (the first-order autocorrelation of that log difference is 0.98), i.e. that government purchases are cointegrated across countries.

When (33) is assumed, a positive innovation to home government purchases induces a lagged rise in foreign government purchases. That innovation has, hence, a negative wealth effect, for the foreign household, which induces that household to raise her labor supply; a positive innovation to home government purchases triggers, thus, a much stronger positive response of foreign output, than in the baseline version of the model. Assuming (33) allows, hence, to make progress in overcoming shortcoming (ii) discussed above.

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APPENDIX

I. Description of data

In what follows, "MEI" refers to the OECD publication (CD-ROM) Main Economic Indicators, Historical Statistics 1960-1996; "IFS" refers to the IMF publication International Financial Statistics (various issues).

Output--GDP in volume terms (MEI).

Investment--gross fixed capital formation plus change in stock of inventories, in volume terms (MEI).

Consumption--private non-durables plus services consumption expenditures, in volume terms, from OECD Quarterly National Accounts.

(OECD QNA does not provide non-durables plus services consumption for Germany. Hence, The G6 consumption index does not include German consumption. For Germany, the MEI series for output and investment start in 1991:Q1; these series were spliced to IFS data for earlier periods; the IFS output series used for that purpose is real GDP; the IFS investment series used for Germany is nominal investment deflated using CPI.)

Money supply--narrow money stock, M1 (MEI). The UK money series starts in 1982:Q3. (G6 money series for 1982:Q3-1994:Q3 is geometric weighted average of M1 in each G6 country; 1982:Q3-1994:Q3 series was spliced to geometric weighted average of M1 in non-UK G6 countries during prior period).

Price level--consumer price index, CPI (IFS).

Nominal interest rate--short term interest rates from Citibase. U.S.: CD rate (series FYUSCD); Japan, Germany, France: call money rate (FYJPCM, FYGECM, FYFRCM); U.K.: interest rate on prime bank bills (FYGBBB); Italy: bond yields, credit institutions (FYITBY); Canada: prime corporate paper, 60 days (FYCACP).

Nominal exchange rate between U.S. and G6--a geometric average of bilateral U.S. dollar exchange rates (IFS).

All time series are used in quarterly form. Interest rates are expressed on a per annum basis. Price level, interest rate and exchange rate time series were obtained at a monthly frequency from data sources. Quarterly averages of these series are used. Output, consumption, investment, price level and money series are seasonally adjusted (the remaining series do not exhibit seasonality). The G6 aggregate series for the interest rate and stock returns are *arithmetic* averages of series for the individual G6 countries; G6 aggregates for other variables are *geometric* averages of individual G6 series. Country weights: Japan, .28; Germany, .20; France, .18; United Kingdom, .14; Britain, .12; Canada, .07. These weights are 1980 shares of individual G6 countries's GDP (in U.S. dollars, at 1980 U.S. exchange rates) in total G6 GDP.

II.

Computation of government purchases multipliers

Estimating the models described in Section 2 using series on log government purchases and logged output, log consumption and log investment allows to compute a response $\Delta\ln(Y^{US}_{t+\tau})/\Delta\ln(G^{US}_{t})$, where Δ denotes the difference compared to the "unshocked" path. A multiplier $(\Delta Y^{US}_{t+\tau}/\Delta G^{US}_{t})$ can be computed by noting that $\Delta\ln(Y^{US}_{t+\tau})/\Delta\ln(G^{US}_{t})=(\Delta Y^{US}_{t+\tau}/\Delta G^{US}_{t})\cdot(G^{US,b}_{t}/Y^{US,b}_{t+\tau})$ and, hence:

$$\Delta Y^{US}_{t+\tau}/\Delta G^{US}_{t}= [\Delta\ln(Y^{US}_{t+\tau})/\Delta\ln(G^{US}_{t})] \;/\; [(G^{US,b}_{t}/Y^{US,b}_{t})\cdot(Y^{US,b}_{t+\tau}/Y^{US,b}_{t})],$$

where $Y^{US,b}$ and $G^{US,b}$ denote the unshocked paths. In Table 1, the sample average of the ratio of G^{US} to Y^{US} is used for $G^{US,b}_{t}/Y^{US,b}_{t}$ (the numbers reported in Table 1 ignore the growth factor $Y^{US,b}_{t+\tau}/Y^{US,b}_{t}$).

