exports—this is so in both asset market structures.

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

(INSET FIGURE 8 ABOUT HERE)

Equation (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:

$$
\widehat{\vartheta}_t^1 = \xi \widehat{\vartheta}_{t-1}^1 + \psi \widehat{\vartheta}_{t-1}^2 + \epsilon_t^1, \quad \widehat{\vartheta}_t^2 = \psi \widehat{\vartheta}_{t-1}^1 + \xi \widehat{\vartheta}_{t-1}^2 + \epsilon_t^2, \quad (17)
$$

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

$$
\widehat{\vartheta}_t^1 \widehat{\vartheta}_t^2 = (\xi-\psi) (\widehat{\vartheta}_{t-1}^1 - \widehat{\vartheta}_{t-1}^2) + (\epsilon_t^1 - \epsilon_t^2).
$$

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 ($\epsilon_t^1$, $\epsilon_t^2$) on net exports hinges on $\xi-\psi$, i.e. on the persistence of the cross-country productivity differential: combinations of $\xi, \psi$ 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 Figure 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 U.S. 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 U.S. 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 U.S. and G6 productivity shifts.

5. Conclusions

This paper has used a two-country RBC model to quantitatively study the dynamics of the U.S. trade balance, during the period 1975-1991. Historical quarterly series on total factor productivity, government consumption and
the average tax rates in the U.S. and in an aggregate of the remaining G7 countries (G6) were fed into the structural model. The model simulations suggest that U.S. productivity shocks are the dominant source of movements in the U.S. 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 U.S. trade balance data for the period 1975-91. The simulations of that structure suggest, in particular, that the relatively rapid growth in U.S. productivity and the drop in the U.S. average tax rate during the first half of the 1980s explain the sharp drop in U.S. net exports during that period.
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 U.S. 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 U.S., series LPHH from Citibase is used. Hours for other countries come from 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 U.S. 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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REFERENCES


### TABLE 1. Augmented Dickey-Fuller unit root tests.

**(a) U.S. and G6 forcing variables**

<table>
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<th>k=0</th>
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<th>k=2</th>
<th>k=3</th>
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<th>k=5</th>
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<td>U.S. productivity</td>
<td>-1.31</td>
<td>-1.76</td>
<td>-1.89</td>
<td>-2.03</td>
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<td>-2.27</td>
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<td>G6 productivity</td>
<td>-1.62</td>
<td>-1.76</td>
<td>-1.50</td>
<td>-1.48</td>
<td>-1.74</td>
<td>-1.95</td>
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<td>U.S. govt. consumption</td>
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<td>-1.30</td>
<td>-1.24</td>
<td>-1.70</td>
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<td>-2.27</td>
</tr>
<tr>
<td>G6 govt. consumption</td>
<td>-2.62*</td>
<td>-2.27</td>
<td>-2.09</td>
<td>-1.53</td>
<td>-1.89</td>
<td>-1.69</td>
</tr>
<tr>
<td>U.S. tax rate</td>
<td>-2.24</td>
<td>-2.30</td>
<td>-2.27</td>
<td>-2.34</td>
<td>-1.82</td>
<td>-1.69</td>
</tr>
<tr>
<td>G6 tax rate</td>
<td>-4.71**</td>
<td>-3.68*</td>
<td>-3.53*</td>
<td>-2.82$</td>
<td>-2.68$</td>
<td>-2.87$</td>
</tr>
</tbody>
</table>

**Notes:** ADF test statistics based on the following regression are reported

\[
\Delta x_t = \alpha_0 + \alpha_1 t + \alpha_2 x_{t-1} + \sum_{s=1}^{s=k} \psi_s \Delta x_{t-s} + u_t, \text{ where } \Delta x_t = x_t - x_{t-1}.
\]

N.B. k: number of lagged \( \Delta x \) terms included on the right-hand side of this regression. The ADF test statistic is the studentized value of the OLS estimate of \( \alpha_2 \).

