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University of Warwick, Department of Economics

1998

ELSEVIER

Economic Modelling 15 (1998) 163–195

Economic Modelling

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Abstract

Spillovers resulting from fiscal and monetary policy are compared and analysed in small static, small dynamic and large dynamic multi-country models. To compare the size of the spillovers, we consider simulations in which GDP for a certain number of years is held one percent above base in the country where the shock originates. The results indicate that spillovers are large in size. An important transmission mechanism in the contribution to foreign GDP is found to be the foreign real interest rate, contributions to foreign GDP generated through trade are found to be small. In empirical models with endogenous exchange and interest rates, it was found that under floating exchange rate regimes spillovers are much smaller than under pegged exchange rate regimes. Furthermore, we note that under floating exchange rate regimes, spillovers seem to be larger in small (dynamic) models than in large empirical models. © 1998 Elsevier Science B.V.

JEL Classifications: E62; F41; C52

Keywords: Multi-country model; International spillovers; Evaluation and simulation

1. Introduction

Due to the increasing integration process in capital, financial and product markets economic interaction across countries is becoming more important. Fiscal

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PII S0264-9993(97)00026-6

or monetary policy in one country will in general have a non-negligible effect on the economies of neighbour-countries. These external effects called spillovers can be large, in particular when linkages between countries are strong. Therefore in theoretical and empirical economics there is a growing interest in the measure, sign and size of spillovers.

Theoretical work analysing international spillovers mainly refers to the work of Mundell (1963) and Fleming (1962) and to modified versions of their model, see e.g. McKibbin and Sachs (1991) and Krugman (1995). The standard static, symmetric, two-country Mundell-Fleming model assumes complete capital mobility, flexible exchange rates, and sticky wages and prices. In this model an expanding fiscal policy originating in the home country raises foreign GDP whereas an expanding home monetary policy lowers foreign GDP. In general however, the sign and size of spillovers crucially depends upon the model assumptions.

Another branch of research involves studies with empirical multi-country models. Multi-country models seem to be very suitable for analyzing transmission mechanisms across countries. Since different models normally provide different spillover responses it seems that the first task is to identify these differences. The next step may then be to evaluate these different responses and to use this knowledge when building models in the future. An important initiating multi-country comparison project was sponsored by the Brookings Institution, see Bryant et al. (1988).

Some comparative research concerning spillovers has been undertaken by Helliwell and Padmore (1985); Frankel (1988); Whitley (1992b). They apply the same type of shock-analyses on different multi-country models and the responses of the different models are compared and analysed. For example, they compare the responses of GDP in foreign countries to a fiscal or monetary shock originating in a domestic country.

For fiscal shock experiments, Helliwell and Padmore (1985) show the importance of considering the exchange rate and monetary linkages jointly. For a monetary shock the type of exchange rate regime is important. A flexible exchange rate increases the domestic income and price effects of domestic monetary policy while reducing the foreign effects. Frankel's study considers a permanent government expenditure shock of one percent of GDP and a permanent increase in the money stock of four percent. In the short run he finds that there is less ambiguity across models about the effect of a fiscal expansion than of a monetary expansion. A fiscal expansion raises foreign GDP in the second year of the simulation whereas the negative Mundell-Fleming effect of domestic monetary expansion on foreign GDP is often not present in the models. The explanation of a positive foreign GDP response is that the appreciation of the foreign currency has one or more of the following four expansionary effects: an increase in the real money supply or real wealth or a decrease in wages or imported input costs.

Whitley (1992a) considers fiscal policy shocks originating in several European economies and a fiscal policy shock originating in the US, with fixed real interest rates. The fiscal expansion in a European country results only in very small spillover effects in other EU-economies, for most models. On the other hand, for a

US fiscal expansion Whitley reports European GDP figures of 10–25% of the US GDP-response. These outcomes cannot easily be compared with the previous two studies since the experimental conditions were different, incorporating fixed assumptions about the exchange rate regime and (nominal or real) interest rates and so closing off important channels. Since the exchange rate is a key element in these comparison projects, Whitley (1992a) incorporated endogenous exchange-rate behaviour in the simulations. Small European spillovers were again found, although it is also shown that the sign of various spillovers are sensitive to the assumed monetary policy regime.

These moderate spillovers obtained with empirical macromodels are in some contrast to the common belief that interdependencies among countries, especially in integrating Europe, are large. Comparisons of spillovers are however difficult to interpret. Suppose for example that the same monetary shock induces in the first year in model A a home GDP-response of 1% above base and in model B a home GDP-response of 0.3% above base, but both models produce the same GDP-spillover effect of, let's say, 0.2% above base in the foreign country. Are now spillover effects large in model A and B or only in model A or in none of the two models? This interpretation problem enhances over time and since comparisons across models are likely to be contaminated by different domestic responses we will introduce a standardization concept in this paper.

The definition normally used for a spillover is the extent to which a foreign variable changes due to fiscal policy, monetary policy or another exogenous shock in the domestic country. A GDP-spillover is thus the change in foreign GDP that has been spilled over from the domestic country, due to some exogenous domestic shock.

The main aim of this paper is to compare the spillover-effects with the domestic effects that are both caused by some domestic shock, first in a static model, then in a dynamic model and finally in a large calibrated and a large estimated multi-country model. Our comparative analyses are always undertaken with fully operating models so that the simulation exercises always exploit all the interdependencies built into the model. Whenever possible, the spillover is disentangled into its major components. To make some judgement about the size of the spillover we introduce the following standardization of a GDP-spillover.

The standardization concerns the foreign GDP-response expressed as a percentage of the domestic GDP-response, where the domestic shock is constructed such that domestic GDP is of a constant (but nonzero) magnitude for a certain number of years.

