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).

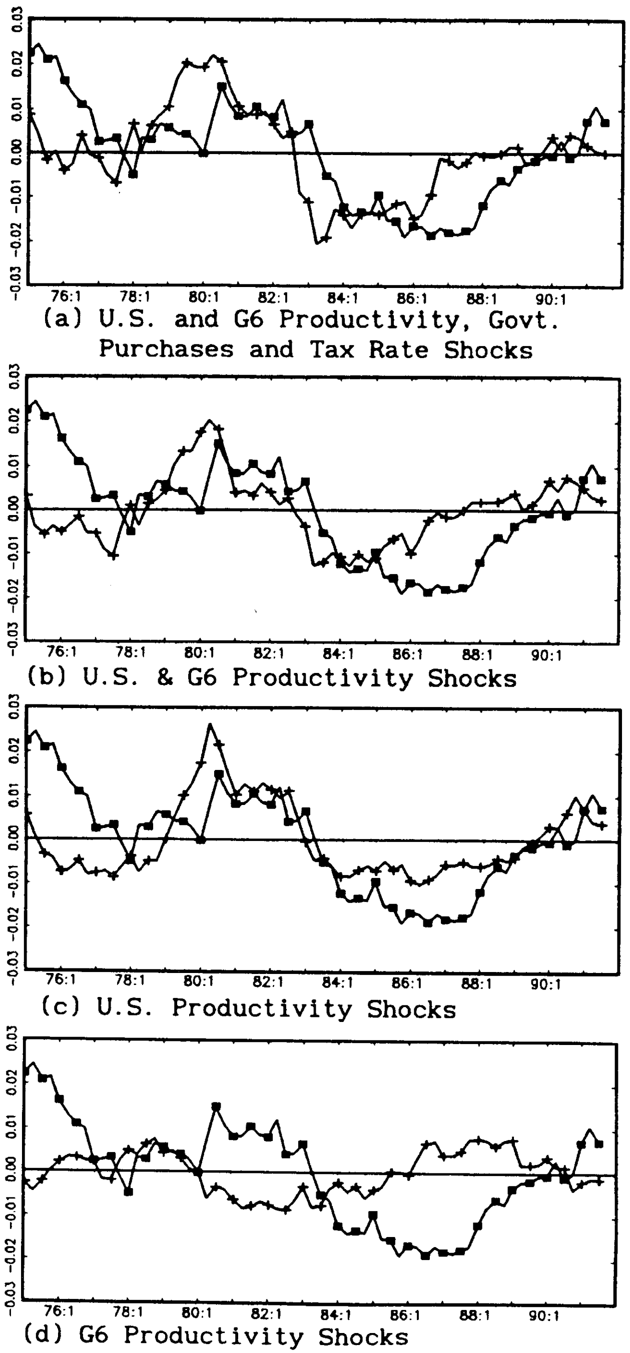

Fig. 4 (a)–(d).