The multiplier of G6 output with respect to U.S. government purchases is computed using:

$$\Delta Y^{G6}_{t+\tau}/\Delta G^{US}_{t} = [\Delta \ln(Y^{G6}_{t+\tau})/\Delta \ln(G^{US}_{t})]/[(G^{US,b}_{t}/Y^{US,b}_{t}) \cdot (Y^{US,b}_{t}/Y^{G6,b}_{t}) \cdot (Y^{G6,b}_{t+\tau}/Y^{G6,b}_{t})].$$

In Table 1, the sample average of Y^{US}/Y^{G6} is used as an estimate of $Y^{US,b}_{t}/Y^{G6,b}_{t}$ (the sample average is computed using U.S. and G6 output, expressed in constant 1980 prices, G6 output being expressed in U.S. dollars, at the 1980 exchange rate). The remaining multipliers are computed analogously.

Table 1. VAR models fitted to U.S. and G6 government purchases

(a) U.S. and G6 government consumption

$$\begin{bmatrix} \ln(\mathfrak{G}_t^{US}) \\ \\ \ln(\mathfrak{G}_t^{G6}) \end{bmatrix} = \begin{bmatrix} \underset{(0.01)}{0.96^{**}} & \underset{(0.02)}{0.06^{*}} \\ \underset{(0.02)}{0.02} & \underset{(0.02)}{0.97^{**}} \end{bmatrix} \cdot \begin{bmatrix} \ln(\mathfrak{G}_t^{US}) \\ \\ \ln(\mathfrak{G}_t^{G6}) \end{bmatrix} + \begin{bmatrix} e_t^{US} \\ \\ e_t^{G6} \end{bmatrix}$$

$$\mathrm{Var}\ e_t^{US} = 0.007^2, \quad \mathrm{Var}\ e_t^{G6} = 0.007^2, \quad \mathrm{Corr}(e_t^{US}, e_t^{G6}) = -0.00$$

(b) U.S. military purchases and G6 government consumption

$$\begin{bmatrix} \ln(\mathfrak{G}_t^{US,mil}) \\ \\ \ln(\mathfrak{G}_t^{G6}) \end{bmatrix} = \begin{bmatrix} \underset{(0.02)}{0.96^{**}} & \underset{(0.07)}{0.29^{**}} \\ \underset{(0.02)}{0.01^{\S}} & \underset{(0.01)}{0.95^{**}} \end{bmatrix} \cdot \begin{bmatrix} \ln(\mathfrak{G}_t^{US,mil}) \\ \\ \ln(\mathfrak{G}_t^{G6}) \end{bmatrix} + \begin{bmatrix} \ell_t^{US,mil} \\ \\ \ell_t^{G6} \end{bmatrix}$$

$$\mathrm{Var}\ \ell_t^{US,mil} = 0.017^2, \quad \mathrm{Var}\ \ell_t^{G6} = 0.006^2, \quad \mathrm{Corr}(\ell_t^{US,mil}, \ell_t^{G6}) = 0.00$$

Note: Estimates of autoregressive coefficients of a first order VAR fitted to quarterly U.S. and G6 government purchases series are reported, as well as the variances of the regression residuals and the correlation between the U.S. and G6 regression residuals.

Panel (a) shows results for VAR in U.S. military purchases and G6 government consumption; Panel (b) shows results for a VAR in U.S. and G6 government consumption. Also included in the regressions were a constant and a linear time trend (not reported in Table).

Figures in parentheses are standard errors.
**, *, †, §: coefficient significant at 1%, at 5%, at 10%, or at the 20% level, respectively (significance levels for two-sided tests).

Sample period: 1973:Q1-97:Q1.