The measure used in previous mentioned studies was that foreign GDP-spillovers were always expressed as a percentage of a fluctuating domestic GDP response. Clearly, the interpretation of this measure becomes blurred if domestic GDP is close to zero. This problem does occur often in practice since after a permanent fiscal or monetary shock most multi-country models show rather fast crowding out responses. Therefore, we adopt the approach to fix the domestic GDP-response (instead of fixing the domestic shock). It also conforms more closely to popular usage. For instance, 'the improvement in Germany's growth will stimulate growth in the Netherlands' occurs more often than comparisons such as 'the increase in German government expenditure will boost Dutch growth'. Different policy instruments may be used to achieve such a constant GDP-response, and the calculation of the required instrument setting in typical British model-handling software is referred to as a *a Type II fix*, see e.g. Wallis et al. (1985).

It should be kept in mind that any standardization of measuring spillovers in macromodels has drawbacks since comparisons may be contaminated by different domestic responses. A way out could be to exogenize home GDP and increase it permanently by, for example, one percent. However, in the absence of a specification of the mechanism whereby the stimulus is achieved, its interpretation is almost impossible and important second-round effects may be excluded (see Andrews et al. (1985) on the distinction between 'what-if' and 'if-only' experiments).

The outline of this paper is as follows. In Section 2 the transmission channels through which foreign GDP is affected by fiscal and monetary policy is analyzed by means of a static Mundell-Fleming model. In Section 3 the same type of analysis is extended to four dynamic versions of the Mundell-Fleming model adapted from Ghosh and Masson (1994). In Section 4 three large multi-country models are used to evaluate the spillovers from US fiscal and monetary policy to Germany, the United Kingdom and France and, similarly, the effects of German policy to the US, the United Kingdom, and France. The models under investigation are the MSG2-model (see McKibbin and Sachs (1991)), MULTIMOD of the IMF and NiGEM of the National Institute—(London), as recently studied by Mitchell et al. (1997). Section 5 concludes.

2. Modified static versions of the Mundell-Fleming model

Most multi-country models have the Mundell-Fleming framework as their basic foundation. Across the economies that are modelled in detail, specifications often have a broad similarity with the values of key coefficients sometimes being set equal across countries (MSG2 and MULTIMOD). To fix ideas we first consider the spillover effects from fiscal and monetary policy in a standard two-country Mundell-Fleming model. Table 1 presents a modified static version that is similar to the one presented by McKibbin and Sachs (1991) (see their Table 2-1), the only difference being that we deviate from the symmetric country assumption and allow the parameters of the domestic and foreign country to take different values. An extensive and comprehensive explanation of the (symmetric) model is given by McKibbin and Sachs. We repeat only the basics here. The two economies are a domestic country (represented without asterisks) and a foreign country (represented with asterisks), described by 12 equations in Table 1.

Eq. (1-1) is the standard LM curve for the domestic country. Eq. (1-2) describes real aggregate demand (in semi-reduced form) as a function of the real exchange rate (described in Eq. (1-6)), the nominal interest rate, foreign GDP, government expenditure and taxes. Eq. (1-3) represents the domestic price level as a markup over wages and demand. In order to keep analyses tractable, nominal wages in Eq.

Table 1
A modified version of a static two-country Mundell-Fleming model

$m - p = \phi_1 q - \beta_1 i$	(1-1)
$m^* - p^* = \phi_2 q^* - \beta_2 i^*$	(1-1*)
$q = \delta_1 \lambda - \sigma_1 i + \gamma_1 q^* + \mu_1 g - \nu_1 t$	(1-2)
$q^* = -\delta_2 \lambda - \sigma_2 i^* + \gamma_2 q + \mu_2 g^* - \nu_2 t^*$	(1-2*)
$p = w + \theta_1 q$	(1-3)
$p^* = w^* + \theta_2 q^*$	(1-3*)
$w = \zeta_1 p^c$	(1-4)
$w^* = \zeta_2 p^{c*}$	(1-4*)
$p^c = \alpha_1 p + (1 - \alpha_1)(e + p^*)$	(1-5)
$p^{c*} = \alpha_2 p^* + (1 - \alpha_2)(-e + p)$	(1-5*)
$\lambda = e + p^* - p$	(1-6)
$i = i^*$	(1-7)

Notes: Variables without an asterisk are domestic country variables, variables with an asterisk are foreign country variables. All variables, except i, are in logarithmic form. Parameters are assumed to be positive, with $0 < \gamma_1, \gamma_2, \alpha_1, \alpha_2 < 1$. Symmetry holds if $\phi_1 = \phi_2$, $\beta_1 = \beta_2$, $\delta_1 = \delta_2$, $\sigma_1 = \sigma_2$, $\gamma_1 = \gamma_2$, $\nu_1 = \nu_2$, $\theta_1 = \theta_2$, $\zeta_1 = \zeta_2$, $\alpha_1 = \alpha_2$.

Definitions of endogenous variables:

q = real GDP
i = level of nominal interest rate
e = exchange rate defined as the price in domestic currency of a unit of foreign currency
λ = real exchange rate
p = price level
p^c = consumer price level
w = nominal wage

Definitions of exogenous variables:

m = nominal money balances
g = real government expenditure
t = real taxes.

(1-4) are assumed to be either fixed ($\zeta_1 = \zeta_2 = 0$) or fully indexed to the consumer price level ($\zeta_1 = \zeta_2 = 1$). Eq. (1-5) represents the consumer price level as a weighted average of the price of domestically produced goods and the price of imported goods. Finally, Eq. (1-7) represents the perfect capital mobility condition.

Only short-run effects appear in the model, which makes it easy to obtain analytical solutions for shock experiments. To critically assess the model with respect to GDP-spillovers we consider two shocks. The first shock is a fiscal expenditure shock in the home country such that home GDP raises by 1. The second shock is a monetary shock in the home country such that home GDP raises by 1. In this static model the value 1 is not particularly important as any size of shock can be performed to report the statistic $\Delta q^* / \Delta q$, where Δ denotes absolute deviation from the base simulation (since all variables are in logarithms). However, in subsequent sections where dynamic models are considered this choice is crucial.

