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US trade balance dynamics: the role of fiscal policy and productivity shocks and of financial market linkages

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Abstract

This paper examines whether domestic and foreign productivity and fiscal policy changes can account for the wide swings in US net exports during the period 1975–1991. A two-country Real Business Cycle model is used for that purpose. The model is simulated using data on productivity, government purchases and taxes, for the G7 countries. A version of the model with incomplete asset markets, in which only bonds can be used for international capital flows, tracks the US trade balance fairly closely, provided permanent country-specific productivity shifts are assumed. The simulations suggest that US productivity changes were the main source of fluctuations in US net exports.

JEL classifications: F32, E32

Keywords: US trade balance; Total factor productivity; Fiscal policy; RBC models; Incomplete asset markets

1. Introduction

This paper examines whether domestic and foreign productivity and fiscal policy changes can account for the wide swings in US net exports during the period 1975–1991. A two-country Real Business Cycle (RBC) model with a government

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sector is used for that purpose. The analysis focuses on the response of optimizing, forward looking private decision makers to exogenous shocks, and on the way that this response is affected by international asset market linkages.

Historical quarterly series on total factor productivity, government consumption and average tax rates in the US and in an aggregate of the remaining G7 countries (G6, henceforth) are fed into the model. A version of the model in which international asset markets are incomplete, in the sense that only non-contingent debt contracts (bonds) can be used for international financial transactions, tracks the observed behavior of the US trade balance rather closely, provided permanent country-specific productivity shifts are assumed (statistical tests presented in the paper support the assumption of permanent idiosyncratic US and G6 productivity shocks).[1]

The simulations of the structural model suggest that US productivity changes were the major source of fluctuations in US net exports during the period 1975–1991; they show that tax changes too had a noticeable impact on the trade balance, but that government spending only played a secondary role. The simulations suggest, in particular, that the relatively rapid productivity growth and the large tax cuts that occurred in the US during the first half of the 1980s were important forces behind the sharp drop in US net exports during that period.

In contrast to the structure with incomplete asset markets, a version of the model that postulates complete international asset markets, as assumed in many International RBC models (see, e.g. Dellas, 1986; Baxter and Crucini, 1993; Backus et al., 1995), fails to explain the observed behavior of the US trade balance — predicted trade balance series generated by that version of the model are *negatively* correlated with the actual US trade balance.

The success of the incomplete markets structure is mainly due to the fact that, in that structure, a permanent country-specific productivity increase lowers the net exports of the country that experiences the productivity increase. This is important as, empirically, US net exports (and the net exports of the G6 countries) co-move *negatively* with domestic productivity. The complete markets structure cannot capture this empirical regularity — with complete markets, net exports are predicted to rise in response to a country-specific increase in domestic productivity.

The intuition for this difference in responses across asset market structures is that a productivity increase in a given country raises that country's wealth more strongly when asset markets are incomplete (than when complete markets exist), as the elimination of trade in state contingent assets limits international risk sharing. When markets are incomplete, consumption in the country that receives a positive productivity shock rises therefore more strongly (than when markets are complete), and that country's net exports are, hence, more susceptible of responding negatively to such a shock.

The results here provide strong evidence against the hypothesis of complete risk

[1] Two-country RBC models with a bonds-only asset market structure have recently been presented by Kollmann (1991, 1996) and by Baxter and Crucini (1995), among others.

sharing between the US and the G6 countries. However, asset market incompleteness alone is not sufficient to explain the observed behavior of US net exports — to rationalize that behavior, permanent (or extremely persistent) idiosyncratic productivity shifts are required, namely shocks that have a very long-lasting effect on the cross-country productivity differential. When even a relatively small degree of mean reversion of productivity is assumed — say, when productivity follows an AR(1) process with an autocorrelation of 0.95 — then the response of consumption in a given country to an idiosyncratic productivity increase in that country is much weaker than the response triggered by a permanent productivity shift; hence, net exports *rise* in response to such a non-permanent productivity increase — even when asset markets are incomplete. In contrast, the complete markets structure fails to explain the actual behavior of US net exports, irrespective of whether permanent or transitory idiosyncratic productivity shocks are assumed.

In a certain sense, the simulation results here might thus be viewed as 'indirect' support for the assumption of extremely long-lasting idiosyncratic US and G6 productivity shifts.

Section 2 discusses the basic facts on which this study focuses. Section 3 discusses the model. Simulation results are presented in Section 4. Section 5 summarizes the results.

2. Fiscal policy, productivity and net exports: US and G6 data

Fig. 1 plots quarterly US net exports (as a share of GDP) as well as average tax rates, government consumption and total factor productivity for the US and for the G6 during the period 1975:Q1–1991:Q3.

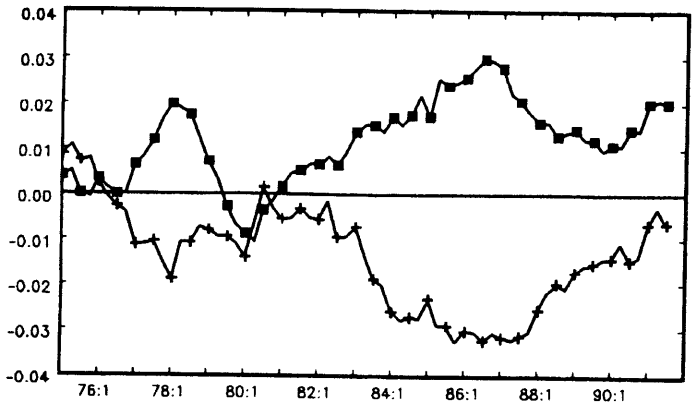
The net exports variable is exports minus imports of goods and services. Fig. 1 also shows net exports of the G6 countries. While G6 net exports are not an exact mirror image of US net exports (as they would be if — as assumed in the model discussed below — the G7 did not trade with other countries), the two series are highly negatively correlated.

The average tax rate shown in Fig. 1 is the ratio of total tax revenues and social security contributions received by governments (minus transfer payments made by governments) to the net domestic product (GDP minus consumption of fixed capital). The index of total factor productivity in country i (i = US, G6) is defined as:

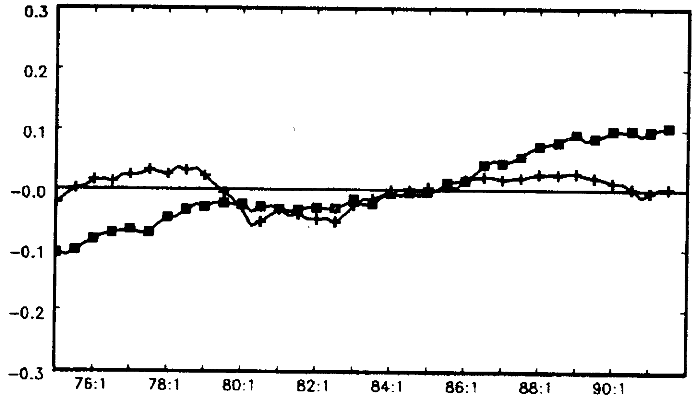
$$\ln(\theta_t^i) = \ln(Y_t^i) - (1-\eta)\ln(K_t^i) - \eta\ln(N_t^i),$$

where Y_t^i, K_t^i and N_t^i are real GDP, physical capital and labor input (total hours worked) in country i, respectively. η is a parameter that represents the wage share; Fig. 1 uses $\eta = 0.75$.[2] The productivity and government consumption series in

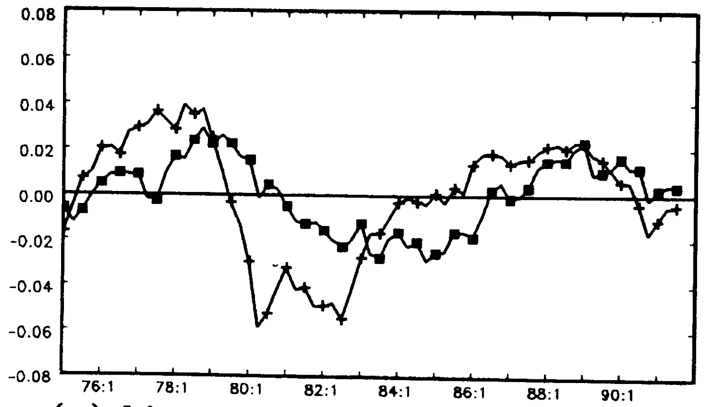
[2] In the US (and in the other G7 countries), the ratio of labor income to capital income fluctuates around 2.5, which suggests a value of η in the range of 0.75.



(a) + (■): U.S (G6) Trade Balance Surplus (Relative to U.S. GDP)

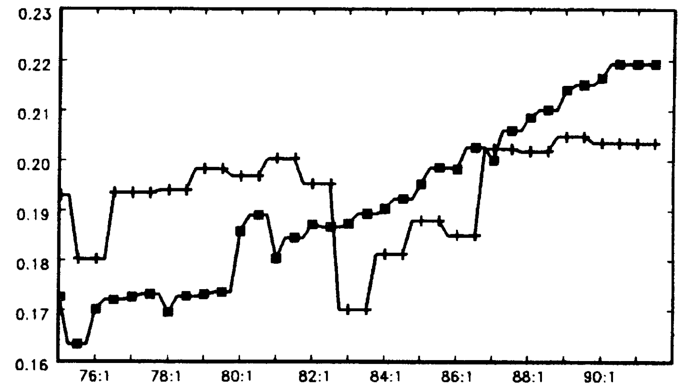


(c) Productivity Index (ln(θ))

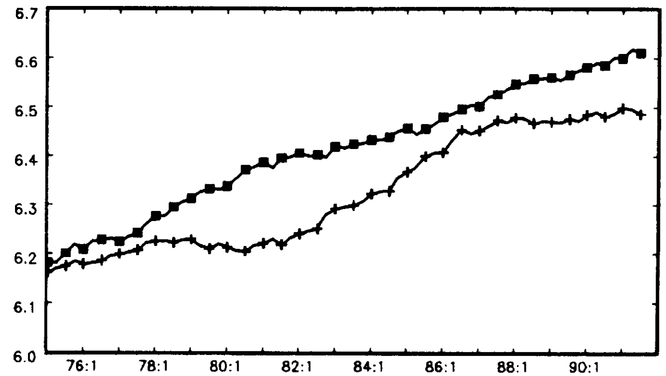


(e) Linearly Detrended Productivity

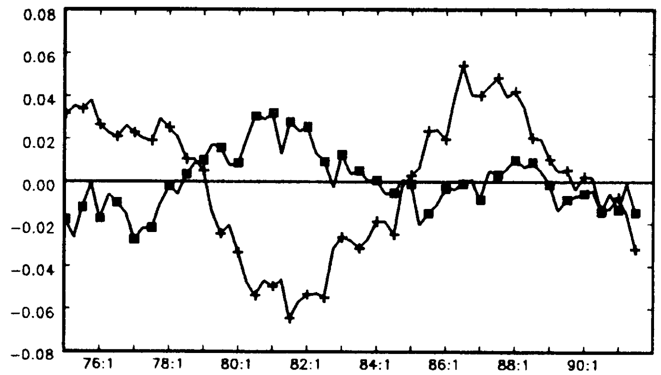
Fig. 1. Quarterly macroeconomic data, US (+), and G6 (■), 1975:Q1–1991:Q3.