Table 2. Estimated responses to increase in U.S. purchases

	Y^{US}	C^{US}	I^{US}	NX^{US}	P^{US}	r^{US}	e^{US}	Y^{G6}	C^{G6}	I^{G6}	P^{G6}	r^{G6}
(a) **Shock to US military spending** (military spending assumed exogenous)												
τ=0	1.10	-	+	-2.66	-0.83	-	+	+	0.22	-1.24	1.16	-1.00
τ=4	+	+	-	-3.16	+	+	-	+	0.40	-	+	+
τ=8	1.13	+	-	-	+	-	-	1.91	0.63	+	+	1.33
τ=12	+	+	-	-	+	-	+	2.45	0.81	+	+	+
(b) **Shock to US military spending** (VAR, military spending ordered first)												
τ=0	+	+	-	-	+	-	+	-	+	-0.81	+	-0.50
τ=4	+	+	-	-	-	-2.16	+	+	+	+	-	-
τ=8	+	+	-	-	-2.16	-0.50	+	+	+	+	-1.50	-
τ=12	+	+	-	-	-	-	+	1.59	0.46	1.37	-2.00	-
(c) **Shock to US military spending** (VAR, military spending ordered last)												
τ=0	u	u	u	u	u	u	u	u	u	u	u	u
τ=4	-	+	-0.87	-1.66	-2.33	-3.50	-	+	+	+	-0.07	-
τ=8	+	0.45	0.05	-2.16	-4.33	-3.66	+	+	+	+	-0.15	-
τ=12	2.08	0.69	0.38	-1.00	-4.66	-2.66	11.16	1.97	0.50	1.73	-0.22	-
(d) **Shock to US government consumption** (G assumed exogenous)												
τ=0	-	-	-0.99	-1.49	+	-	+	-	+	-0.85	+	-
τ=4	-	-	-2.17	3.35	-	-	+	+	0.40	1.04	-	-
τ=8	+	-	-1.80	5.11	-	-	14.13	2.61	0.63	2.51	-	+
τ=12	+	-	-1.56	6.30	-	-	18.43	3.28	0.79	3.01	+	+
(e) **Shock to US government consumption** (VAR, G ordered first)												
τ=0	-	+	-1.24	-	-	-1.60	-	-0.85	+	-1.46	+	-0.73
τ=4	+	0.53	-	-	-3.86	-4.33	+	1.98	0.54	1.72	-2.00	-1.53
τ=8	2.48	0.80	+	-	-4.33	-2.73	10.80	3.09	0.72	2.56	-2.73	-
τ=12	1.92	0.56	-	2.06	-3.13	-	18.80	2.99	0.80	2.35	-2.93	-
(f) **Shock to US government consumption** (VAR, G ordered last)												
τ=0	u	u	u	u	u	u	u	u	u	u	u	u
τ=4	-	+	-	-	-3.20	-4.06	+	1.77	0.33	1.66	-0.26	-
τ=8	1.58	0.48	+	-	-4.20	-3.06	9.06	1.91	0.40	1.63	-0.39	-
τ=12	1.61	+	+	+	-3.60	-	15.86	2.06	0.52	1.71	-0.47	-

Note: Table presents estimated responses, to U.S. government purchases shocks, of U.S. and G6 output (Y), consumption (C), investment (I), price level (P), short term interest rate (r), in U.S. net exports (NX^{US}), and the nominal bilateral U.S.-G6 exchange rate (e^{US}). The shocks (innovations) correspond to a rise in government purchases by 1% of (pre-shock) U.S. GDP. Responses are shown τ=0, 4, 8 and 12 quarters after the shocks, provided that these responses are statistically significant at the 20% level (two-sided test). When the response is not significant, merely the *sign* of the response is reported.

Panel (a): responses for shocks to U.S. military purchases, estimated using bivariate systems, assuming exogeneity of military purchases. Panels (b), (c): responses to U.S. military purchases estimated using a VAR. Panels (d)-(f): counterparts to (a)-(c), for shock to U.S. government consumption.

Responses of GDP, consumption and investment are expressed in multiplier form. Responses of the price level and the exchange rate are percentage changes, relative to the "unshocked" paths of these variables, while responses of interest rates and net exports are expressed as percentage point differences compared to "baseline" paths (interest rates are expressed in % per annum; net exports defined as *(ex-im)/(ex+im)*, where *ex* and *im* are U.S. exports and imports of goods and services, in current U.S. dollars).