Four wage regimes and three exchange rate regimes are distinguished, mainly as

Table 2
Decomposition of foreign output after a fiscal policy shock

	$\Delta q^*/\Delta q$	$\Delta \lambda/\Delta q$	$\Delta i^*/\Delta q$
Fixed wages and prices in both countries			
(1A)	$\dfrac{\beta_2 \phi_1}{\beta_1 \phi_2}$	$\dfrac{\phi_2(\beta_1 \gamma_2 - \phi_1 \sigma_2) - \beta_2 \phi_1}{\beta_1 \delta_2 \phi_2}$	$\dfrac{\phi_1}{\beta_1}$
(2A)	$\dfrac{\beta_2 \gamma_2}{\beta_2 + \phi_2 \sigma_2}$	0	$\dfrac{\gamma_2 \phi_2}{\beta_2 + \phi_2 \sigma_2}$
(3A)	$\dfrac{\beta_1 \gamma_2 - \phi_1 \sigma_2}{\beta_1}$	0	$\dfrac{\phi_1}{\beta_1}$
Fixed wages and prices in the home country and foreign indexation			
(1B)	$\dfrac{(1-\alpha_2)(\beta_1 \gamma_2 - \phi_1 \sigma_2)}{\beta_1(1-\alpha_2+\delta_2 \theta_2)}$	$\dfrac{\theta_2(\beta_1 \gamma_2 - \phi_1 \sigma_2)}{\beta_1(1-\alpha_2+\delta_2 \theta_2)}$	$\dfrac{\phi_1}{\beta_1}$
(2B)	$\dfrac{(1-\alpha_2)\beta_2 \gamma_2}{(1-\alpha_2)(\beta_2+\phi_2 \sigma_2)+\theta_2(\beta_2 \delta_2+\sigma_2)}$	$\dfrac{\beta_2 \gamma_2 \theta_2}{(1-\alpha_2)(\beta_2+\phi_2 \sigma_2)+\theta_2(\beta_2 \delta_2+\sigma_2)}$	$\dfrac{\gamma_2((1-\alpha_2)\phi_2+\theta_2)}{(1-\alpha_2)(\beta_2+\phi_2 \sigma_2)+\theta_2(\beta_2 \delta_2+\sigma_2)}$
(3B)	$\dfrac{(1-\alpha_2)(\beta_1 \gamma_2 - \phi_1 \sigma_2)}{\beta_1(1-\alpha_2+\delta_2 \theta_2)}$	$\dfrac{\theta_2(\beta_1 \gamma_2 - \phi_1 \sigma_2)}{\beta_1(1-\alpha_2+\delta_2 \theta_2)}$	$\dfrac{\phi_1}{\beta_1}$

Home indexation and fixed wages and prices in the foreign country			
(1C)	$\frac{\beta_2((1-\alpha_1)\gamma_2+\delta_2\theta_1)}{(1-\alpha_1)(\beta_2+\phi_2\sigma_2)}$	$-\frac{\theta_1}{1-\alpha_1}$	$\frac{\phi_2((1-\alpha_1)\gamma_2+\delta_2\theta_1)}{(1-\alpha_1)(\beta_2+\phi_2\sigma_2)}$
(2C)	$\frac{\beta_2((1-\alpha_1)\gamma_2+\delta_2\theta_1)}{(1-\alpha_1)(\beta_2+\phi_2\sigma_2)},$	$-\frac{\theta_1}{1-\alpha_1}$	$\frac{\phi_2((1-\alpha_1)\gamma_2+\delta_2\theta_1)}{(1-\alpha_1)(\beta_2+\phi_2\sigma_2)}$
(3C)	$\frac{(1-\alpha_1)(\beta_1\gamma_2-\phi_1\sigma_2)+(\beta_1\delta_2-\sigma_2)\theta_1}{(1-\alpha_1)\beta_1}$	$-\frac{\theta_1}{1-\alpha_1}$	$\frac{(1-\alpha_1)\phi_1-\theta_1}{(1-\alpha_1)\beta_1}$
Home and foreign indexation			
(1D)	$-\frac{(1-\alpha_2)\theta_1}{(1-\alpha_1)\theta_2}$	$-\frac{\theta_1}{1-\alpha_1}$	$\frac{(1-\alpha_2+\delta_2\theta_2)\theta_1+(1-\alpha_1)\gamma_2\theta_2}{(1-\alpha_1)\sigma_2\theta_2}$
(2D)	$-\frac{(1-\alpha_2)\theta_1}{(1-\alpha_1)\theta_2}$	$-\frac{\theta_1}{1-\alpha_1}$	$\frac{(1-\alpha_2+\delta_2\theta_2)\theta_1+(1-\alpha_1)\gamma_2\theta_2}{(1-\alpha_1)\sigma_2\theta_2}$
(3D)	$-\frac{(1-\alpha_2)\theta_1}{(1-\alpha_1)\theta_2}$	$-\frac{\theta_1}{1-\alpha_1}$	$\frac{(1-\alpha_2+\delta_2\theta_2)\theta_1+(1-\alpha_1)\gamma_2\theta_2}{(1-\alpha_1)\sigma_2\theta_2}$

in McKibbin and Sachs (1991). This enables us to compare the foreign GDP-responses across the different regimes. The wage regimes are:

- (A) Fixed wages and prices in both economies: $\zeta_1 = \zeta_2 = \theta_1 = \theta_2 = 0$;
- (B) Fixed wages and prices in the home country, full indexation to consumer prices in the foreign country: $\zeta_1 = \theta_1 = 0$, $\zeta_2 = 1$;
- (C) Full indexation to consumer prices in the home country, fixed wages and prices in the foreign country: $\zeta_1 = 1$, $\zeta_2 = \theta_2 = 0$;
- (D) Home and foreign indexation to consumer prices: $\zeta_1 = \zeta_2 = 1$.

The exchange rate regimes are:

- (1) A floating exchange rate;
- (2) A fixed exchange rate, where the home country is pegging the rate;
- (3) A fixed exchange rate, where the foreign country is pegging the rate.

A country that is pegging the (nominal) exchange rate ($e = 0$) is assumed to choose its level of money accordingly.

Tables 2 and 4 present the decomposition of a foreign GDP-response to a fiscal policy shock and a monetary shock in the home country, respectively. The different exchange rate and wage regimes are denoted (1)–(3) and (A)–(D), as above. Δq and Δq^* represent home and foreign GDP deviation from the base simulation, respectively. $\Delta\lambda$ and Δi^* are similar notations for the real exchange rate and the nominal interest rate.