(b) Tax Rate



(d) Government Consumption (in Logs), Billions of 1980 U.S. $



(f) Linearly Detrended Log Government Consumption

Fig. 1. *Continued*

Fig. 1 are presented in (log) levels, as well as in linearly detrended form. Further information about the data is provided in Appendix A.

The most striking aspect of the net exports series is the strong increase in the US trade deficit during the first half of the 1980s, as well as the persistence of that deficit.

As possible explanations of the behavior of the US trade balance, the following features of the other time series plotted in Fig. 1 seem noteworthy:

1. The average US tax rate dropped sharply in 1982 and stayed below its pre-1982 level during the next 4 years; during the sample period as a whole, the US tax rate showed no pronounced trend, in contrast to the G6 tax rate that increased steadily (from approx. 17% in the mid-1970s to 22% in 1991).
2. US net exports co-move negatively with (detrended) US productivity and government consumption; note, in particular, that during the first half of the 1980s (i.e. during the sharp drop in US net exports), US productivity and government consumption grew much more rapidly than during the sample period as a whole.[3] Note also that detrended productivity and government consumption show more variation in the US than in the G6.

This paper investigates whether the behavior of US net exports can be explained by the changes in productivity, government consumption and tax rates in the US and the G6 that are documented in Fig. 1. The next Section presents the model that will be used for that purpose.

3. The model

3.1. Preferences and technologies

The world considered here consists of two countries, indexed by $i = 1,2$. Each country is inhabited by consumers and by a government. There exists a unique good in this world. This good is produced and consumed by both countries, and it can also be used as an investment good. Private sector preferences and technologies are similar to those assumed in the International RBC literature (for a survey of that literature, see Backus et al., 1995).

All residents of the same country are identical. Private sector decisions in country i are taken by a representative consumer whose intertemporal preferences are given by

$$E_t \sum_{j=0}^{j=\infty} \beta^j \, u\left(c^i_{t+j}\right), \tag{1}$$

[3] The correlations between US net exports (expressed as a share of US GDP) and the linearly detrended US (log) productivity and (log) government consumption are −0.35 and −0.33, respectively, during the sample period. The correlations between US net exports and linearly detrended G6 productivity and government consumption are positive (0.14 and 0.10, respectively).

where E_t denotes the mathematical expectation conditional on information available at date t. β is the country's subjective discount factor and C^i_t denotes country i's aggregate consumption. A CRRA period utility function is assumed:

$$u(C) = [1/(1-\sigma)]C^{1-\sigma}, \quad \text{with } \sigma > 0. \tag{2}$$

Country i's output in period t is given by:

$$Y^i_t = \theta^i_t \, (K^i_t)^{1-\eta} (N^i_t)^{\eta}, \tag{3}$$

where K^i_t is country i's aggregate capital stock, while N^i_t is the country's labor force. Labor is immobile internationally. The labor force grows at a constant rate: $N^i_t = g^i_N N^i_{t-1}$. Total factor productivity (θ^i_t) is given by

$$\theta^i_t = (Z^i_t)^{\eta} \exp(\nu^i_t), \tag{4}$$

where ν^i_t is an exogenous random variable with mean zero, while Z^i_t is a deterministic geometric trend. Z^i_t grows at a constant rate: $Z^i_t = g^i_Z Z^i_{t-1}$. Let $X^i_t \equiv Z^i_t N^i_t$ denote the deterministic trend of country i's labor force measured in efficiency units. The growth factor of this variable is identical in the two countries: $g_X \equiv X^1_{t+1}/X^1_t = X^2_{t+1}/X^2_t$ (thus, $g_X = g^1_Z g^1_N = g^2_Z g^2_N$; this makes balanced growth possible).

The law of motion of the capital stock in country i is

$$K^i_{t+1} + \phi(K^i_{t+1}, K^i_t) = (1-d)K^i_t + I^i_t, \tag{5}$$

where I^i_t denotes how much output is required to change the capital stock from K^i_t to K^i_{t+1}. $0 \le d \le 1$ is the depreciation rate of the capital stock and $\phi(K^i_{t+1}, K^i_t)$ is a convex adjustment cost function that is homogeneous of degree 1 in K^i_{t+1} and K^i_t:

$$\phi(K^i_{t+1}, K^i_t) = 0.5\,\Phi\,\{K^i_{t+1} - \vartheta K^i_t\}^2/K^i_t, \quad \Phi > 0, \ \vartheta > 0. \tag{6}$$

3.2. Government behavior

Governments purchase units of the homogeneous good and finance these purchases by levying a distorting tax. In addition, governments trade in real one-period bonds. The budget constraint of the government of country i is

$$G^i_t + D^i_t\,(1 + r_t) = T^i_t + D^i_{t+1}, \tag{7a}$$

where G^i_t and T^i_t are, respectively, government purchases and tax revenues, while D^i_t is government debt that matures in period t, and r_t is the real risk-free interest rate. The only tax available to governments is a flat-rate tax on net output (output net of capital depreciation and of adjustment costs). Government tax revenues are, hence, given by

$$T_t^i = s_t^i\left[Y_t^i - dK_t^i - \phi(K_{t+1}^i,K_t^i)\right], \tag{7b}$$

where s_t^i is the rate of the flat-rate tax.

Government purchases and the tax rate depend on government debt and on the ratio of debt to the tax base, respectively:

$$G_t^i = -\mu_G D_t^i + \gamma_t^i, \tag{8a}$$

$$s_t^i = \mu_T D_t^i/\left[Y_t^i - dK_t^i - \phi(K_{t+1}^i,K_t^i)\right] + \sigma_t^i\,. \tag{8b}$$

Here, γ_t^i and σ_t^i are exogenous random variables. Eq. (8a) and Eq. (8b) are assumed because, by selecting appropriate values for μ_G and μ_T (in particular, $\mu_G > 0$ and/or $\mu_T > 0$), one can guarantee that government solvency conditions are satisfied (fiscal policy rules similar to Eq. (8a) and Eq. (8b) have frequently been used in the public finance literature and in macroeconometric models (see, e.g., Buiter, 1990, pp. 265–266; and Masson et al., 1990).

Autonomous fiscal spending (γ_t^i) is given by

$$\gamma_t^i = X_t^i\,\bar{\gamma}^i\exp(\varepsilon_t^i), \tag{9}$$

where $\bar{\gamma}^i$ is a constant and ε_t^i is an exogenous random variable with mean zero (X_t^i is defined after Eq. (4); the fact that X_t^i appears in Eq. (9) makes balanced growth possible).

In contrast to productivity and autonomous government spending, the exogenous tax rate shock, σ_t^i, does not have a deterministic trend.

3.3. Asset markets

Two asset market structures are considered. In the first (incomplete asset markets), agents have to use real risk-free one-period bonds in their international financial transactions (agents are, thus, unable to buy foreign assets with state-contingent pay-offs, such as equity). In contrast, the second asset market structure assumes complete international markets for date- and state-contingent claims.

3.3.1. Incomplete asset markets

Two-country models with the incomplete asset market structure considered here have recently been studied by Kollmann (1991, 1996) and Baxter and Crucini (1995), among others. The assumption that agents' financial transactions are restricted to risk-free bonds is a key assumption in permanent income models of consumption behavior (see, e.g., Sargent, 1987, ch. 12). This asset markets structure has also been assumed in much research on small open economies (see, e.g., Obstfeld and Rogoff, 1996, ch. 2).

In the version of the model with incomplete asset markets, the budget constraint of the private sector of country i is given by:

$$C_t^i + I_t^i + A_{t+1}^i = Y_t^i - T_t^i + (1 + r_t)A_t^i, \tag{10}$$

where T_t^i denotes the period t tax liability of the private sector, while A_t^i denotes the (net) stock of one-period bonds held by the private sector that mature in t (r_t is the real risk-free interest rate on these bonds).

The decision problem of country i's private sector is to maximize the intertemporal utility defined in Eq. (1) subject to the restriction that the budget constraint Eq. (10) holds in all periods. The solution to this decision problem satisfies the following Euler equations (assuming that Ponzi games are ruled out):

$$u_t^{i,} = (1 + r_{t+1})\beta E_t\left[u_{t+1}^{i,}\right] \tag{11a}$$

and

$$u_t^{i,} = \beta E_t\left[\mathrm{MPK}_{t+1}^i\, u_{t+1}^{i,}\right]. \tag{11b}$$

Here, $u_t^{i,}$ is country i's marginal utility of consumption at date t, while MPK_{t+1}^i is its intertemporal marginal rate of transformation between t and $t+1$ ($\mathrm{MPK}_{t+1}^i \equiv \{(1 - s_{t+1}^i)[\theta_{t+1}^i(1-\eta)(K_{t+1}^i)^{-\eta}(N_{t+1}^i)^{\eta} - \phi_{2,t+1}^i - d] + 1\}/\{1 + (1 - s_t^i)\phi_{1,t}^i\}$, where $\phi_{s,t}^i$ is the derivative of the adjustment cost function $\phi(K_{t+1}^i,K_t^i)$ with respect to the sth argument of that function).

Given exogenous processes $\{\theta_t^i,\gamma_t^i,\sigma_t^i\}$ $i = 1,2$, an equilibrium in the economy with incomplete asset markets is a set of stochastic processes for the endogenous variables $\{Y_t^i, K_t^i, C_t^i, I_t^i, D_t^i, G_t^i, T_t^i, s_t^i, A_t^i, r_t\}$ for $i = 1,2$ that satisfies Eqs. (3), (5), (7a), (7b), (8a), (8b), (10), (11a) and (11b) as well as the condition that the goods market clears:

$$C_t^1 + C_t^2 + I_t^1 + I_t^2 + G_t^1 + G_t^2 = Y_t^1 + Y_t^2. \tag{12}$$

By Walras' law, equilibrium in the goods market implies that the asset market clears as well.

3.3.2. Complete asset markets

Two-country RBC models typically assume that asset markets are complete (see, e.g., Baxter and Crucini, 1993; Backus et al., 1995) . The existence of complete asset markets implies that (weighted) marginal instantaneous utilities of consumption are equated in the two countries, and that for all states of the world:

$$u_t^{1,} = \Lambda u_t^{2,}, \tag{13}$$

where $\Lambda > 0$ is a time- and state-invariant term reflecting the distribution of private sector wealth between the two countries.[4] When the CRRA utility function Eq. (2) is assumed, this risk-sharing condition implies that consumption is perfectly correlated across countries:

$$C_t^1 = \Lambda C_t^2.$$

Obviously, the first-order conditions Eqs. (11a),(11b) and the market clearing condition Eq. (12) continue to be valid equilibrium conditions in an economy with complete asset markets.

Given a weight Λ and exogenous processes $\{\theta_t^i, \gamma_t^i, \sigma_t^i\}$ $i = 1,2$, an equilibrium in the economy with complete asset markets is therefore a set of stochastic processes for the endogenous variables $\{Y_t^i, K_t^i, C_t^i, I_t^i, D_t^i, G_t^i, T_t^i, s_t^i, r_t\}$ for $i = 1,2$ that satisfies equations Eqs. (3), (5), (7a), (7b), (8a), (8b), (11a), (11b), (12) and (13).