Table 3. Estimated responses to increase in G6 government consumption

	Y^{US}	C^{US}	I^{US}	NX^{US}	P^{US}	r^{US}	e^{US}	Y^{G6}	C^{G6}	I^{G6}	P^{G6}	r^{G6}
(a) G6 government consumption assumed exogenous												
$\tau=0$	+	+	-	0.74	-	-	-	-	+	-0.86	-	-
$\tau=4$	+	0.81	-	-1.38	+	-	+	1.48	0.56	+	+	+
$\tau=8$	2.16	1.03	+	-3.57	+	+	+	2.93	0.85	+	+	+
$\tau=12$	2.70	1.12	+	-4.62	+	+	-	3.72	1.02	1.90	9.47	1.77
(b) VAR, G6 government consumption ordered first												
$\tau=0$	+	-	-	-	-	-	-	+	+	-	-0.66	-
$\tau=4$	+	0.26	-	-	-2.92	-3.58	-7.07	1.30	+	1.15	-1.12	-
$\tau=8$	1.33	0.39	+	-2.50	-3.69	-3.12	+	1.23	+	0.93	-1.73	-
$\tau=12$	1.42	0.45	+	+	-3.63	-2.00	13.58	1.39	0.36	1.31	-2.81	-1.12
(c) VAR, G6 government consumption ordered last												
$\tau=0$	u	u	u	u	u	u	u	u	u	u	u	u
$\tau=4$	0.75	0.27	+	-	-1.58	-2.04	-6.96	1.04	0.19	0.83	-	-
$\tau=8$	0.98	0.31	+	-2.10	-2.04	-1.94	+	0.96	0.19	+	-	-
$\tau=12$	0.98	0.33	+	+	-2.04	-1.27	9.58	1.05	0.29	0.75	-1.38	-

Note: Table presents estimated responses, to shock to G6 government consumption (size of shock: 1% of pre-shock G6 GDP). Responses are shown $\tau=0$, 4, 8 and 12 quarters after the shock, provided that these responses are statistically significant at the 20% level (two-sided test). When the response is not significant, the Table merely reports the *sign* of the response.

Panel (a): responses estimated using bivariate systems, assuming exogeneity of government consumption. Panels (b), (c): responses estimated using a VAR.

See Table 2, for further informations.

Table 4. Model predictions: increase in government purchases in both countries

	Labor supply elasticity, η=2				η=.1		η=∞	
	$\mathfrak{D}_p$=0	$\mathfrak{D}_p$=.75	$\mathfrak{D}_p$=0	$\mathfrak{D}_p$=.75	$\mathfrak{D}_p$=0	$\mathfrak{D}_p$=.75	$\mathfrak{D}_p$=0	$\mathfrak{D}_p$=.75
	$\mathfrak{D}_w$=0	$\mathfrak{D}_w$=0	$\mathfrak{D}_w$=.75	$\mathfrak{D}_w$=.75	$\mathfrak{D}_w$=0	$\mathfrak{D}_w$=.75	$\mathfrak{D}_w$=0	$\mathfrak{D}_w$=.75
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(a) Impact responses								
Y	0.71	1.36	1.04	1.45	0.09	1.33	1.08	1.39
C	-0.46	-0.15	-0.29	-0.10	-0.92	-0.35	-0.20	-0.05
I	0.18	0.52	0.34	0.55	0.02	0.69	0.28	0.45
P	0.64	0.21	0.41	0.14	1.27	0.48	0.28	0.07
(b) Responses 4 periods after shock								
Y	0.73	0.83	0.81	0.93	0.10	0.11	1.09	1.16
C	-0.43	-0.36	-0.38	-0.31	-0.92	-0.88	-0.16	-0.12
I	0.17	0.20	0.19	0.24	0.02	-0.00	0.26	0.28
P	0.60	0.49	0.52	0.42	1.26	1.21	0.23	0.16
(c) Long run responses								
Y	0.80	0.80	0.80	0.80	0.12	0.12	1.14	1.14
C	-0.29	-0.29	-0.29	-0.29	-0.89	-0.89	0.00	0.00
I	0.10	0.10	0.10	0.10	0.01	0.01	0.14	0.14
P	0.40	0.40	0.40	0.40	1.22	1.22	0.00	0.00

Note: Model predictions are shown for an unexpected, simultaneous, identical, permanent rise in government purchases, in both countries (size of shock: 1% of pre-shock national GDP). Rows labelled Y, C, I and P show responses of output (GDP), private consumption, physical investment and the price level, respectively. Responses of output, consumption and investment are reported in multiplier form; responses of the price level are percentage deviations from the "unshocked" path.

Columns (1)-(4) assume a Frisch labor supply elasticity of η=2; columns (5), (6) and (7),(8) assume labor supply elasticities of η=0.1 and η=∞, respectively.

Columns (1), (5), (7) assume flexible prices and wages; column (2): sticky prices, flexible wages; column (3): flexible prices, sticky wages; columns (4), (6) and (8) assume sticky prices *and* sticky wages (average duration between price and wage changes, in seller's currency: 4 periods); N.B.: 1-$\mathfrak{D}_p$ and 1-$\mathfrak{D}_w$ are per-period probabilities of price and wage change, for individual firm and individual labor type (average number of periods between price and wage changes: $1/(1-\mathfrak{D}_p)$, $1/(1-\mathfrak{D}_w)$, respectively).