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 U.S.-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 Figure 1 (1975:Q1-91:Q3).

***, *, +, $, #: rejection of unit root hypothesis at 1%, 5%, 10%, 20% and 50%, respectively.**
TABLE 2. Phillips and Ouliaris cointegration tests

<table>
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<th></th>
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<th>(5)</th>
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<td>( Z_\alpha ) statistic</td>
<td>-18.65</td>
<td>-20.62</td>
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<td>-30.60#</td>
<td>-14.62</td>
<td>-25.09</td>
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<tr>
<td>( Z_t ) statistic</td>
<td>-3.79#</td>
<td>-3.62</td>
<td>-3.05</td>
<td>-4.20#</td>
<td>-3.33</td>
<td>-5.01+</td>
</tr>
</tbody>
</table>

Notes: Phillips and Ouliaris (1990) \( Z_\alpha \) and \( Z_t \) 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 \( Z_\alpha \) and \( Z_t \) statistics labelled (1) use U.S. 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, U.S. government consumption, G6 government consumption, the U.S. 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 Figure 1 (1975:Q1-91:Q3). Productivity and government purchases are used in logs.

**, *, †, §, #: rejection of null of no cointegration at 1%, 5%, 10%, 20% and 50% levels, respectively.
TABLE 3. Six-variable VAR fitted to forcing variables (in first-differences)

\[
RHO = \begin{bmatrix}
0.21 & -0.04 & 0.24 & 0.05 & -0.02 & -0.63 \\
(0.13) & (0.16) & (0.11) & (0.11) & (0.19) & (0.33) \\
0.02 & -0.04 & 0.14 & 0.06 & -0.18 & -0.15 \\
(0.10) & (0.17) & (0.09) & (0.09) & (0.16) & (0.28) \\
0.12 & 0.00 & 0.03 & 0.00 & 0.02 & -0.42 \\
(0.16) & (0.21) & (0.14) & (0.14) & (0.25) & (0.43) \\
-0.17 & 0.12 & 0.00 & -0.32 & ** & -0.54 ** & 0.15 \\
(0.14) & (0.17) & (0.12) & (0.12) & (0.20) & (0.36) \\
-0.01 & 0.13 & 0.01 & 0.07 & 0.00 & 0.26 \\
(0.08) & (0.11) & (0.07) & (0.07) & (0.13) & (0.22) \\
-0.04 & 0.12 & 0.01 & -0.01 & -0.06 & -0.09 \\
(0.04) & (0.05) & (0.04) & (0.04) & (0.07) & (0.12)
\end{bmatrix}
\]

Notes: Let \( z_t = (\Delta \ln(\theta^t), \Delta \ln(G^t), \Delta \ln(G^t_{US}), \Delta \ln(G^t_{G6}), \Delta s^t_{US}, \Delta s^t_{G6})' \), where \( \theta^t, G^t, s^t \) are productivity, government consumption and the tax rate, for i=US, G6, respectively (N.B. \( \Delta x_t = x_t - x_{t-1} \)). The following model is fitted to the time series shown in Figure 1 (1975:Q1-91:Q3): \( z_t = b + \text{RHO} \; z_{t-1} + \epsilon_t \), 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.
NOTES

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.

2 In the U.S. (and in other G7 countries), the ratio of labor income to capital income fluctuates around 2.5, which suggests a value of $\eta$ in the range of 0.75.

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

4 See, e.g., Obstfeld and Rogoff (1996, Ch. 5) and Kollmann (1995), for derivations of this fundamental risk sharing condition. (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: $\beta u_1^{t+1}/u_t^1 = \beta u_2^{t+1}/u_t^2$. In the bonds-only world, marginal rates of substitution are merely equated in expected value: $\beta E_t u_1^{t+1}/u_t^1 = \beta E_t u_2^{t+1}/u_t^2$ (as (11a) holds for i=1,2, in equilibrium).