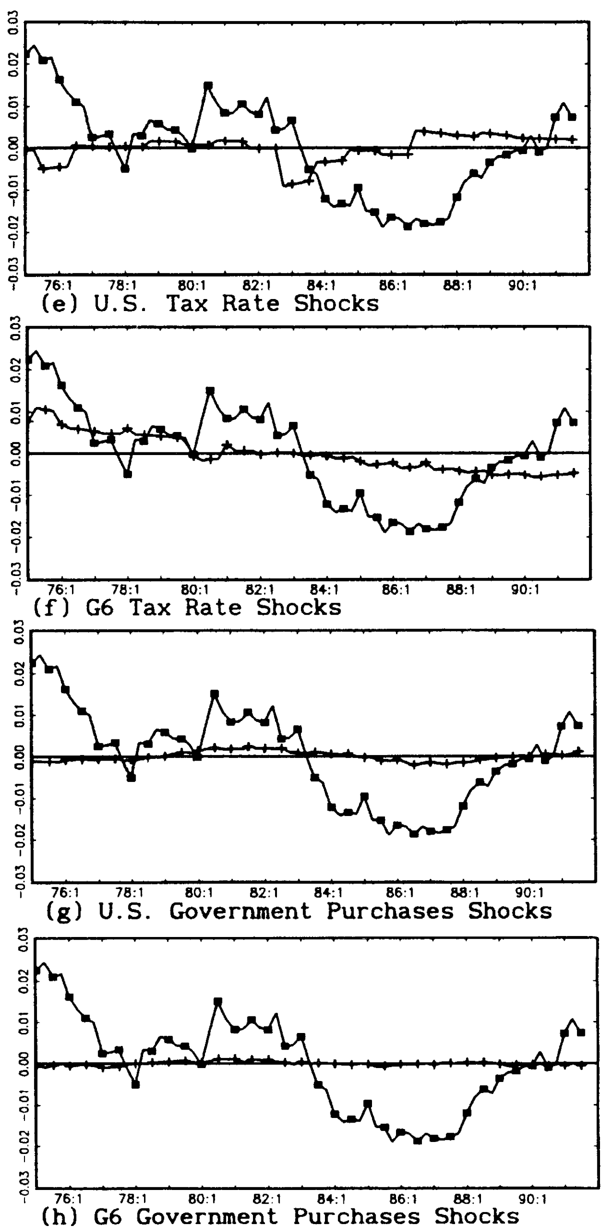

Fig. 4. Incomplete asset markets (forcing variables assumed to follow random walks): simulated US net exports (as share of output).
Model subjected to actual US and G6 productivity, government purchases and tax rate series. Panel (a): Six forcing variables fed simultaneously into the model. Panel (b): 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.

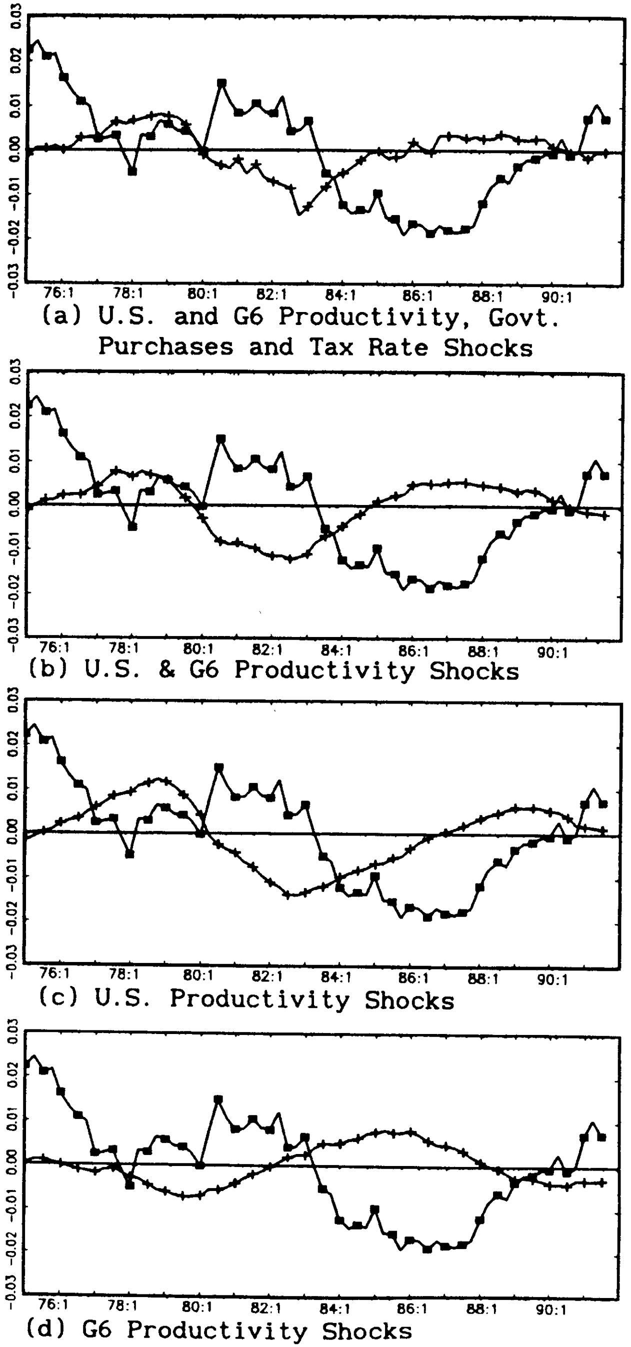

Fig. 5 (a)–(d).