The shocks are constructed such that $\Delta q = 1$ by which the decomposition of foreign GDP is

$$\Delta q^* = -\delta_2 \Delta\lambda - \sigma_2 \Delta i^* + \gamma_2 \quad (1)$$

The exchange rate, nominal interest rate and γ_2 thus completely determine foreign GDP. Government expenditure, g^*, and fiscal expenditure, t^*, do not appear as they are exogenous.

The results partly correspond with the results presented by McKibbin and Sachs (1991) in their Table 2-2. A main difference is that McKibbin and Sachs only report whether the response is positive, negative or undetermined. Here, instead, the multipliers of the full analytical solutions (obtained with Mathematica) are shown. This enables us to trace which coefficients determine the sign of the responses and so offers greater insight.

2.1. Fiscal policy shock

A government expenditure shock directly raises home GDP, which through the money demand equation affects interest rates positively. This always holds in all regimes, except (3C) where $\theta_1 < (1 - \alpha_1)\phi_1$ also needs to be satisfied. An increase in interest rates affects home and foreign GDP negatively through aggregate demand (Eqs. (1-2),(1-2*)), but positively through money demand (Eqs. (1-1),(1-1*)). It is the trade off between these two effects, and in particular the sign and size of

$\beta_1\gamma_2 - \phi_1\sigma_2$, which determines the ultimate sign on the foreign GDP response (see column (1) in Table 2). In some cases the real exchange rate, see column 2, has appreciated from the point of view of the home country. Foreign goods thus become cheaper relative to home goods. How this actually feeds through to foreign GDP depends crucially on the sign and size of the other components in the foreign aggregate demand equation. The table shows that if $\beta_1\gamma_2 - \phi_1\sigma_2$ is negative in a fixed exchange rate regime where the foreign country is pegging the rate (case (3)), foreign GDP is almost always negative. In the home and foreign indexation case (D), the full homogeneity property implies that the real side of the foreign economy is not affected by monetary effects. The multipliers are the same for all exchange rate regimes and result in a fall of foreign GDP. Interestingly, in this case Δq^* is independent of any of the main multipliers δ_2, σ_2 and γ_2 which one would expect to determine foreign aggregate demand.

In this simple model the size of the spillover effect of home fiscal policy on foreign GDP can be rather big. In the symmetric case $\Delta q^*/\Delta q$ is equal to one under regime (1A), less than one in (2A)–(3A), less than one in absolute value under (B), and ambiguous and possibly even greater than one under regime (C). Under regime (D) which is most similar to existing large macro-economic models in the long run, the GDP-spillover exactly mirrors the effect on home GDP. For these cases one can argue that the sign of the foreign GDP response is not appropriate and that the size is rather large in comparison with what one would expect in reality for spillover effects. The finding is due to the strong positive impact of the interest rate which fully compensates the impact of home GDP, γ_2, and the real exchange rate, $-\delta_2\Delta\lambda$, in Eq. (1). In the asymmetric case, the spillover effect can be larger than one in all the regimes of (A)–(C). This depends mainly on the coefficients in the money demand equation, under regime (A), on γ_2 and the weights in the consumption price equation (α_1 and α_2).

Another interesting aspect is the impact of a change in some key parameters. These are shown in Table 3 where + indicates a positive, − a negative and ± an ambiguous impact on foreign GDP. Cases where the effect is zero are neglected. Three clear signs occur. A decrease in ϕ_2 increases the foreign GDP response since foreign money demand needs to be kept at the same level. As in general interest rates react positively, a decrease in σ_2 increases foreign demand. An increase in γ_2 has a direct effect on foreign GDP.

We conclude that the spillover effect of a fiscal shock in the home country on foreign GDP can be rather large in size. In the asymmetric case, it can even be larger than the effect on home GDP (in absolute value). A remarkable fact is that

Table 3
The effect of a change in some key parameters on foreign GDP

	ϕ_1	β_1	θ_1	α_1	ϕ_2	β_2	δ_2	σ_2	θ_2	α_2	γ_2
$\Delta q^*/\Delta q$	±	±	±	±	−	±	±	−	±	±	+

the coefficient γ_2 does not appear in all the spillover effects. So some spillover effects, measured in this way, are independent of the direct effect of home GDP on foreign GDP. Furthermore, the case of home and foreign indexation in any of the exchange rate regimes yields spillover responses larger than the initial domestic response.

2.2. Monetary policy shock

In Table 4, a zero indicates the cases in which it is not possible, because of the homogeneity condition, to obtain $\Delta q = 1$ by means of a money demand shock in the home country. Our first observation from Table 4 is that the remaining signs for the foreign GDP and real exchange rate responses are less ambiguous than in the previous table. A main difference with the fiscal policy shock in Table 2 is that interest rates now fall rather than increase, which leads to a depreciation (devaluation) from the point of view of the home country. There is thus a shift from foreign to home products. As the higher world interest rate depresses foreign GDP, the ultimate spillover effect on foreign GDP is negative. This is the well-known beggar-thy-neighbour result. This however only holds in the standard Mundell-Fleming model with fixed wages and floating exchange rates, i.e. case (1A). This negative spillover effect on foreign GDP is found if $\delta_1\gamma_2 - \delta_2 < 0$.[1] In all the other cases we report that the foreign GDP response is positive or zero because of the homogeneity properties of the model. Neglecting the zero cases, the real exchange rate depreciates in all cases except for regime (3C)[2], and the real interest rate decreases if $\delta_1\gamma_2 - \delta_2 < 0$ in (1A), (1B) and (3B) and $\delta_1 - \delta_2\gamma_1 < 0$ in (3C). In this simple model the size of the spillover effect from home monetary policy on foreign GDP can be rather big, as in the case of fiscal policy in Table 2. In the symmetric case, the size equals one in (3A) and is smaller than one in all other cases. In the asymmetric case however spillover effects greater than one (or smaller than minus one in (1A)) are possible.