3.4. Solving the model

A solution of the model is obtained by considering the 'detrended' variables $\hat{Y}_t^i \equiv Y_t^i/X_t^i$, $\hat{K}_t^i \equiv K_t^i/X_t^i$, $\hat{C}_t^i \equiv C_t^i/X_t^i$, $\hat{I}_t^i \equiv I_t^i/X_t^i$, $\hat{D}_t^i \equiv D_t^i/X_t^i$, $\hat{G}_t^i \equiv G_t^i/X_t^i$, $\hat{T}_t^i \equiv T_t^i/X_t^i$, $\hat{A}_t^i \equiv A_t^i/X_t^i$, $\hat{\theta}_t^i \equiv \theta_t^i/(Z_t^i)^\eta$ and $\hat{\gamma}_t^i \equiv \gamma_t^i/X_t^i$ (N.B. $X_t^i \equiv Z_t^i N_t^i = X_0^i \cdot (g_X)^t$). Under the assumptions about preferences and technologies stated above, the model can be written as a system of equations in the variables $\hat{\theta}_t^i$, $\hat{\gamma}_t^i$, $\hat{\sigma}_t^i$, $\hat{Y}_t^i$, $\hat{K}_t^i$, $\hat{C}_t^i$, $\hat{I}_t^i$, $\hat{D}_t^i$, $\hat{G}_t^i$, $\hat{T}_t^i$, s_t^i, r_t and $\hat{A}_t^i$, for $i = 1,2$ (the variable $\hat{A}_t^i$ is only relevant when asset markets are incomplete). The model is solved using a linear approximation of this system of equations near a deterministic steady state, i.e. near an equilibrium in which the (detrended) endogenous and exogenous variables are constant (this solution method is standard in the RBC literature (see, e.g. King et al., 1988)). In the simulations described below, the model is linearized around a symmetric deterministic steady state in which the variables have the same value in each country (in the simulations of the complete markets structure, the weight Λ in the risk sharing condition Eq. (13) is, thus, set at $\Lambda = 1$).

The linearized versions of the incomplete markets structure and of the complete markets structure can be expressed as

$$E_t h_{t+1} = \mathcal{G} h_t + \mathcal{H} q_t + \mathcal{J} E_t q_{t+1}, \quad \text{and} \quad E_t w_{t+1} = \mathcal{S} w_t + \mathcal{Q} q_t + \mathcal{R} E_t q_{t+1}, \tag{14}$$

respectively, where $h_t \equiv (\nabla r_t, \nabla\hat{D}_t^1, \nabla\hat{D}_t^2, \nabla\hat{A}_t^1, \nabla\hat{K}_t^1, \nabla\hat{K}_t^2, \nabla\hat{C}_t^1, \nabla\hat{C}_t^2, \nabla\hat{K}_{t+1}^1)'$, $w_t \equiv (\nabla\hat{D}_t^1, \nabla\hat{D}_t^2, \nabla\hat{K}_t^1, \nabla\hat{K}_t^2, \nabla\hat{C}_t^1, \nabla\hat{C}_t^2, \nabla\hat{K}_{t+1}^1)'$ and $q_t \equiv (\nabla\hat{\theta}_t^1, \nabla\hat{\theta}_t^2, \nabla\hat{\gamma}_t^1, \nabla\hat{\gamma}_t^2, \nabla\sigma_t^1, \nabla\sigma_t^2)'$. $\nabla\alpha_t \equiv (\alpha_t - \alpha)/\alpha$ denotes the relative deviation of variable α_t from its value in the deterministic steady state around which the linearization is taken (α).[5]

[4] See, e.g., Obstfeld and Rogoff (1996, ch. 5) and Kollmann (1995), for derivations of this fundamental risk sharing condition. Eq. (13) holds as intertemporal marginal rates of substitution are equated across countries, and that for all possible states of the world, when complete asset markets exist: $\beta u_{t+1}^{1,}/u_t^{1,} = \beta u_{t+1}^{2,}/u_t^{2,}$. In the bonds-only world, marginal rates of substitution are merely equated in expected value: $\beta E_t u_{t+1}^{1,}/u_t^{1,} = \beta E_t u_{t+1}^{2,}/u_t^{2,}$ (as Eq. (11a) holds for $i = 1,2$ in equilibrium).

the deterministic steady state around which the linearization is taken (α).[5] $\mathcal{G}$, $\mathcal{H}$, $\mathcal{J}$, $\mathcal{S}$, $\mathcal{Q}$ and $\mathcal{R}$ are matrices. The first six elements of the vector h_t and the first four elements of w_t are predetermined at date t (i.e. they are known at $t-1$), while the remaining elements are non-predetermined. The simulations assume that the forcing variables (q_t) are AR(1) processes. Under this assumption, the solutions of Eq. (14) are of the following form (see Blanchard and Kahn, 1980):

$$Q_t = \mathcal{K}_0 Q_{t-1} + \mathcal{K}_1 q_{t-1}, \quad P_t = \mathcal{F}_0 Q_t + \mathcal{F}_1 q_t, \tag{15}$$

where Q_t is the vector of variables that are predetermined at date t, while P_t is the vector of non-predetermined endogenous variables ($\mathcal{K}_0$, $\mathcal{K}_1$, $\mathcal{F}_0$ and $\mathcal{F}_1$ are matrices). The trade balance and other variables of interest are functions of Q_t and P_t and can be computed easily once one has solved for Q_t and P_t.

3.5. Parameters

3.5.1. Technology and preference parameters, growth rates

The technology parameter η is set at $\eta = 0.75$ (see Section 2 for a discussion of that value). Aggregate data indicate a capital depreciation rate of approx. 2.5% per quarter, and hence $d = 0.025$ is used. The steady state real interest rate is set at $r = 0.01$, a value close to the long run average real return on capital. These (or very similar) values of η, d and of r are generally used in RBC models. The adjustment cost parameter Φ (see Eq. (6)) is set at $\Phi = 3$, in order to match the variability of net exports seen in the data (for lower values of ϕ, the simulated net exports series are excessively volatile). The second parameter of the adjustment cost function (ϑ) is selected in such a way that, in deterministic steady state, adjustment costs are zero; this requires $\vartheta = g_X$ (recall that $g_X \equiv X_{t+1}^i/X_t^i$). In the model, the steady state growth factor of output is g_X; $g_X = 1.0061$ is assumed (1.0061 is the average quarterly growth factor of total G7 output during the sample period, 1975:Q1–1991:Q3).

The relative risk aversion coefficient is set at $\sigma = 2$. This value lies in the range of risk aversion coefficients usually assumed in RBC studies (Friend and Blume (1975) present empirical evidence suggesting that σ is in the range of 2). β is set at $\beta = 1.0022$, as $(1+r)\beta g_X^{-\sigma} = 1$ holds in steady state (N.B. despite $\beta > 1$, the representative agents' lifetime utility Eq. (1) is finite, as $\beta g_X^{1-\sigma} < 1$ holds, i.e. the agents' decision problem is well behaved).

3.5.2. Fiscal policy parameters

The model is linearized around a deterministic steady state in which the share of government purchases in output is 0.15, which is close to the average value of the government consumption-to-GDP ratio in the US (16%) and the G6 (14%) during the sample period. It is also assumed that, in steady state, the stock of government

[5] To allow for cases where steady state net private asset holdings ($\hat{A}^i$) and government debt ($\hat{D}^i$) are zero, $\nabla\hat{A}_t^i$, $\nabla\hat{D}_t^i$ are defined as $\nabla\hat{A}_t^i \equiv \hat{A}_t^i - \hat{A}^i$, $\nabla\hat{D}_t^i \equiv \hat{D}_t^i - \hat{D}^i$.

Table 1
Augmented Dickey–Fuller unit root tests

	$k = 0$	$k = 1$	$k = 2$	$k = 3$	$k = 4$	$k = 5$
(a) US and G6 forcing variables						
US productivity	−1.31	−1.76	−1.89	−2.03	−2.23	−2.27
G6 productivity	−1.62	−1.76	−1.50	−1.48	−1.74	−1.95
US govt. consumption	−1.13	−1.30	−1.24	−1.70	−2.29	−2.27
G6 govt. consumption	−2.62‡	−2.27	−2.09	−1.53	−1.89	−1.69
US tax rate	−2.24	−2.30	−2.27	−2.34	−1.82	−1.85
G6 tax rate	−4.71**	−3.68*	−3.53*	−2.82§	−2.68‡	−2.87§
(b) US–G6 differentials						
US–G6 productivity	−1.53	−1.80	−1.74	−1.99	−2.07	−2.25
US–G6 govt. consumption	−1.49	−1.59	−1.56	−1.50	−2.01	−1.95
US–G6 tax rate	−2.79‡	−2.76‡	−2.59	−2.56	−2.24	−2.36

Notes: ADF test statistics based on the following regression are reported: $\Delta x_t = \alpha_0 + \alpha_T t + \alpha_2 x_{t-1} + \Sigma_{s=1}^{s=k} \varphi_s \Delta x_{t-s} + u_t$, where $\Delta x_t \equiv x_t - x_{t-1}$, and k is the number of lagged Δx terms included on the right-hand side of this regression. The ADF test statistic is the studentized value of the OLS estimate of α_2. In Panel (a), the ADF test is applied to each of the six forcing variables (productivity and government purchases are logged); in Panel (b), the ADF test is applied to US–G6 differences of (logged) productivity, of (logged) government consumption, and of the tax rate. The time series used for these tests are those shown in Fig. 1 (1975:Q1–1991:Q3).
**, *, †, §, ‡: Rejection of unit root hypothesis at 1, 5, 10, 20 and 50%, respectively.

debt is zero (this assumption is made because governments in the G7 countries own large stocks of capital — the simulation results are not sensitive to this particular choice for steady state government debt). Given these values, the government budget constraint implies that the steady state tax rate equals 18% (which is close to the mean value of the US and G6 average tax rates during the sample period: 19%). The fiscal policy parameters μ_G and μ_T are set at $\mu_G = \mu_T = 0.005$ (the aim in setting μ_G and μ_T is to use values that are numerically 'small' and that ensure that the government debt to output ratio D_t^i/Y_t^i is non-explosive in equilibrium; the latter ensures that government Ponzi schemes are ruled out, as the steady state growth factor of output is smaller than the gross interest rate; N.B. $\mathcal{g}_X < 1 + r$).

3.5.3. Forcing variables

The graphs in Fig. 1 suggest that US and G6 productivity, government consumption and tax rates are highly serially correlated. Table 1 presents Augmented Dickey–Fuller (ADF) unit root tests for these six variables. The results yield little evidence against the unit root hypothesis.[6] Table 1 tests also whether the difference between US and G6 productivity, as well as the US–G6 differences in

[6]A possible exception is the G6 tax rate. For lag lengths $k = 0,1,2$ the ADF test statistic yields strong evidence against the unit root hypothesis; it appears, however, that for $k \geq 3$, there is little evidence against this hypothesis.