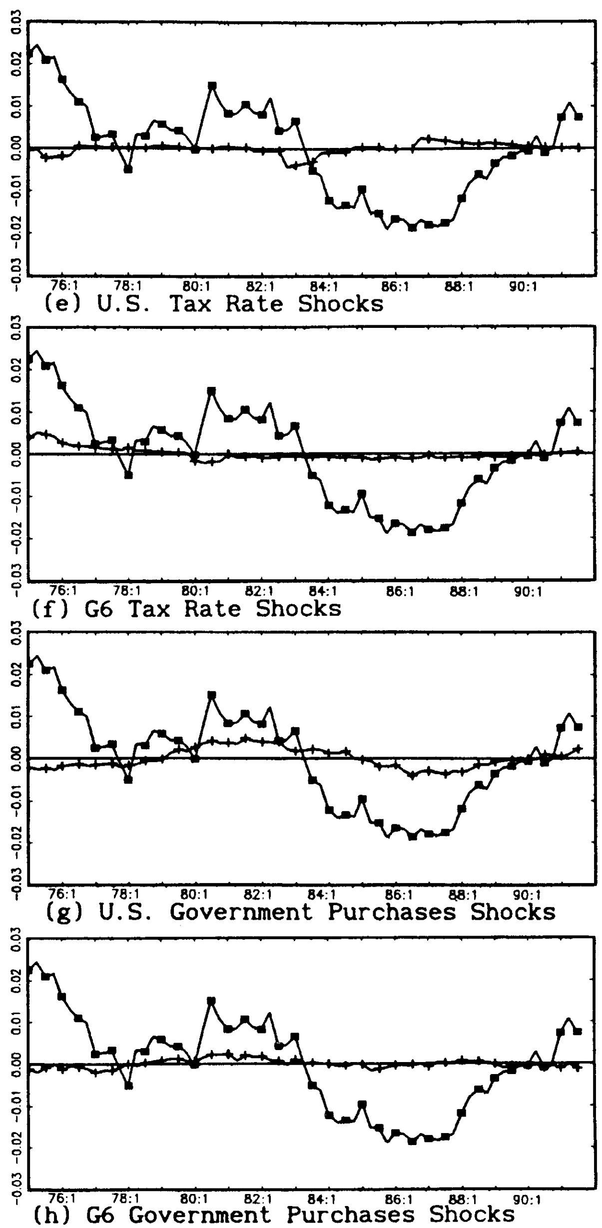

Fig. 5. Complete asset markets (forcing variable assumed to follow random walks): simulated US net exports (as share of output).
Model subjected to actual US and G6 productivity, government purchases and tax rate series. Panel (a): Six forcing variables fed simultaneously into the model. Panel (b): US 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.