The impact of a change in some key parameters is shown in Table 5 and corresponds only to those cases where the shock had a non-zero impact on foreign demand. Due to the fact that most entries in the first column are zero, six clear cases are found. The parameters θ_1 and α_1 appear only in regime (3C). An increase in θ_1 increases home prices in Eq. (1-3) in Table 1. The most important channel is now through the real exchange rate; an increase in home prices appreciates the real exchange rate and thus increases foreign demand. If α_1 increases, the home economy is less open, which depresses the real exchange rate response in (3C). The parameter ϕ_2 only has an impact in (1A) and due to the fixed price assumption it is negatively correlated with foreign demand. The parameters θ_2 and α_2 appear in (1B) and (3B). They each raise the foreign price,

[1] As $\gamma_1 < 1$ in McKibbin and Sachs (1991) and $\delta_1 = \delta_2$, they report a negative effect in their Table 2-2.
[2] McKibbin and Sachs (1991) report a positive effect in case (3C) whereas here clearly a negative effect is found.

Table 4
Decomposition of foreign output after a monetary policy shock

	$\Delta q^*/\Delta q$	$\Delta\lambda/\Delta q$	$\Delta i^*/\Delta q$
Fixed wages and prices in both countries			
(1A)	$\frac{\beta_2(\delta_1\gamma_2 - \delta_2)}{\beta_2(\delta_1 - \delta_2\gamma_1) + \phi_2(\delta_1\sigma_2 + \delta_2\sigma_1)}$	$\frac{\beta_2(1 - \gamma_1\gamma_2) + \phi_2(\gamma_2\sigma_1 + \sigma_2)}{\beta_2(\delta_1 - \delta_2\gamma_1) + \phi_2(\delta_1\sigma_2 + \delta_2\sigma_1)}$	$\frac{\phi_2(\delta_1\gamma_2 - \delta_2)}{\beta_2(\delta_1 - \delta_2\gamma_1) + \phi_2(\delta_1\sigma_2 + \delta_2\sigma_1)}$
(2A)	0	0	0
(3A)	$\frac{\gamma_2\sigma_1 + \sigma_2}{\sigma_1 + \gamma_1\sigma_2}$	0	$-\frac{1 - \gamma_1\gamma_2}{\sigma_1 + \gamma_1\sigma_2}$
Fixed wages and prices in the home country and foreign indexation			
(1B)	$\frac{(1 - \alpha_2)(\gamma_2\sigma_1 + \sigma_2)}{(\sigma_1 + \sigma_2\gamma_1)(1 - \alpha_2) + \theta_2(\delta_1\sigma_2 + \sigma_1\delta_2)}$	$\frac{\theta_2(\gamma_2\sigma_1 + \sigma_2)}{(\sigma_1 + \sigma_2\gamma_1)(1 - \alpha_2) + \theta_2(\delta_1\sigma_2 + \sigma_1\delta_2)}$	$\frac{\theta_2(\delta_1\gamma_2 - \delta_2) - (1 - \alpha_2)(1 - \gamma_1\gamma_2)}{(\sigma_1 + \sigma_2\gamma_1)(1 - \sigma_2) + \theta_2(\delta_1\sigma_2 + \sigma_1\delta_2)}$
(2B)	0	0	0
(3B)	$\frac{(1 - \alpha_2)(\gamma_2\sigma_1 + \sigma_2)}{(\sigma_1 + \sigma_2\gamma_1)(1 - \alpha_2) + \theta_2(\delta_1\sigma_2 + \sigma_1\delta_2)}$	$\frac{\theta_2(\gamma_2\sigma_1 + \sigma_2)}{(\sigma_1 + \sigma_2\gamma_1)(1 - \alpha_2) + \theta_2(\delta_1\sigma_2 + \sigma_1\delta_2)}$	$\frac{\theta_2(\delta_1\gamma_2 - \delta_2) - (1 - \alpha_2)(1 - \gamma_1\gamma_2)}{(\sigma_1 + \sigma_2\gamma_1)(1 - \alpha_2) + \theta_2(\delta_1\sigma_2 + \sigma_1\delta_2)}$
Home indexation and fixed wages and prices in the foreign country			
(1C)	0	0	0
(2C)	0	0	0
(3C)	$\frac{(1 - \alpha_1)(\gamma_2\sigma_1 + \sigma_2) + \theta_1(\delta_2\sigma_1 + \delta_1\sigma_2)}{(1 - \alpha_1)(\sigma_1 + \gamma_1\sigma_2)}$	$-\frac{\theta_1}{1 - \alpha_1}$	$-\frac{(1 - \alpha_1)(1 - \gamma_1\gamma_2) + \theta_1(\delta_1 - \delta_2\gamma_1)}{(1 - \alpha_1)(\sigma_1 + \gamma_1\sigma_2)}$
Home and foreign indexation			
(1D)	0	0	0
(2D)	0	0	0
(3D)	0	0	0

Table 5
The effect of a change in some key parameters on foreign GDP

	δ_1	σ_1	θ_1	α_1	ϕ_2	β_2	δ_2	σ_2	θ_2	α_2	γ_2
$\Delta q^*/\Delta q$	$\pm$	$\pm$	+	+	+	$\pm$	$\pm$	$\pm$	−	−	+

and hence boost the real exchange rate depressing foreign output. Finally, γ_2 appears in all non-zero entries of the first column of Table 4. It is positively correlated with foreign demand, which conforms intuition. The monetary shock affects home GDP and immediately feeds into the foreign GDP equation if $\gamma_2 \neq 0$. We stress again that if $\gamma_2 > \delta_2/\delta_1$ then the Mundell-Fleming beggar-thy-neighbour result no longer holds.

We conclude that the spillover effect of a monetary shock in the home country on foreign GDP is zero in the case of full price homogeneity, which is a long-run property of many empirical models. In all symmetric cases, except one where at least one country has fixed wages and prices, the absolute size of the foreign GDP response is smaller than the size of the home GDP response. The parameter γ_2 is important in the determination of the size of the shock. So monetary policy in the home country affects foreign GDP through the direct effect of home GDP. Comparing the two shock experiments, we conclude that the foreign demand response can be very large and that sometimes important transmission mechanisms are missing (γ_2) in the case of a fiscal shock. Transmission mechanisms and the sign and size of spillovers in the case of a monetary shock seem to be modelled more conform intuition.