Table 2
Phillips and Ouliaris cointegration tests

	(1)	(2)	(3)	(4)	(5)	(6)
$\hat{Z}_\alpha$ statistic	−18.65	−20.82	−16.18	−30.60‡	−14.62	−25.09
$\hat{Z}_t$ statistic	−3.79‡	−3.62	−3.05	−4.20‡	−3.33	−5.01†

Notes: Phillips and Ouliaris (1990) $\hat{Z}_\alpha$ and $\hat{Z}_t$ test statistics are reported for the set of six forcing variables considered in the paper. These tests set up the null hypothesis that the set of variables is not cointegrated. The $\hat{Z}_\alpha$ and $\hat{Z}_t$ statistics labelled (1) use US productivity as the left-hand side variable in the cointegrating regressions used to compute these statistics (see Phillips and Ouliaris, 1990). The columns labelled (2)–(6) use G6 productivity, US government consumption, G6 government consumption, the US tax rate and the G6 tax rate, respectively, as left-hand side variables. A linear time trend was included in all cointegrating regressions. The Newey–West method (allowing for 10 autocorrelations) was used to correct for serial correlation in the residual of the cointegrating regressions. The time series used for the tests are those shown in Fig. 1 (1975:Q1–1991:Q3). Productivity and government purchases are used in logs.
**, *, †, §, ‡: Rejection of null of no cointegration at 1, 5, 10, 20 and 50% levels, respectively.

government consumption and in tax rates, have a unit root. For these US–G6 differentials, the unit root hypothesis fails likewise to be rejected. Table 2 reports Phillips and Ouliaris (1990) test statistics that suggest that the six forcing variables are not cointegrated. This implies that these series can be modeled as a vector autoregression (VAR) in first differences (see Campbell and Perron, 1991, p. 170). Estimation results for a six-variable VAR in first differences are reported in Table 3. The autoregressive coefficients are almost all statistically insignificant, at conventional significance levels. The results here suggest, hence, that shifts in the forcing variables (and in the cross-country differences of these variables) are permanent and that there are little or no 'spillovers' between these forcing variables.

The baseline case assumes, thus, that the six forcing variables are random walks:

$$q_t = q_{t-1} + \zeta_t,$$

where $q_t \equiv (\nabla\hat{\theta}_t^1, \nabla\hat{\theta}_t^2, \nabla\hat{\gamma}_t^1, \nabla\hat{\gamma}_t^2, \nabla\sigma_t^1, \nabla\sigma_t^2)'$ is the vector of exogenous variables in the linearized version of the model (see Eq. (14) and Eq. (15)), while ζ_t is a vector of white noises.[7]

4. Simulations

4.1. Impulse response functions

Figs. 2 and 3 show impulse responses functions for the incomplete and the

[7]Using the estimated coefficients of the VAR in Table 3 to simulate the model yields results that are very similar to those that are obtained when the forcing variables are random walks.

Table 3
Six-variable VAR fitted to forcing variables (in first-differences)

$\hat{\text{RHO}} =$

0.21	−0.04	0.24*	0.05	−0.02	−0.63†
(0.13)	*(0.16)*	*(0.11)*	*(0.11)*	*(0.19)*	*(0.33)*
0.02	−0.04	0.14	0.06	−0.18	−0.15
(0.10)	*(0.13)*	*(0.09)*	*(0.09)*	*(0.16)*	*(0.28)*
0.12	0.00	0.03	0.00	0.02	−0.42
(0.16)	*(0.21)*	*(0.14)*	*(0.14)*	*(0.25)*	*(0.43)*
−0.17	0.12	0.00	−0.32**	−0.54**	0.15
(0.14)	*(0.17)*	*(0.12)*	*(0.12)*	*(0.20)*	*(0.36)*
−0.01	0.13	0.01	0.07	0.00	0.26
(0.08)	*(0.11)*	*(0.07)*	*(0.07)*	*(0.13)*	(0.22)
−0.04	0.12	0.01	−0.01	−0.06	−0.09
(0.04)	*(0.05)*	*(0.04)*	*(0.04)*	*(0.07)*	*(0.12)*

Notes: Let $z_t \equiv (\Delta\ln(\theta_t^{US}), \Delta\ln(\theta_t^{G6}), \Delta\ln(G_t^{US}), \Delta\ln(G_t^{G6}), \Delta s_t^{US}, \Delta s_t^{G6})'$, where θ_t^i, G_t^i, s_t^i are productivity, government consumption and the tax rate, for i = US, G6, respectively (N.B. $\Delta x_t \equiv x_t - x_{t-1}$). The following model is fitted to the time series shown in Fig. 1 (1975:Q1–1991:Q3): $z_t = b + \text{RHO}\, z_{t-1} + \varepsilon_t$, where b is a column vector and RHO a matrix. The table reports OLS estimates of the elements of RHO (standard deviations in parentheses).
**, *, †: Significant at 1, 5 and 10%, respectively.

complete markets versions of the model, respectively. The following shocks are considered: a permanent 1% increase in country 1 productivity (θ^1), a permanent 1% increase in country 1 autonomous government purchases (γ^1) and a permanent one percentage point reduction in the autonomous component of the country 1 tax rate (σ^1). The figures show the responses of net exports, output, consumption, investment and government purchases (in countries 1 and 2) to these shocks (note that country i net exports are $Y_t^i - C_t^i - I_t^i - G_t^i$). The responses of all variables are expressed as percentages of the value of output in the steady state around which the model is linearized (initially, the system is assumed to be in that steady state).

The simulations show that the responses of output and investment to exogenous shocks are identical across the two asset market structures;[8] differences in the behavior of net exports across these asset structures are thus entirely due to differences in consumption behavior.

[8] Kollmann (1991) shows that this is due to the fact that labor supplies are inelastic in the model here. Fixed labor supplies are assumed merely to simplify the presentation. With variable labor supplies, the responses of labor would differ across asset structures, and hence output and investment behavior would differ too. However, assuming variable labor would not affect the key predictions concerning the behavior of net exports (simulation results for a version of the model with variable labor are available from the author).

4.1.1. Response to permanent increase in country 1 productivity

In both asset market structures, a permanent rise in country 1 productivity raises worldwide consumption. It induces a rise in country 1 investment and output, but it has only a relatively small impact on output and investment in country 2. The productivity shock induces a rise in country 1 net exports when asset markets are complete and a fall when markets are incomplete.

To understand this difference in the response of net exports across asset market structure, note that with *complete markets* consumption in both countries rises by the same amount. As output, investment (and government purchases) change relatively little in country 2, that country's net exports fall — country 1 net exports rise, hence, when markets are complete. Intuitively, complete international sharing implies that resources are transferred from the country that experiences a favorable productivity shock to the other country — thus, the net exports of the country that receives the shock rise.

When asset markets are *incomplete*, then country 1 consumption rises much more strongly than when complete markets exist, while consumption falls in country 2.[9] Intuitively, the reason why country 1 consumption increases more strongly in the bonds-only structure is that a productivity increase in country 1 raises that country's wealth more strongly when asset markets are incomplete (than when complete markets exist), as the elimination of trade in state-contingent assets restricts international risk sharing.[10] The much stronger rise of country 1 consumption explains why country 1 net exports fall, on impact, in the bonds-only structure. Note that country 1 output continues to rise *after* the permanent productivity shock has occurred, as that shock induces a long run rise in the country 1 capital stock — gross investment in country 1 rises, on impact, and it decreases gradually thereafter. The 'cash flow' that is at the disposal of the country 1 household, in the *bonds-only structure* (country 1 output minus taxes minus gross investment; see the budget constraint Eq. (10)) is thus larger in the long run than in the current period; the household's consumption smoothing motive thus induces it to reduce its net financial asset position — hence, the current account of country 1 deteriorates and its net exports fall, in the bonds-only structure.

4.1.2. Fiscal policy shocks

A reduction in the tax rate of country 1 increases private sector wealth and the after-tax marginal product of capital, in that country. This raises the consumption

[9] The world interest rate (not shown in Fig. 2) rises as a result of a permanent productivity shock, which induces country 2 to lower its current consumption.

[10] King (1990) has presented a method for decomposing the responses of consumption to an exogenous shock into 'Hicksian' wealth and intertemporal substitution effects. The working paper version of the paper (available from the author) applies that method and shows that the much stronger response of country 1 consumption to a permanent rise in country 1 productivity, when markets are incomplete, is due to the fact that the (Hicksian) wealth effect of the shock on country 1 consumption is much stronger, in that asset structure (than when markets are complete).

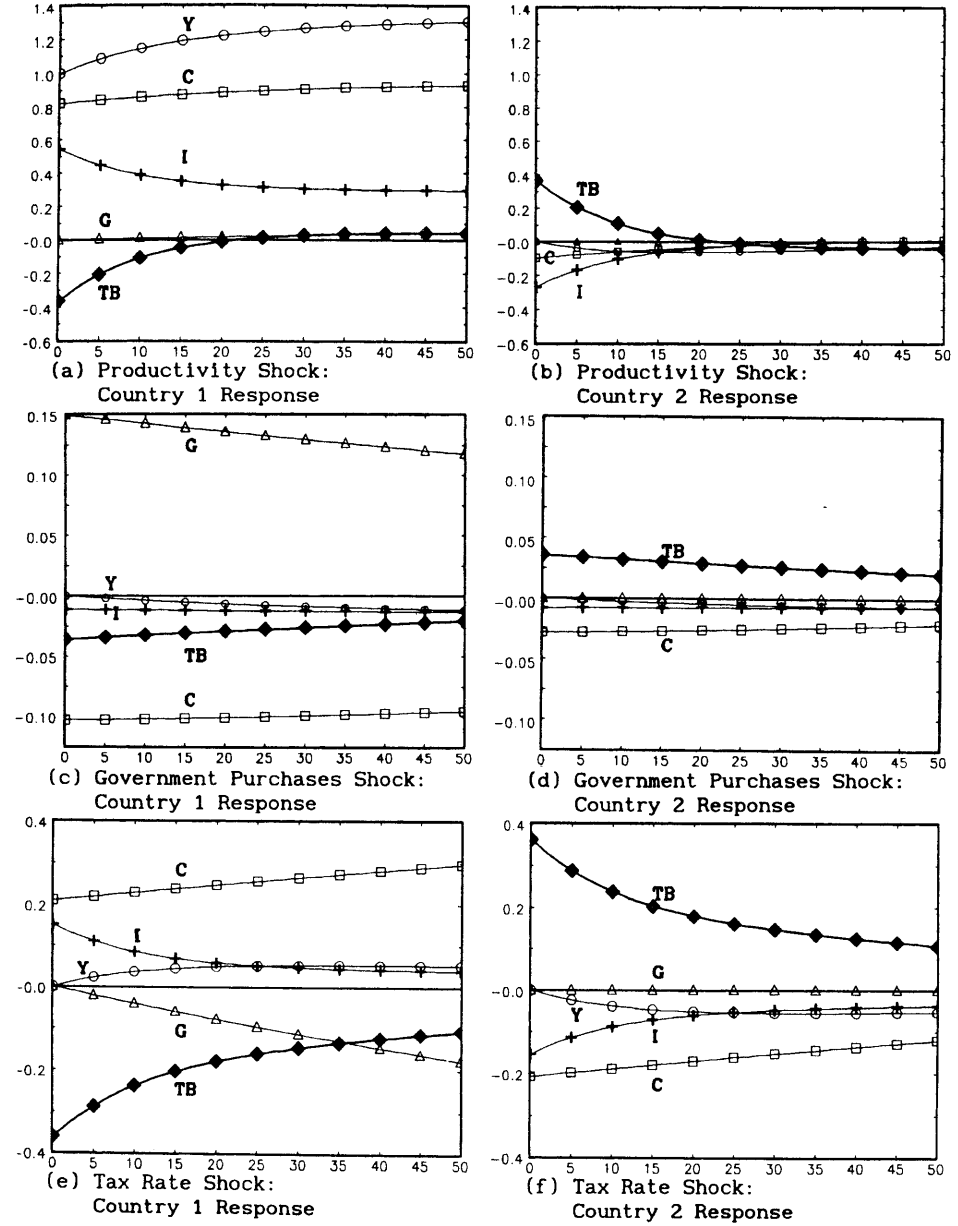


Fig. 2. Incomplete asset markets: effects of permanent shocks.
Responses to permanent 1% rise in country 1 productivity and in country 1 autonomous government purchases, and to permanent one percentage point drop in autonomous component of country 1 tax rate. Responses are expressed as percentage of steady state output. Abscissa: quarters after shock. ○: output (Y); □: private consumption (C); △: government purchases (G); +: gross investment (I); ◆: net exports (TB).