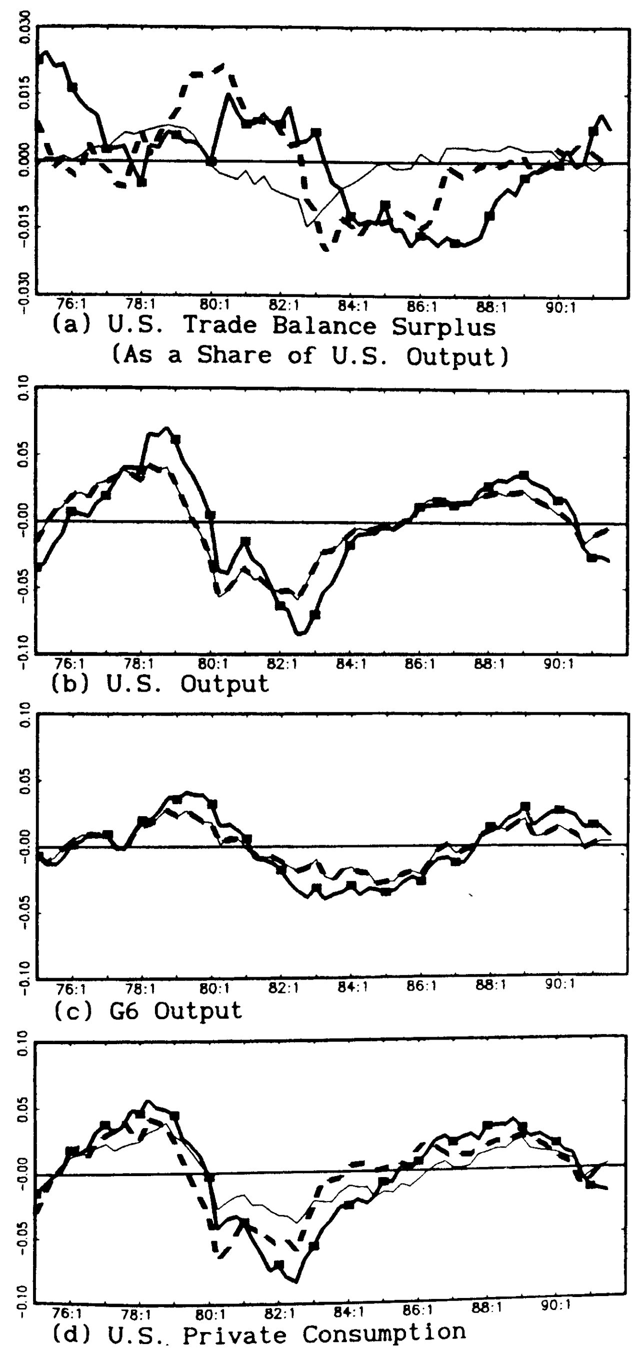

Fig. 6 (a)–(d).

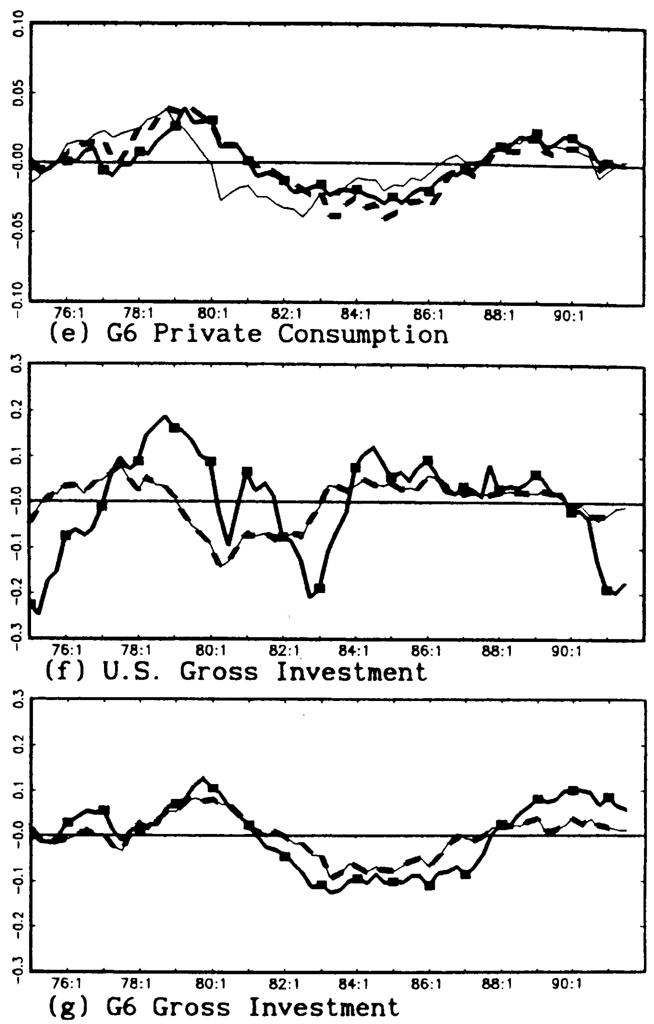

Fig. 6. (In)complete asset markets (forcing variables assumed to follow random walks): simulated net exports (as share of output), output, consumption and investment.
Model subjected to actual US and G6 productivity, government purchases and tax rate series (six forcing variables fed simultaneously into 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