Table 5. Model predictions: responses to increase in home government purchases

	Y	C	I	NX	P	e	Y^*	C^*	I^*	P^*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(a) Flexible prices & wages										
$\tau=0$	0.71	-0.51	0.17	-0.05	0.70	1.26	0.00	0.04	0.01	-0.06
$\tau=4$	0.73	-0.48	0.15	-0.04	0.66	1.26	0.00	0.05	0.01	-0.06
$\tau=\infty$	0.80	-0.37	0.08	0.10	0.51	1.26	0.01	0.08	0.01	-0.10
(b) Sticky prices & wages: baseline structure										
$\tau=0$	1.40	-0.18	0.50	-0.14	0.25	1.26	0.04	0.08	0.04	-0.11
$\tau=4$	0.92	-0.37	0.22	-0.05	0.51	1.26	0.01	0.06	0.02	-0.08
$\tau=\infty$	0.80	-0.37	0.08	0.01	0.51	1.26	0.01	0.08	0.01	-0.10
(c) Sticky prices & wages: Pricing to Market										
$\tau=0$	1.34	-0.11	0.56	-0.17	0.15	1.26	0.10	0.01	-0.01	-0.01
$\tau=4$	0.91	-0.34	0.24	-0.05	0.47	1.26	0.02	0.03	0.00	-0.04
$\tau=\infty$	0.80	-0.37	0.08	0.01	0.51	1.26	0.00	0.08	0.01	-0.10
(d) Sticky prices & wages (baseline); government purchases raise productivity										
$\tau=0$	1.39	0.02	0.24	-0.06	-0.04	1.11	0.00	0.09	0.02	-0.12
$\tau=4$	1.72	0.21	0.37	-0.09	-0.29	1.11	0.01	0.11	0.03	-0.16
$\tau=\infty$	1.89	0.49	0.21	0.02	-0.67	1.11	0.01	0.18	0.02	-0.25
(e) Sticky prices & wages (baseline); home, foreign government purchases cointegrated										
$\tau=0$	1.25	-0.11	0.43	-0.47	0.15	0.40	0.19	0.00	0.11	-0.01
$\tau=4$	0.80	-0.27	0.18	-0.36	0.35	0.40	0.13	-0.03	0.06	0.04
$\tau=\infty$	0.43	-0.19	0.04	0.18	0.22	0.40	0.37	-0.10	0.05	0.13

Note: Model predictions are shown for an unexpected, permanent rise in government purchases, in the home country (size of shock: 1% of pre-shock national GDP). Columns labelled Y, C, I, NX, P, e show responses of *home* output, consumption, investment, net exports, the home price level and of the home currency price of foreign currency, respectively; columns labelled Y^*, C^*, I^* and P^* show responses of *foreign* output, consumption, investment and price level.

Responses of output, consumption and investment are reported in multiplier form; responses of the price level and the nominal exchange rate are percentage deviations from the "unshocked" path. Responses of net exports are expressed as percentage point differences compared to "baseline" paths (net exports defined as $(ex-im)/(ex+im)$, where ex and im are home country exports and imports of goods and services, in home currency).

Rows labelled $\tau=0$, $\tau=4$ and $\tau=\infty$ show responses 0, 4 and ∞ periods after shock, respectively.

Panel (a): version of model with flexible prices and wages.

Panels (b)-(d) assume sticky prices and wages (average duration between price and wage changes: 4 quarters); Panel (b): baseline structure (prices of intermediate goods sticky in seller's currency); Panel (c): version of model in which producers of intermediate goods engage in "pricing to market" (stickiness of prices in buyer's currency); Panel (d): version of model in which a 1% rise in home government purchases induces a 0.15% rise in home total factor productivity; Panel (e): version of model in which home and foreign government purchases (in logs) are cointegrated:

$\ln(\mathcal{G}_t)=0.99\cdot\ln(\mathcal{G}_{t-1})+0.11\cdot\ln(\mathcal{G}^*_{t-1})+\varepsilon_t$, $\ln(\mathcal{G}^*_t)=0.01\cdot\ln(\mathcal{G}_{t-1})+0.99\cdot\ln(\mathcal{G}^*_{t-1})+\varepsilon^*_t$.