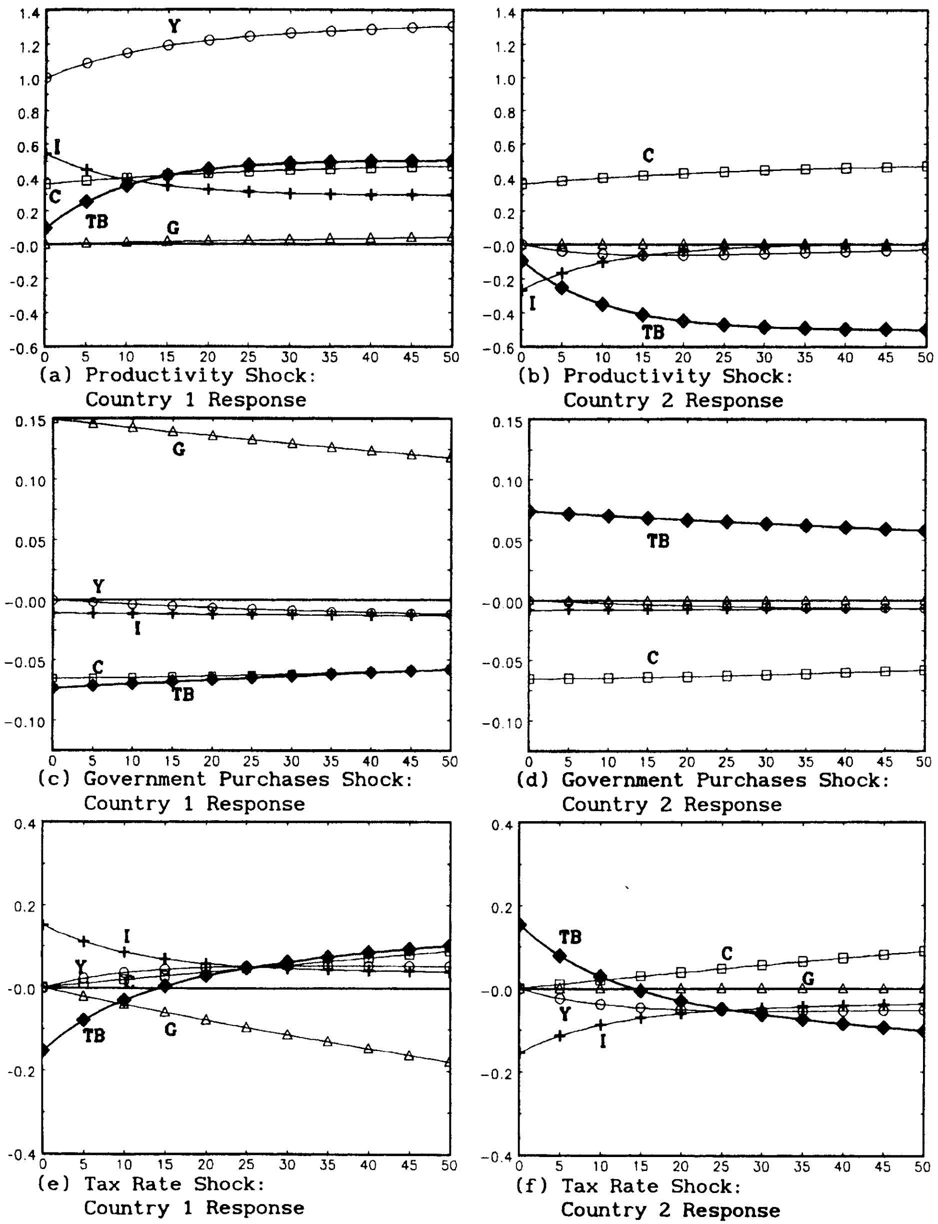


Fig. 3. Complete asset markets: effects of permanent shocks.
Responses to permanent 1% rise in country 1 productivity and in country 1 autonomous government purchases, and to permanent one percentage point drop in autonomous component of country 1 tax rate. Responses are expressed as percentage of steady state output. Abscissa: quarters after shock. ○: output (Y); □: private consumption (C); △: government purchases (G); +: gross investment (I); ◆: net exports (TB).

and investment of country 1 (in contrast, the tax cut does not affect country 1 output, on impact). Therefore country 1 net exports fall. This logic holds for both asset structures.

A rise in government purchases in country 1 has only a relatively weak effect on output and investment in the two countries and, hence, is accompanied by a reduction in world consumption. When markets are *complete*, consumption falls in both countries and, thus, country 2 net exports rise — in other words, country 1 net exports fall. When asset markets are *incomplete*, consumption in country 1 drops much more strongly than when complete markets exist; as a result, country 1 net exports fall less strongly when markets are incomplete.[11]

4.2. Simulations based on observed productivity, government purchases and tax rate series

Figs. 4–6 show simulated time series that are generated when empirical measures of the exogenous variables $\nabla\hat{\theta}_t^i$, $\nabla\hat{\gamma}_t^i$ and $\nabla\sigma_t^i$ for the US and the G6 are fed into the model (Eq. (15)). The sample period considered in this simulation exercise is 1975:Q1–1991:Q3. Actual US and G6 government consumption and average tax rates are used as empirical counterparts of autonomous government purchases (γ_t^i) and of the autonomous component of the tax rate (σ_t^i), as no direct observations of these exogenous variables are available. (According to the model, government purchases and the tax rate are endogenous — see Eq. (8a) and Eq. (8b); it appears, however, that for low values of the fiscal policy parameters μ_G and μ_T, as used in the simulations, G_t^i is very closely correlated with γ_t^i; s_t^i and σ_t^i are also highly correlated).

Empirical counterparts for $\nabla\hat{\theta}_t^i$ and $\nabla\hat{\gamma}_t^i$ (for i = 1,2) are obtained by linearly detrending the productivity index $\ln(\theta_t^i)$ and logged government consumption (for the US and the G6). The empirical counterpart for $\nabla\sigma_t^i$ used in the simulations is the relative deviation of the period t tax rate in country i (i = US, G6) from the average tax rate observed during the sample period in that country.

4.2.1. Net exports: simulated responses to historical shocks

Figs. 4 and 5 show simulated US net exports series that obtain when historical US and G6 productivity, government purchases and tax rate series are fed into the model. The predicted and the actual net export series are both expressed as shares of output.[12] Panels (c)–(h) in these figures present simulations in which the model is subjected to each of the six forcing variables separately; in Panel (b), US and G6 productivity series are *simultaneously* fed into the model, while Panel (a) shows simulated US net exports that obtain when all six forcing variables are *simultaneously* fed into the model.

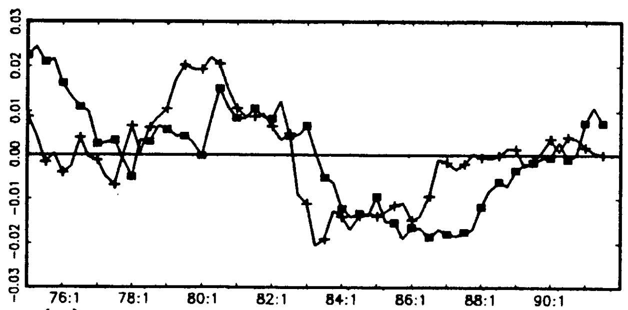
4.2.1.1. Simulated response to historical productivity shocks. Feeding just the historical US *productivity series* into the incomplete markets structure yields a simulated net exports series that captures the major changes in US net exports during the sample period [see Panel (c), Fig. 4]. This success in matching the net exports data is due to the fact that net exports are predicted to respond negatively to permanent productivity shocks, in the bonds-only structure (see discussion in Section 4.1.1). This enables the incomplete markets structure to capture the fact that, empirically, US net exports and US productivity co-move negatively (see Section 2; the correlation between the simulated US net exports series shown in Panel (c) of Fig. 4 and the historical US *productivity* series is −0.80); for example, the strong growth in US productivity during the first half of the 1980s (see Fig. 1) induces a strong contemporaneous decline in simulated net exports, which is consistent with the fall in actual US net exports during the early 1980s. As discussed in Section 4.1.1, net exports respond positively to permanent productivity shocks, when asset markets are complete. Thus, the simulated net exports series that is generated when the historical US productivity series is fed into the complete markets structure (Panel (c), Fig. 5) bears little resemblance to actual US net exports.

When just the historical G6 productivity series are fed into the theoretical structure, then simulated net exports are negatively correlated with actual US net exports — this is the case for both asset market structures (see Panel (d) in Figs. 4 and 5). However, the simulated net exports series that is generated when US and G6 productivity series are *simultaneously* fed into the incomplete markets structure (Panel (b), Fig. 4) still matches relatively well the major fluctuations of historical US net exports — the effect of US productivity shocks on the US trade balance dominates, thus, that of G6 productivity shocks (this is due to the fact that the (detrended) US productivity series that are fed into the model fluctuate more widely than the G6 productivity series, as was noted in Section 2).

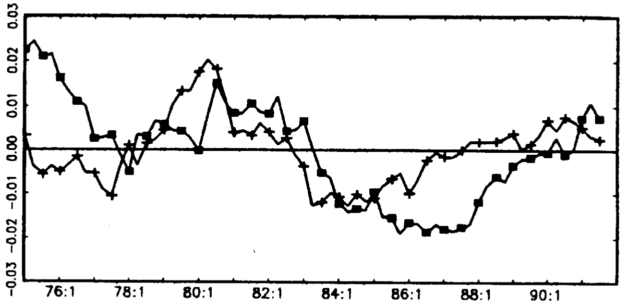
4.2.1.2. Simulated response to historical fiscal policy shocks. Figs. 4 and 5 suggest that fiscal policy changes were less important sources of fluctuations in US net exports than productivity shocks.

[11] A more detailed discussion of the effects of shocks to *autonomous* government purchases (γ^1) can be found in the working paper version of this paper. A permanent rise in γ^1 raises country 1 government purchases (G^1) one-to-one, on impact. Because this shock raises country 1 government debt, government purchases decrease in subsequent periods (cf. the policy rule Eq. (8a); N.B. $\mu_G > 0$), as can be seen in Panel (c) of Figs. 2 and 3. The prediction that country 1 net exports *fall* (in response to the γ^1 shock), when asset markets are *incomplete*, is due to the fact that the rise in G^1 is partly transitory — this explains why the increase in γ^1 induces a fall in country 1 consumption that is sensibly smaller than the rise in government purchases (which results in the fall in country 1 net exports).