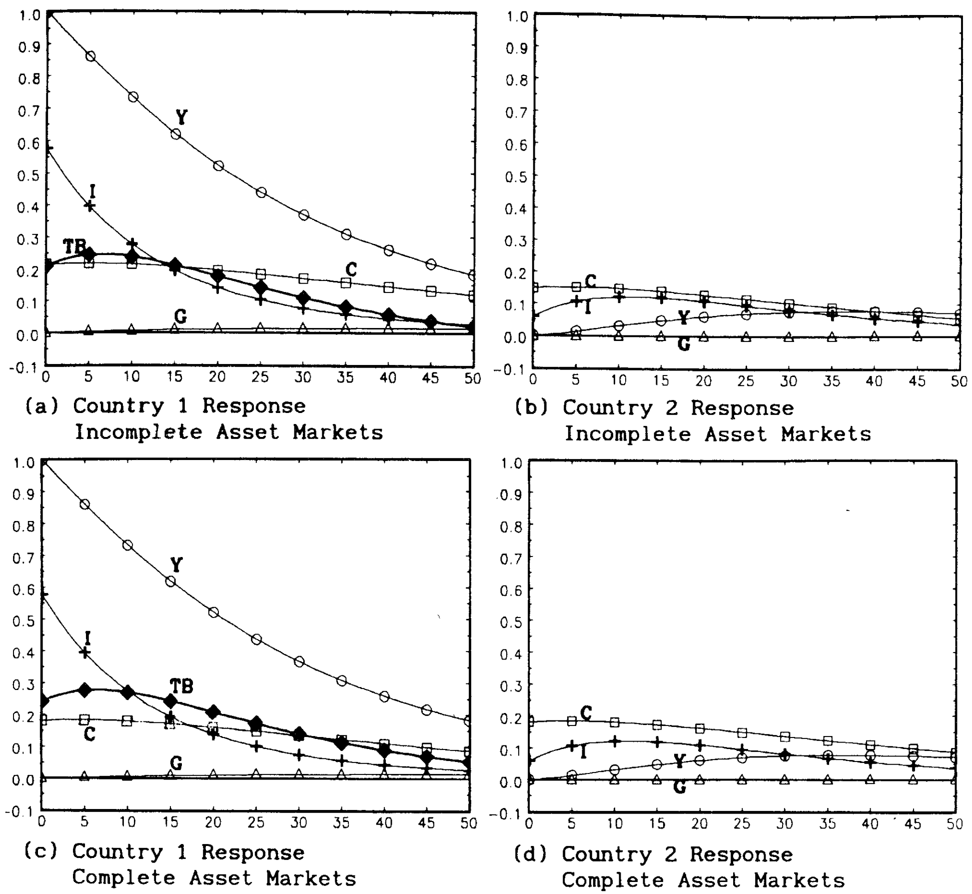

Fig. 7. (In)complete asset markets (autocorrelation of productivity: $\rho = 0.95$): responses to 1% shock to country 1 productivity.
Responses are expressed as percentage of the steady state output. Abscissa: quarters after shock. Panels (a),(b): Responses in incomplete asset markets structure. Panels (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).

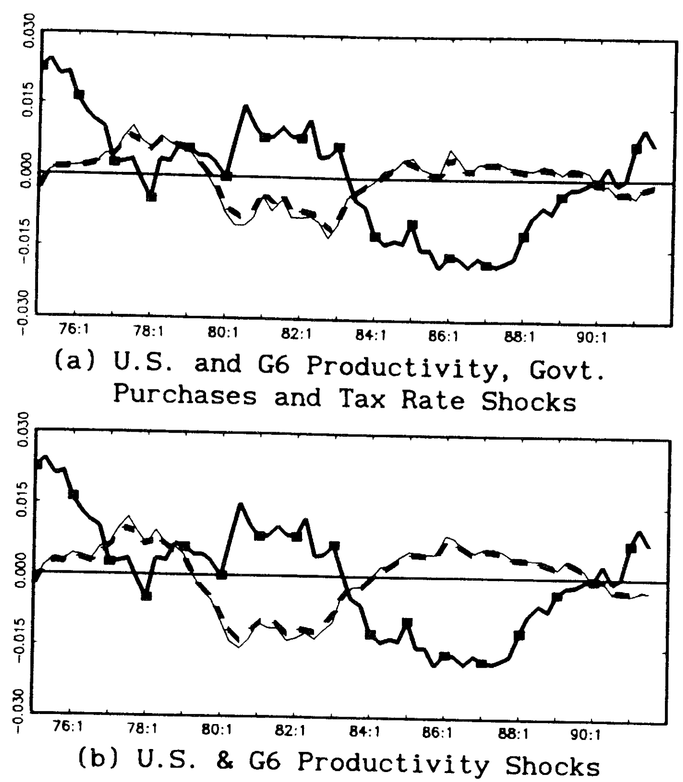

Fig. 8. (In)complete asset markets (autocorrelation of forcing variables: $\rho = 0.95$): simulated US net exports (as share of output).
Model subjected to actual US and G6 productivity, government purchases and tax rate series. Panel (a): Six forcing variables fed. ■: Data (1975:Q1–1991:Q3); ■ ■ ■: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