5 To allow for cases where steady state net private asset holdings $A^1_t$ and government debt $D^1_t$ are zero, $\nabla A_t^1, \nabla D_t^1$ are defined as $\nabla A_t^1 = A_t^1 - A^1$, $\nabla D_t^1 = D_t^1 - D^1$. 
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 $k>3$, there is little evidence against this hypothesis.

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.

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).

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

King (1990) has presented a method for decomposing the response 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).
A more detailed discussion of the effects of shocks to autonomous government purchases ($\gamma^1$) can be found in the working paper version of this paper. A permanent rise in $\gamma^1$ 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 (8a); N.B. $M^G>0$), as can be seen in Panel (c) of Figures 2-3. The prediction that country 1 net exports fall (in response to the $\gamma^1$ 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 $\gamma^1$ 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).

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 contrast, the sample average of U.S. net exports (expressed as a share of U.S. GDP) is -1.38%. Therefore, the simulated and the historical net exports series are presented in de-meaned form in Figures 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).
Yi (1993) has recently used a dynamic two-country general equilibrium model with complete markets to investigate whether government purchases can explain the U.S. net export deficits of the 1980s (in contrast to the paper here, Yi considers an endowment economy and he assumes lump sum taxes). Overall, Yi's results suggest that government purchases explain a relatively small fraction of actual U.S. trade balance movements, which parallels the finding reached here.

The correlation between simulated and actual U.S. net exports (expressed as a share of U.S. 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.

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 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).
(a) + (■): U.S (G6) Trade Balance Surplus (Relative to U.S. GDP)
(b) Tax Rate
(c) Productivity Index (ln(θ))
(d) Government Consumption (in Logs), Billions of 1980 U.S. $
(e) Linearly Detrended Productivity Index (ln(θ))
(f) Linearly Detrended Log Government Consumption

FIGURE 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 1 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).
FIGURE 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 1 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).
Model Subjected to Actual U.S. and G6 Productivity, Government Purchases and Tax Rate Series.

Panel (a): Six Forcing Variables Fed Simultaneously Into Model.
Panels (c)-(h): Each of the Six Forcing Variables Used Separately.

Data (1975:Q1-1991:Q3), : Simulation. All Series in Figure Are De-Meaned.
FIGURE 5 COMPLETE ASSET MARKETS (FORCING VARIABLES ASSUMED TO FOLLOW RANDOM WALKS): SIMULATED U.S. NET EXPORTS (AS SHARE OF OUTPUT)

Model Subjected to Actual U.S. and G6 Productivity, Government Purchases and Tax Rate Series.
Panel (a): Six Forcing Variables Fed Simultaneously Into Model.
Panels (c)-(h): Each of the Six Forcing Variables Used Separately.
- Data (1975:Q1-1991:Q3), +: Simulation. All Series in Figure Are De-Meaned.
FIGURE 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 U.S. and G6 Productivity, Government Purchases and Tax Rate Series (Six Forcing Variables Fed Simultaneously Into Model).

- Simulated Path, Incomplete Markets Structure.
- Simulated Path, Complete Markets Structure.

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.

NB Simulated Output and Investment Series Are Identical Across Asset Structures.
FIGURE 7 (IN)COMPLETE ASSET MARKETS (AUTOCORRELATION OF PRODUCTIVITY: $p=0.95$): RESPONSES TO 1% SHOCK TO COUNTRY 1 PRODUCTIVITY

Responses Are Expressed as Percentage of 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 ($TB$)
Figure 8 (In)complete Asset Markets (Autocorrelation of Forcing Variables: $\rho=.95$): Simulated U.S. Net Exports (as Share of Output)

Model Subjected to Actual U.S. and G6 Productivity, Government Purchases and Tax Rate Series.


- - : Simulated Net Exports, Complete Markets Structure.

All Series in Figure Are De-Meaned.