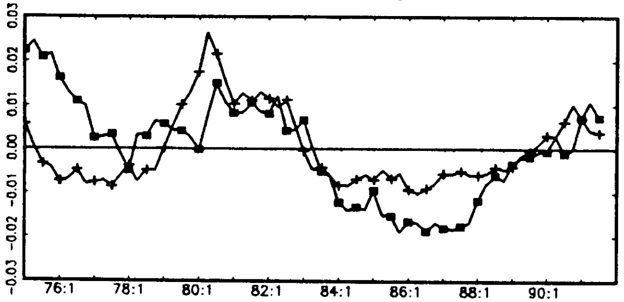
[12] Since, by construction, the (detrended) forcing variables that are fed into the model have a sample mean of zero, the simulated net exports series have a sample mean that is close to zero. In constrast, the sample average of US net exports (expressed as a share of US GDP) is −1.38%. Therefore the simulated and the historical net exports series are presented in de-meaned form in Figs. 4 and 5. The mean of the simulated trade balance series could be set to a non-zero value (without greatly affecting the response of the trade balance to shocks) by assuming that steady state net foreign asset positions of the two countries are non-zero (N.B. as described above, the model is linearized around a symmetric deterministic steady state; net foreign asset positions are zero in that steady state).



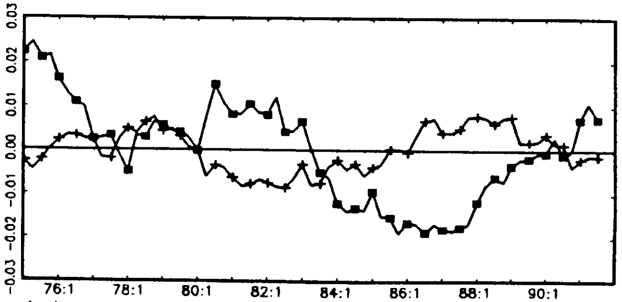
(a) U.S. and G6 Productivity, Govt. Purchases and Tax Rate Shocks



(b) U.S. & G6 Productivity Shocks

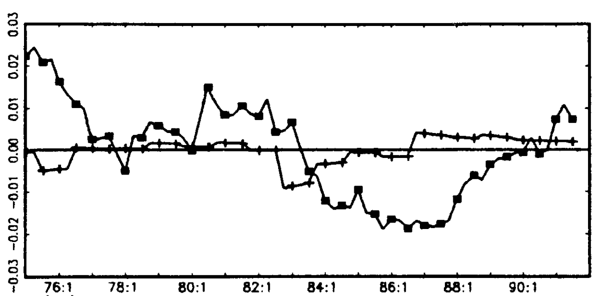


(c) U.S. Productivity Shocks

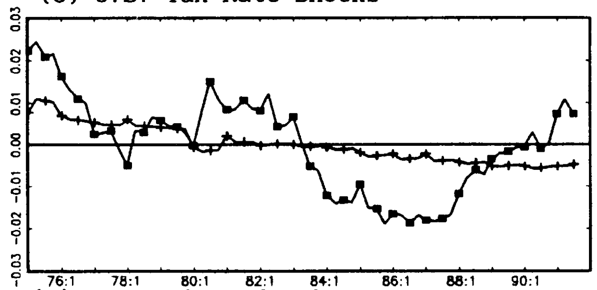


(d) G6 Productivity Shocks

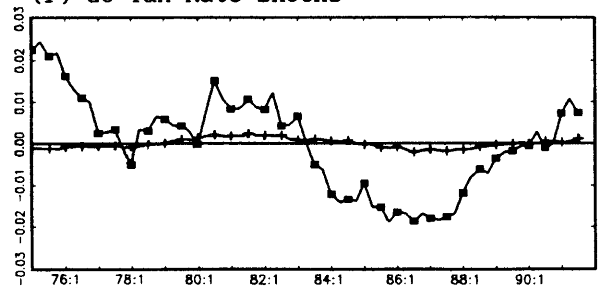
Fig. 4 (a)–(d).



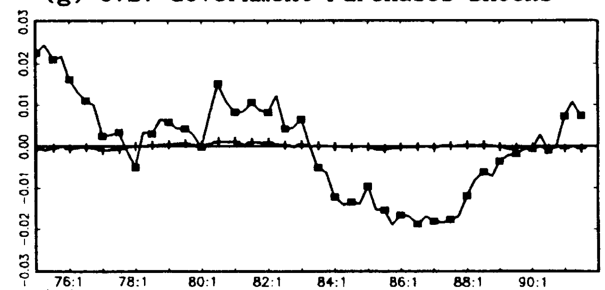
(e) U.S. Tax Rate Shocks



(f) G6 Tax Rate Shocks

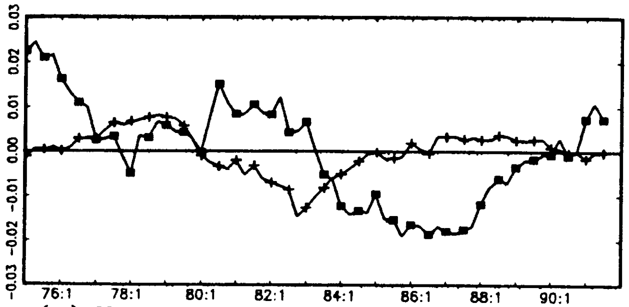


(g) U.S. Government Purchases Shocks

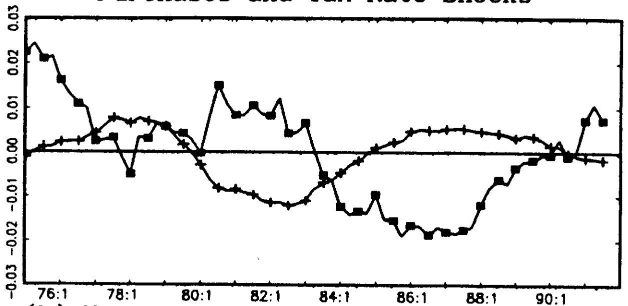


(h) G6 Government Purchases Shocks

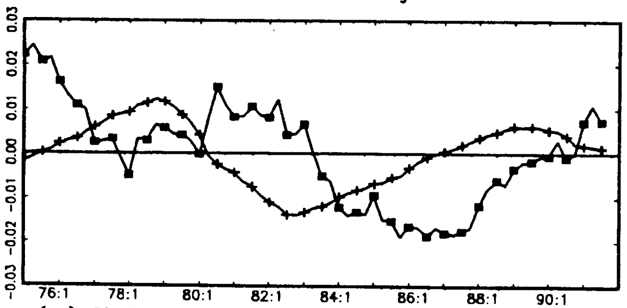
Fig. 4. Incomplete asset markets (forcing variables assumed to follow random walks): simulated US net exports (as share of output).
Model subjected to actual US and G6 productivity, government purchases and tax rate series. Panel (a): Six forcing variables fed simultaneously into the model. Panel (b): US and G6 productivity series used simultaneously. Panels (c)–(h): Each of the six forcing variables used separately. ■: Data (1975:Q1–1991:Q3); +: simulation. All series in the Figure are de-meaned.



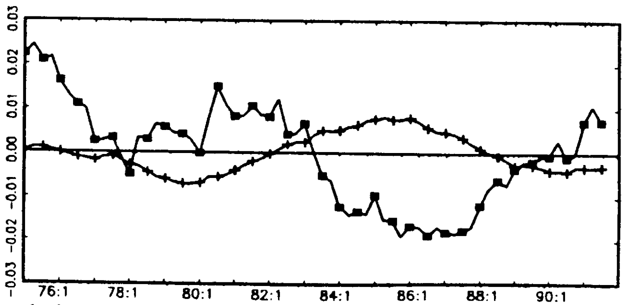
(a) U.S. and G6 Productivity, Govt. Purchases and Tax Rate Shocks



(b) U.S. & G6 Productivity Shocks

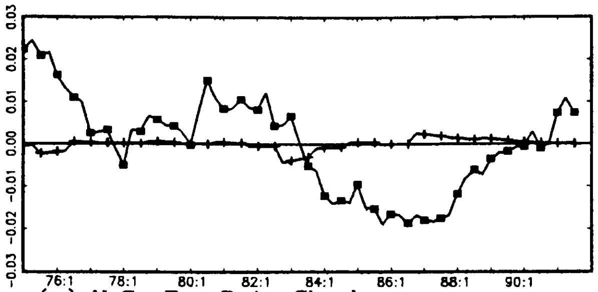


(c) U.S. Productivity Shocks

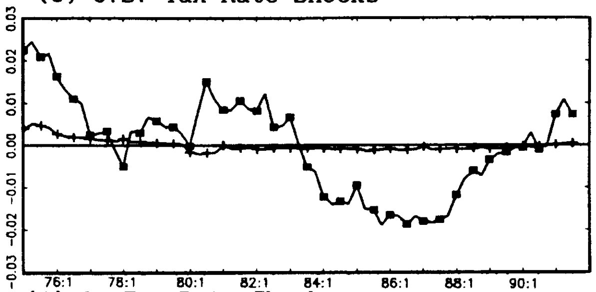


(d) G6 Productivity Shocks

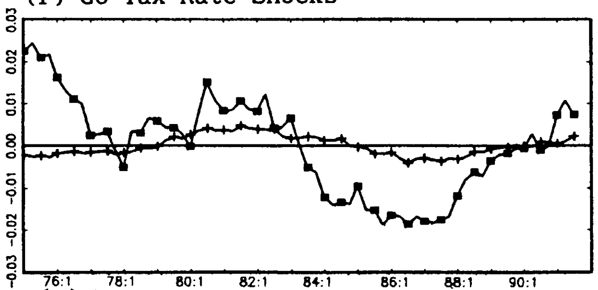
Fig. 5 (a)–(d).



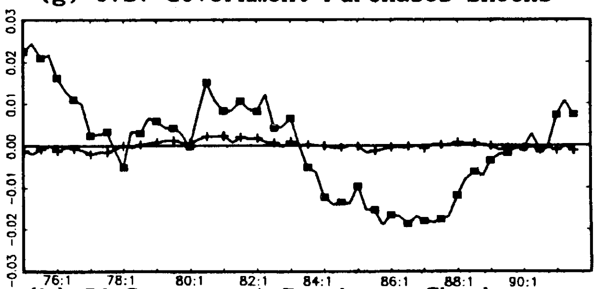
(e) U.S. Tax Rate Shocks



(f) G6 Tax Rate Shocks



(g) U.S. Government Purchases Shocks



(h) G6 Government Purchases Shocks

Fig. 5. Complete asset markets (forcing variable assumed to follow random walks): simulated US net exports (as share of output).
Model subjected to actual US and G6 productivity, government purchases and tax rate series. Panel (a): Six forcing variables fed simultaneously into the model. Panel (b): US and G6 productivity series used simultaneously. Panels (c)–(h): Each of the six forcing variables used separately. ■: Data (1975:Q1–1991:Q3); +: simulation. All series in the Figure are de-meaned.

Feeding the *historical government purchases* series into the model generates trade balance series that are positively correlated with the observed US trade balance series (for both asset market structures), but the variability of the simulated series is much too small compared to the data (see Panels (g)–(h) in Figs. 4 and 5).[13]

Simulations of the incomplete markets structure that use *actual tax rates* as the only source of shocks (Panels (e),(f) in Fig. 4) suggest that tax changes had a non-negligible impact on US net exports (in contrast, when markets are complete, the simulated response to historical tax changes is very weak). According to the incomplete markets structure, the drop in the US average tax rate by approx. 2.5 percentage points that occurred in 1982 led to a drop in US net exports by roughly 1% of GDP. However, US tax changes do not explain the persistence of low US net exports during the second half of the 1980s: the strong rise in the US tax rate in 1986 induces a sharp rise in the simulated US net exports series. The incomplete markets structure suggests, in contrast, that the continual rise in G6 tax rates has contributed to the persistent decline in US net exports during the sample period (see Panel (f), Fig. 4).