3. Dynamic versions of the Mundell-Fleming model

The static Mundell-Fleming model in Table 1 represents a valuable starting point for constructing more sophisticated models but, as indicated by many authors, it makes many simplifying assumptions. For example, it lacks dynamics, wealth effects and expectation effects. Building these features into the model makes it more realistic but in turn more complicated and almost surely impossible to solve analytically. So if one or more of these aspects are added to the model we are limited to numerical illustrations.

In this section, the static model in Table 1 is extended by including certain dynamic and expectation effects. Intertemporal and wealth effects are not yet included but occur in the models in the next section. The model is presented in Table 6 and is similar to the one discussed by Ghosh and Masson (1994)[3], who refer to the home country as the US and the foreign country as the Rest of the

[3]Slightly different versions of the model appeared in Ghosh and Masson (1991). Other studies of estimated small multi-country models are Papell (1989) and West (1987).

World (ROW). For an extensive description of the model we refer to Ghosh and Masson (1994); parameter values can be found in their Appendix. For our purposes only the relevant aspects of the model are described here. Four versions of the model are scrutinized, indicated as Model (A)–(D). Model (A) equals Model (B) but imposes $\varphi_1 = \varphi_1^* = 1$ in Eq. (3-3) and Eq. (3-3*). Model (C) equals Model (B) but replaces Eq. (3-3) and Eq. (3-3*) by a Lucas supply curve. In Model (C) prices are therefore fully flexible, instead of sluggish, see Eqs. (3-3)′ and (3-3*)′. Model (D) differs in two respects from Model (B). First, the money demand equation is modelled in an error correction form instead of with adjustment lags only. Second, the GDP price level instead of the consumer price level is used to deflate money demand.

Apart from the inclusion of dynamics in most equations, the model resembles the static model in Table 1. The aggregate demand Eq. (3-2) corresponds to the static version in Eq. (1-2), except for a different term of the real short-term interest rate, a time trend representing exogenous growth for estimation purposes and the omission of taxes.[4] The Phillips curve in Eq. (3-3) explains GDP-prices. In Model A, the unit coefficient for φ_1 and φ_1^* indicates that there is no long-run tradeoff between GDP-growth and inflation. This contrasts with Model B, where raising GDP permanently produces accelerating rates of inflation. Furthermore Model C is New Classical in that aggregate supply depends on the domestic price level relative to the consumer price level. Unlike the static model, see Eq. (1-4), there is no wage equation. Wages are assumed to be indexed to consumer prices, i.e. $0 <= \zeta_1,\ \zeta_2 <= 1$ in Table 1, but influence the price level only sluggishly. Eqs. (3-5) and (3-6) are identical to their static versions. Eq. (3-7) is the uncovered interest rate parity condition.

As announced in the introduction we carry out a Type II fix in that the simulations are undertaken ensuring that the response of domestic GDP is kept constant, on a one percent level for a certain number of years. This enables us to interpret the spillover effects over a couple of periods in an appropriate way. The period chosen here to keep domestic GDP one percent above base level is 20 years. As before, first a domestic fiscal shock is constructed and next a domestic monetary shock. In addition the same experiments are performed for the foreign country which gives, due to the asymmetry of the model, responses that do not mirror the responses of domestic shocks.

For technical reasons a horizon of 150 years is chosen, so that simulations solve satisfactorily for the rational expectations in the model. An exogenous variable, say g, with an observation length 150 is then increased by $(a_1,\ a_2,\ldots,\ a_{20},\ 0,\ldots,\ 0)$ from its baseline. Subsequently, optimization tools are used to find those $a_i,\ i = 1,\ldots,n$ that increase domestic GDP (or foreign GDP) by one percent above baseline values for the first 20 years[5]. Sensitivity analyses are applied to check if simulation

[4]Using the same type of aggregate demand equation, Douven and Plasmans (1996) found for several EU economies, the US and Japan almost no empirical evidence for including taxes in such an equation.

[5]These analyses are carried out in MATLAB by first solving the models for the rational expectations solutions and thereafter applying Newton algorithms.

Table 6
Modified versions of the dynamic two-country Mundell-Fleming model

Model A ($\varphi_1 = \varphi^*{}_1 = 1$) and Model B	
$m - p^c = \omega_0 + \omega_1 q - \omega_2 i + \omega_3(m_{-1} - p^c_{-1})$	(3-1)
$m^* - p^{c*} = \omega^*_0 + \omega^*_1 q^* - \omega^*_2 i^* + \omega^*_3(m^*_{-1} - p^{c*}_{-1})$	(3-1*)
$q = \nu_0 + \nu_1\lambda - \nu_2(i - p_{+1} + p) + \nu_3 q^* + \nu_4 g + \nu_5 T$	(3-2)
$q^* = \nu^*_0 + \nu^*_1\lambda - \nu^*_2(i^* - p^*_{+1} + p^*) + \nu^*_3 q + \nu^*_4 g^* + \nu^*_5 T$	(3-2*)
$p - p_{-1} = \varphi_0 + \varphi_1(p^c_{-1} - p^c_{-2}) + \varphi_2(q_{-1} - \hat{q}_{-1}) + \varphi_3(q_{-1} - q_{-2})$	(3-3)
$p^* - p^*_{-1} = \varphi^*_0 + \varphi^*_1(p^{c*}_{-1} - p^{c*}_{-2}) + \varphi^*_2(q^*_{-1} - \hat{q}^*_{-1}) + \varphi^*_3(q^*_{-1} - q^*_{-2})$	(3-3*)
$p^c = \rho_1 p + (1 - \rho_1)(e + p^*)$	(3-5)
$p^{c*} = \rho^*_1 p^* + (1 - \rho^*_1)(-e + p)$	(3-5*)
$\lambda = e + p^* - p$	(3-6)
$e_{+1} = e + i - i^*$	(3-7)
Model C	
$q = \varphi_0 + \varphi_1(p^c - p) + \hat{q}$	(3-3)′
$q^* = \varphi^*_0 + \varphi^*_1(p^{c*} - p^*) + \hat{q}^*$	(3-3*)′
Model D	
$\Delta(m - p) = \omega_0 + \omega_1\Delta q - \omega_2\Delta i + \omega_3(m_{-1} - p_{-1} - \gamma_0 - \gamma_1 q + \gamma_2 i - \gamma_3 T)$	(3-1)′
$\Delta(m^* - p^*) = \omega^*_0 + \omega^*_1\Delta q^* - \omega^*_2\Delta i^* + \omega^*_3(m^*_{-1} - p^*_{-1} - \gamma^*_0 - \gamma^*_1 q^* + \gamma^*_2 i^* - \gamma^*_3 T)$	(3-1*)′

Notes: See Table 1. Δ denotes first differences; negative subscripts denote lagged values, positive subscripts denote future (expected) values.

Definitions of endogenous variables:

q = real GDP
i = short-term interest rate
e = nominal exchange rate defined as the price in domestic currency of a unit of foreign currency
λ = real exchange rate
p = price level
p^c = consumer price level

Definitions of exogenous variables:

m = nominal money balances
g = real government expenditure
T = time trend
$\hat{q}$ = potential GDP.

results are stable with respect to the choices of a 150 year horizon and a 20 year simulation period. As all four models satisfy the saddlepoint stability property (see Blanchard and Kahn, 1980), increasing both periods or taking different values for the exogenous variable after year 20, instead of 0, hardly changes the results for the first 20 years. The experiments concern:

- (1) A domestic fiscal shock which raises domestic GDP by one percent for 20 years;
- (2) A foreign fiscal shock which raises foreign GDP by one percent for 20 years;

- (3) A domestic monetary shock which raises domestic GDP by one percent for 20 years;
- (4) A foreign monetary shock which raises foreign GDP by one percent for 20 years.

The results are graphed in Figs. 1–8. Two figures each with four panels are shown for each shock. Figs. 1, 2 and 5–6 each contain (i) the size of the home shock that keeps home GDP at one percent above base for 20 years, divided by ν_4, (ii) foreign GDP and its determinants, (iii) the real interest rate, and (iv) the real exchange rate. Figs. 3,4 and 7–8 each contain the decomposition of foreign (domestic) GDP for each of the four models. For example, a fiscal shock in the domestic country results in a positive foreign GDP-spillover in the first years and negative spillovers after 5 years (see the solid line in Fig. 1(2) or Fig. 3(1), where 3 represents the figure number and (1) the panel number). The decomposition of foreign GDP is

$$\Delta_{q^*} = \nu_1^* \Delta \lambda - \nu_2^* \Delta (i^* - p_{+1}^* + p^*) + \nu_3^* \Delta_q \tag{2}$$

and graphed in Fig. 3(1). The three dashed lines thus represent: (i) $\nu_1^* \Delta \lambda$, (ii) $-\nu_2^* \Delta (i - p_{+1} + p)$, (iii) $\nu_3^* \Delta q = \nu_3^*$. Similar exercises are performed for the shocks in the foreign country. If the domestic and foreign country were symmetric in all respects, then Fig. 1 would coincide with Fig. 2, Fig. 3 with Fig. 4, etc. Further note that the exchange rate graphs, i.e. Fig. 2(4) and Fig. 5(4) are mirrored in the x-axis because of comparison reasons.

3.1. Fiscal policy shock

Fig. 1(1)–(4) and Fig. 2(1)–(4) show the results for a domestic and foreign government expenditure shock, respectively. From Fig. 1(1) it follows that for the sticky price Models (A), (B) and (D), a (positive) incremental shock is needed to keep home GDP at one percent during 20 years. In Model (C) the economy jumps immediately to the steady state and hence horizontal lines are shown in all (sub) Fig. 1(1)–(4). The fiscal shock increases interest rates which leads to an appreciation of the exchange rate from the home country's point of view. As any pressure is fully and immediately reflected in prices, the foreign price level increases more than the domestic price level and consequently instantaneously affects foreign GDP negatively. For the sticky price models, on the other hand, foreign GDP in Fig. 1(2) and Fig. 2(2) is positive in the short run but becomes negative in the medium term. As the home GDP response is equal to one during the whole period, a direct comparison with foreign GDP can be made. From Fig. 1(2) it follows that spillovers are strongly negative in Model (A) and (D), in particular in the long run. Even in the first year in these models, spillovers on foreign GDP are large. As expected, the real interest rate in Fig. 1(3) increases steadily and is positive almost everywhere. Its response is strongest with the error-correction type Model (D). The foreign real exchange rate in Fig. 1(4) is negative, i.e. it appreciates, due to the

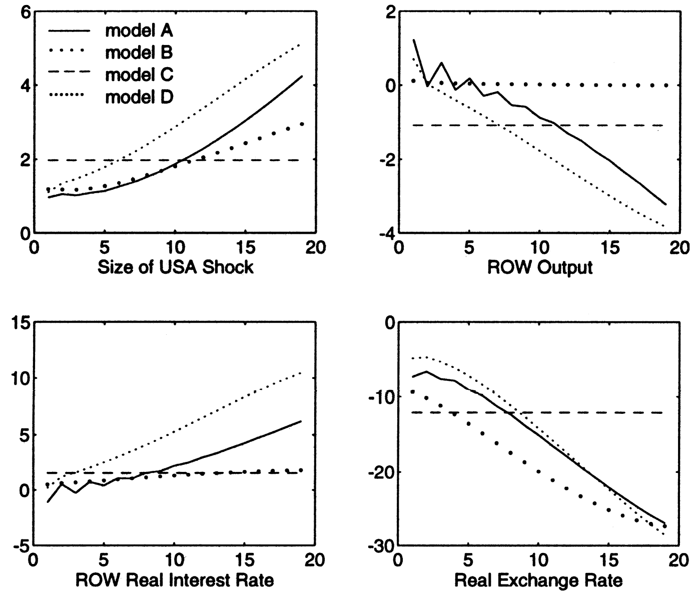

Fig. 1. Domestic fiscal shock, fixing domestic GDP at one percent above base for 20 years.