4.2.1.3. Combined effect of six forcing variables. Simultaneously feeding all six forcing variables into the incomplete markets structure generates a simulated net exports series that tracks the actual behavior of US net exports fairly closely, as can be seen in Panel (a) of Fig. 4 (in contrast, the corresponding simulated series generated by the complete markets structure is *negatively* correlated with actual net exports; see Panel (a) in Fig. 5).[14] A shortcoming of the incomplete markets structure is that it does not fully account for the persistence of the US trade balance deficit — after reaching a trough in the mid-1980s, the simulated US net exports series rises sharply in 1986, whereas actual US net exports start to rise only in 1988. Note also that the simulated net exports series that is generated when all six forcing variables are used simultaneously resembles rather closely the simulated series that is generated when just US productivity shocks are fed into the model. This clearly suggests that US productivity shocks were the major force behind the fluctuations in the US trade balance during the sample period.

4.2.2. Other aggregates: simulated effect of historical shocks

Fig. 6 plots actual (linearly detrended) output, consumption and investment series for the US and the G6, as well as the simulated series for these variables that obtain when the complete and the incomplete asset market versions of the

[13] Yi (1993) has recently used a dynamic two-country general equilibrium model with complete markets to investigate whether government purchases can explain the US net export deficits of the 1980s (in contrast to the paper here, Yi considers an endowment economy and he assumes lump sum taxes). Overall, the results of Yi suggest that government purchases explain a relatively small fraction of actual US trade balance movements, which parallels the finding reached here.

[14] The correlation between simulated and actual US net exports (expressed as a share of US output) is 0.52 when incomplete markets are assumed (and all six forcing variables simultaneously fed into the model). When complete markets are assumed, the corresponding correlation is −0.12.

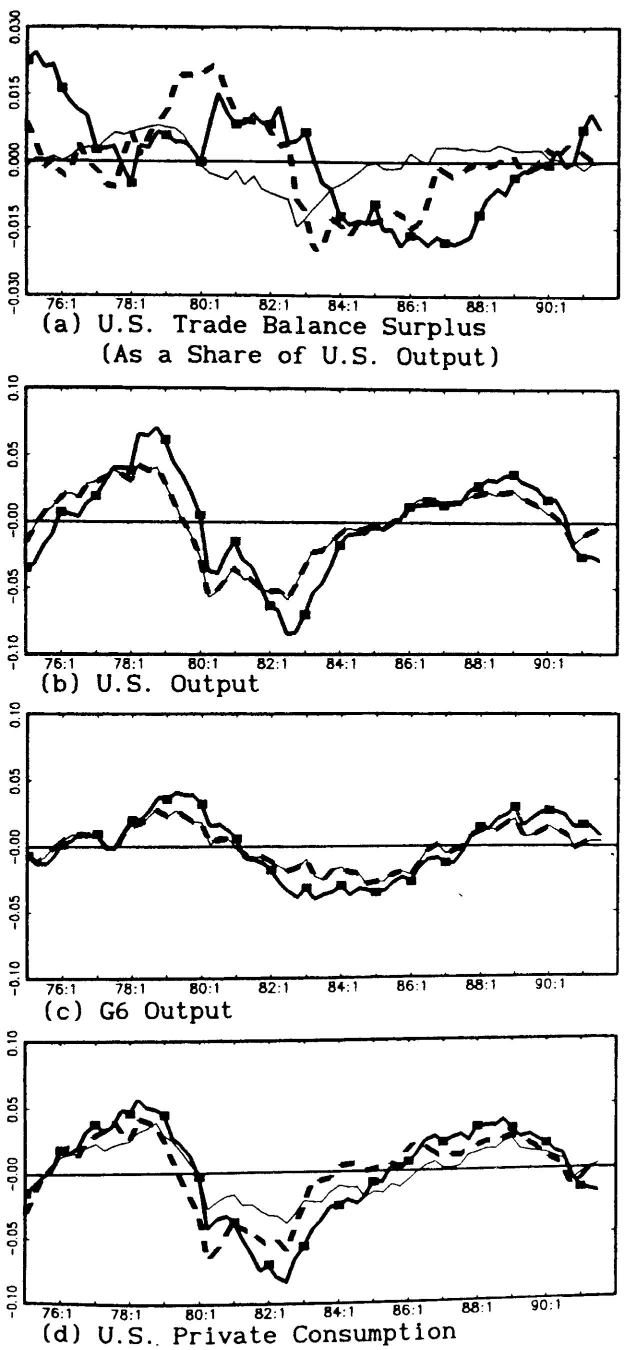


Fig. 6 (a)–(d).

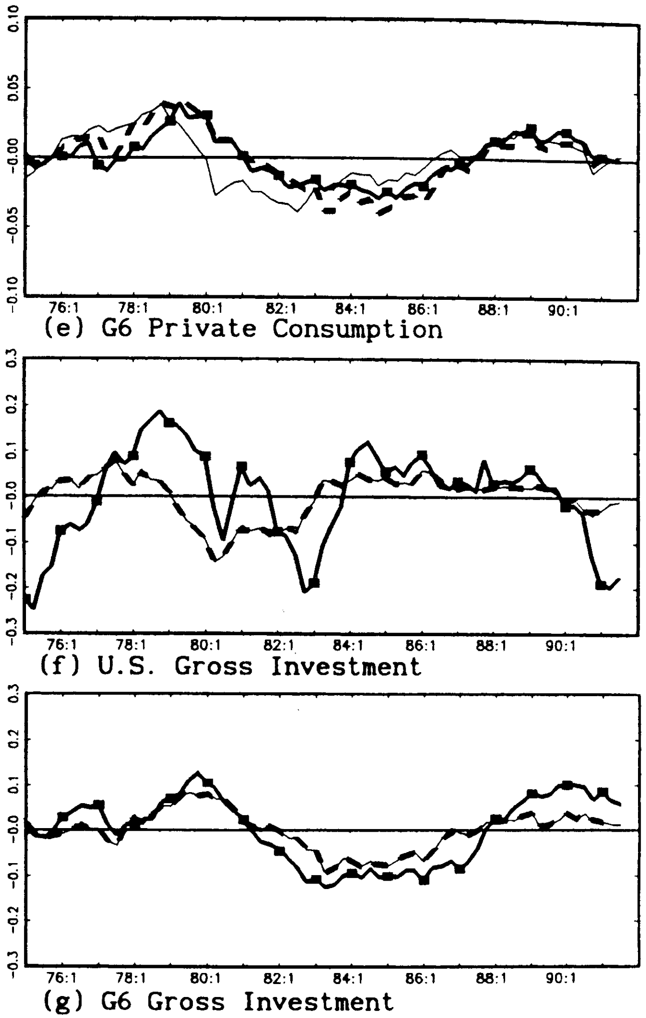


Fig. 6. (In)complete asset markets (forcing variables assumed to follow random walks): simulated net exports (as share of output), output, consumption and investment.
Model subjected to actual US and G6 productivity, government purchases and tax rate series (six forcing variables fed simultaneously into the model). ■: Data (1975:Q1–1991:Q3); ■ ■ ■: simulated path, incomplete markets structure; ———, simulated path, complete markets sturcture. Consumption, investment and output data (in logs) are linearly detrended (predicted series for these variables expressed as relative deviations compared to deterministic steady state). Net exports series (Panel (a)) are de-meaned. N.B. simulated output and investment series are identical across asset structures.

model are simultaneously subjected to the historical productivity, government consumption and tax rate series. The model explains relatively well the behavior of actual US and G6 output; however, it matches less closely the observed investment series — although it captures most of the major swings in that variable (note that

the simulated output and investment series are identical across the two asset market structures; see the discussion regarding this in Section 4.1.).

The incomplete markets structure matches more closely the actual US and G6 consumption series than the complete markets structure (N.B. in the latter, the simulated consumption series are perfectly correlated across countries). Note, in particular, that the incomplete markets structure explains much better the strong idiosyncratic growth in US consumption during the 1982–1988 period that was associated with the rapid rise in US productivity and output during that period — this explains why the incomplete markets structure succeeds in capturing the strong drop in US net exports during the first half of the 1980s.

4.3. Sensitivity analysis

The key results concerning trade balance behavior that were just discussed are robust to changes in preference and technology parameters and to changes in the parameters of the fiscal policy rules (because of space constraints, no sensitivity analysis with respect to these parameters can be presented here; such an analysis is available from the author, upon request). It appears, however, that the predicted behavior of net exports is highly sensitive to changes in the assumed time-series process of *productivity*.

4.3.1. Sensitivity to assumed time-series process of productivity

The simulations so far have assumed that productivity in each country follows a random walk, which implies that the cross-country productivity difference is likewise a random walk. Section 3.5.3 showed that standard unit root tests fail to reject the hypothesis that productivity, as well as the cross-country productivity difference, follows a unit root process. However, as is well known, unit root tests have low power against the alternative hypothesis that the variable is (trend-) stationary but highly persistent (see, e.g. Campbell and Perron, 1991). It thus seems interesting to investigate whether the model predictions change when a stationary productivity process with an autocorrelation coefficient close to unity is assumed.

Fig. 7 shows impulse response functions for the case in which productivity follows an AR(1) process with an autocorrelation of 0.95:

$$\nabla\hat{\theta}_t^i = \rho\nabla\hat{\theta}_{t-1}^i + \varepsilon_t^i \quad \text{with } \rho = 0.95, \tag{16}$$

where ε_t^i is a white noise. A comparison with the baseline case in Figs. 2 and 3 (where $\rho = 1$ is assumed) shows that the response of consumption in country 1 to a productivity shock experienced by that country is much weaker when $\rho = 0.95$ is used. In contrast, the short run response of country 1 output and investment to a productivity shock is much less affected by the change in the persistence parameter ρ (note, e.g. that a 1% productivity increase raises output by 1%, on impact — i.e. that impact response does not depend on ρ). The explanation for the much weaker response of country 1 consumption (when $\rho = 0.95$) is that exogenous shocks have a much weaker effect on private sector wealth in country 1 when these shocks are

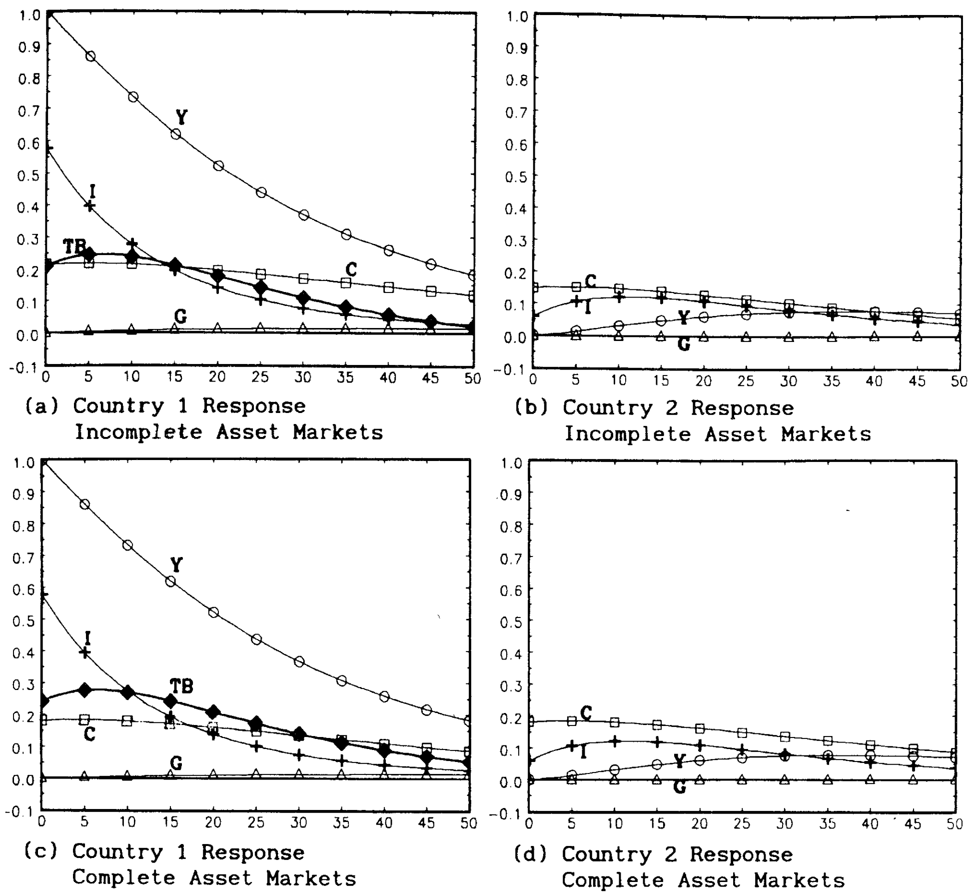


Fig. 7. (In)complete asset markets (autocorrelation of productivity: $\rho = 0.95$): responses to 1% shock to country 1 productivity.
Responses are expressed as percentage of the steady state output. Abscissa: quarters after shock. Panels (a),(b): Responses in incomplete asset markets structure. Panels (c),(d): Responses in complete markets structure. ○: Output (Y); □: private consumption (C); △: government purchases (G); +: gross investment (I); ◆: net exports (TB).

decaying at a rate of 5% per period ($\rho = 0.95$) than when the shocks are permanent ($\rho = 1$).[15] The weaker country 1 consumption response has important

[15] The consumption volatility literature has pointed out that, in life-cycle consumption models, the effects of income shocks on wealth (and, hence the response of consumption to these shocks) may be much stronger when these shocks are permanent than when the income shifts are non-permanent but highly persistent — see Deaton (1987) (the working paper version of this paper shows that the 'Hicksian' wealth effect, as defined in King (1990), of a country 1 productivity shock on country 1 consumption is 15 times smaller when $\rho = 0.95$ than when $\rho = 1$). Glick and Rogoff (1995) have recently noted that this implies that the predicted response of the trade balance to country-specific productivity shocks can be quite sensitive to changes in the persistence of these shocks (see discussion below). The sensitivity of the predictions of IRBC models to the persistence of shocks is also discussed in Baxter and Crucini (1995).

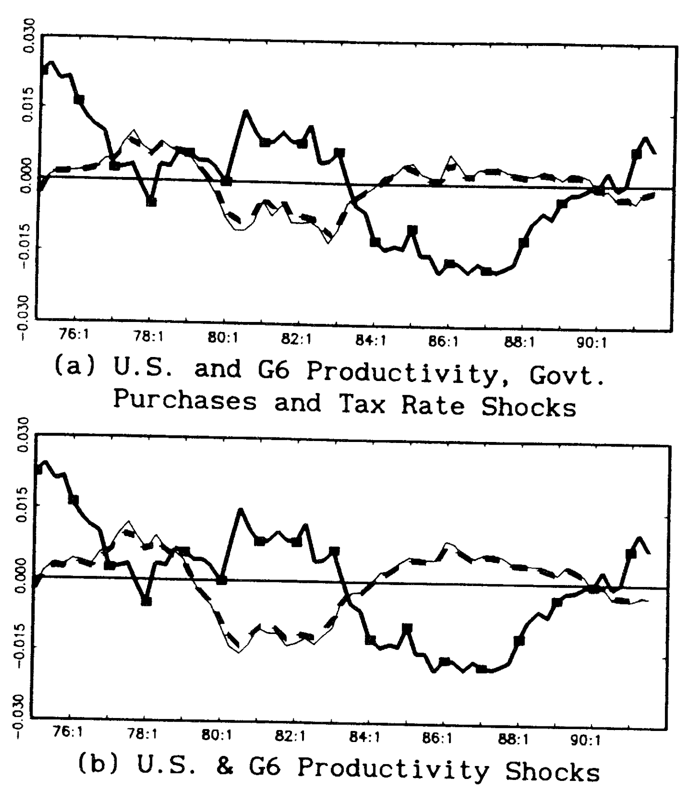


Fig. 8. (In)complete asset markets (autocorrelation of forcing variables: $\rho = 0.95$): simulated US net exports (as share of output).
Model subjected to actual US and G6 productivity, government purchases and tax rate series. Panel (a): Six forcing variables fed. ■: Data (1975:Q1–1991:Q3); ■ ■ ■: simulated net exports, incomplete markets structure; ——: simulated net exports, complete markets structure. All series in the figure are de-meaned.

consequences for the response of the trade balance to productivity shocks: note, in particular, that when $\rho = 0.95$ is assumed, then a productivity increase in country 1 triggers a *rise* in that country's net exports — this is so in *both* asset market structures.

This implies that when $\rho = 0.95$ is assumed, the incomplete markets structure cannot explain the observed behavior of US net exports — see Fig. 8 (feeding US and G6 productivity series into the incomplete markets structure generates simulated net exports series that are negatively correlated with actual US net exports; this holds also when all six forcing variables are used simultaneously).

Eq. (16) implies that productivity and the cross-country productivity difference are stationary. It seems interesting to also consider cases in which productivity in each country is non-stationary, but in which cross-country productivity *differences* are stationary (but highly persistent). The following process allows to capture situations of this type:

$$\nabla\hat{\theta}_t^1 = \xi\nabla\hat{\theta}_{t-1}^1 + \psi\nabla\hat{\theta}_{t-1}^2 + \varepsilon_t^1, \nabla\hat{\theta}_t^2 = \psi\nabla\hat{\theta}_{t-1}^1 + \xi\nabla\hat{\theta}_{t-1}^2 + \varepsilon_t^2, \quad (17)$$

where ε_t^1, ε_t^2 are white noises and ξ,ψ are parameters. Eq. (17) implies that the cross-country productivity differential is an AR(1) process with first-order autocorrelation coefficient $\xi - \psi$:

$$\nabla\hat{\theta}_t^1 - \nabla\hat{\theta}_t^2 = (\xi - \psi)\left(\nabla\hat{\theta}_{t-1}^1 - \nabla\hat{\theta}_{t-1}^2\right) + (\varepsilon_t^1 - \varepsilon_t^2).$$

When $\xi + \psi = 1$ and $|\xi - \psi| < 1$ holds, then productivity in each country has a unit root, but the cross-country productivity *differential* is stationary.

It appears that, in both asset market structures, the effect of productivity innovations (ε_t^1, ε_t^2) on net exports hinges on $\xi - \psi$, i.e. on the persistence of the cross-country productivity *differential*: combinations of ξ,ψ for which the difference $\xi - \psi$ is identical, generate the same response of net exports to productivity innovations. The response of net exports to productivity innovations depends, thus, on the effects of these innovations on the cross-country productivity differential (intuitively, idiosyncratic shocks — movements in productivity that are not common to the two countries — are critical for the behavior of net exports). This implies, for example, that when $\xi = 0.975$, $\psi = 0.025$ is assumed (autocorrelation of cross-country productivity differential of 0.95, but non-stationarity of productivity in each country), the responses of country 1 net exports to productivity shocks are *identical* to those shown in Fig. 7 (where $\xi = 0.95$, $\psi = 0$ is assumed) — i.e. in both asset structures, a positive shock to productivity in country 1 induces a *rise* in that country's net exports.

The simulation results presented in this paper provide strong evidence against the complete markets structure — that structure fails to explain the actual behavior of US net exports, irrespective of whether permanent or transitory shocks to the cross-country productivity differential are assumed. They show, however, that asset market incompleteness alone is not sufficient to explain the behavior of US net exports — productivity shifts that have a permanent (or extremely long-lasting) effect on the cross-country productivity differential are required to rationalize that behavior. Experiments with different values of the autocorrelation coefficient of the cross-country productivity differential, $\xi - \psi$, show that values of $\xi - \psi$ above 0.99 are needed to generate a negative response of net exports to a country-specific technology shock, in the bonds-only structure. In a certain sense, the simulation results here might thus be viewed as 'indirect' support for the assumption of extremely long-lasting idiosyncratic country-specific US and G6 productivity shifts.

5. Conclusions

This paper has used a two-country RBC model to quantitatively study the dynamics of the US trade balance, during the period 1975–1991. Historical quarterly series on total factor productivity, government consumption and the average tax rates in the US and in an aggregate of the remaining G7 countries (G6) were fed into the structural model. The model simulations suggest that US productivity shocks are the dominant source of movements in the US trade balance.

A version of the model that postulates that only bonds can be used for international capital flows, and that assumes permanent country-specific productivity shifts, captures rather well the US trade balance data for the period 1975–1991. The simulations of that structure suggest, in particular, that the relatively rapid growth in US productivity and the drop in the US average tax rate during the first half of the 1980s explain the sharp drop in US net exports during that period.

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Appendix: The data

Output, (private) consumption, government purchases, investment: These variables are constructed by deflating nominal series for GDP (for Germany: GNP), government consumption, and gross fixed capital formation, respectively, using national Consumer Price Indexes (source: International Financial Statistics, IFS, published by the IMF). *Capital stock*: The US capital stock is taken from Survey of Current Business (1992, pp. 106–137); for other countries, the source is the OECD publication 'Flows and Stocks of Fixed Capital'. These capital stock series are annual. Quarterly series are constructed by linear interpolation of the annual series. *Hours worked*: For the US, series LPHMU from Citibase is used. Hours for other countries come from the Bulletin of Labour Statistics (International Labour Office) and from national statistical sources. *Net exports*: Exports minus imports of goods and services (source: IFS). *Tax rates*: The tax rate in a given fiscal year is estimated by subtracting transfer payments made by governments from total tax revenues (all levels of government) and by dividing the difference by the net domestic product. Social security contributions received by governments are included in tax revenues. Tax revenue and transfer data come from Revenue Statistics of OECD Member Countries (OECD) and from Government Finance

Statistics (IMF). Construction of net domestic product series: GDP minus consumption of fixed capital (from OECD National Accounts). Quarterly tax rate series are constructed by assuming that tax rates are constant during all quarters of a given fiscal year.

Construction of aggregate time series for G6 countries: Aggregate output, consumption, government purchases, investment, capital stock, and trade balance series for the G6 are constructed by expressing national series in domestic currencies at constant 1980 prices, converting these series into US dollars using 1980 exchange rates, and summing over the G6 countries. As hours series for several G6 countries are available in index form only, aggregate G6 hours were constructed by normalizing the national series to unity in 1980:Q1 and taking a weighted sum of the normalized series (weights: national shares in total 1980 G6 GDP); the aggregate G6 tax rate too is a weighted average of the national tax rates of the G6 countries (using the same weights).

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