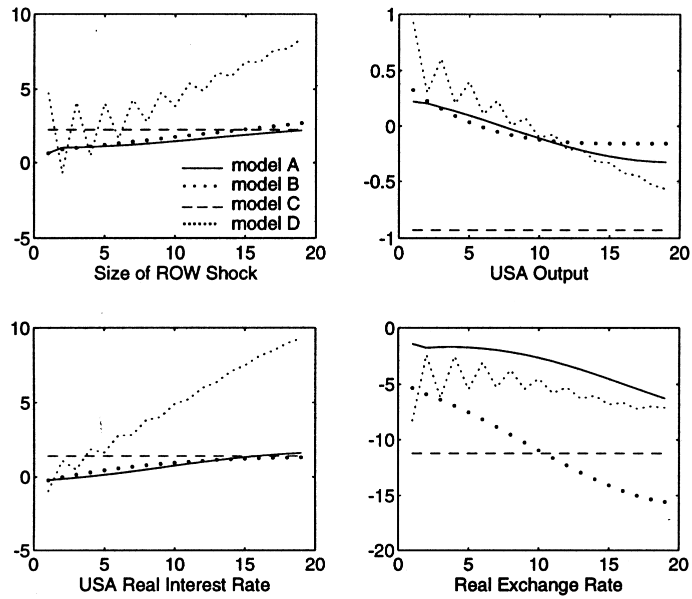

Fig. 2. Foreign fiscal shock, fixing foreign GDP at one percent above base for 20 years.

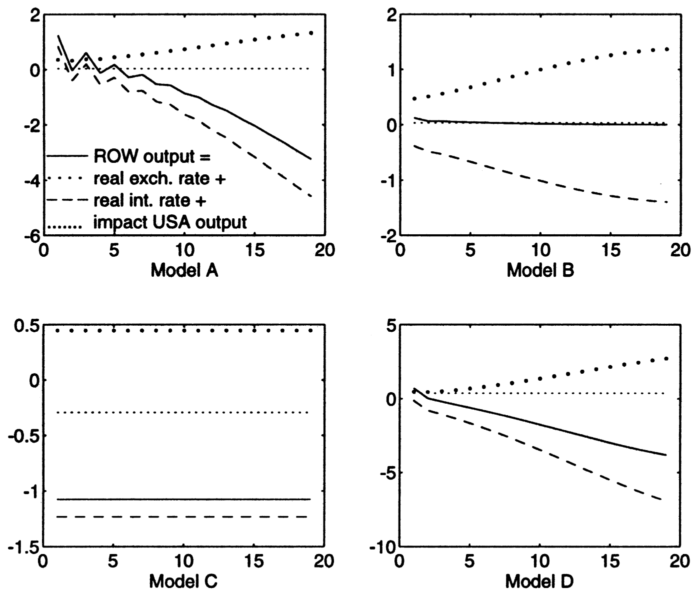

Fig. 3. Domestic fiscal shock, fixing domestic GDP at one percent above base for 20 years.

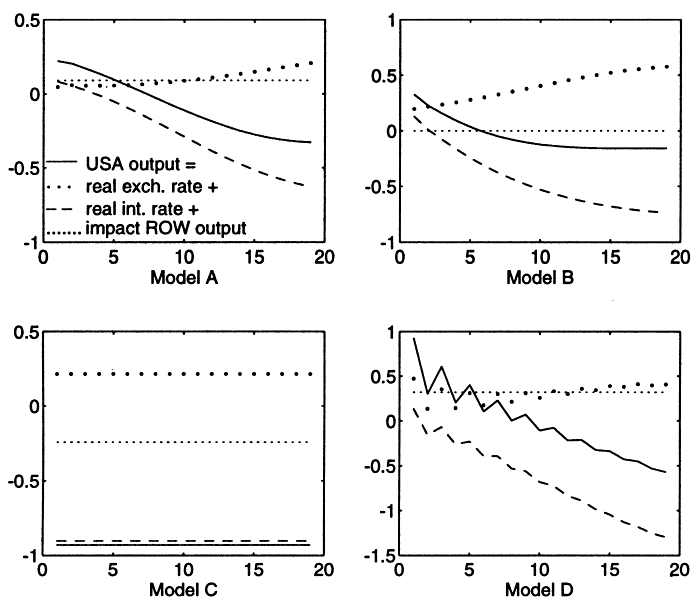

Fig. 4. Foreign fiscal shock, fixing foreign GDP at one percent above base for 20 years.

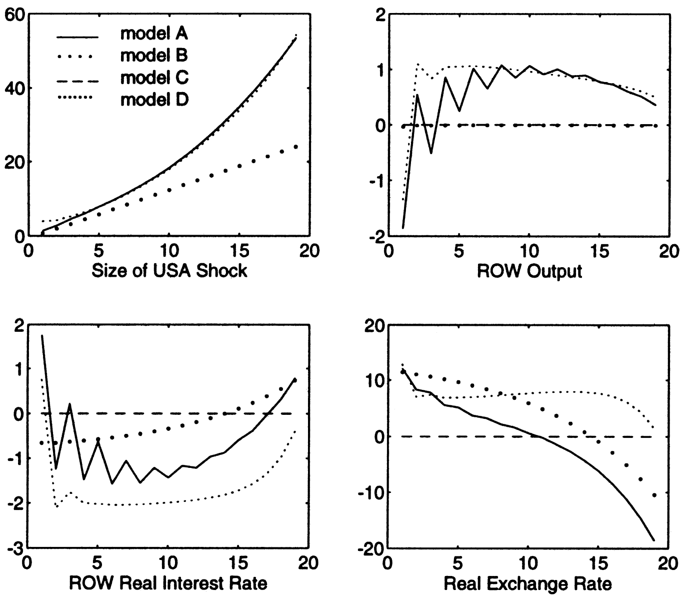

Fig. 5. Domestic monetary shock, fixing domestic GDP at one percent above base for 20 years.

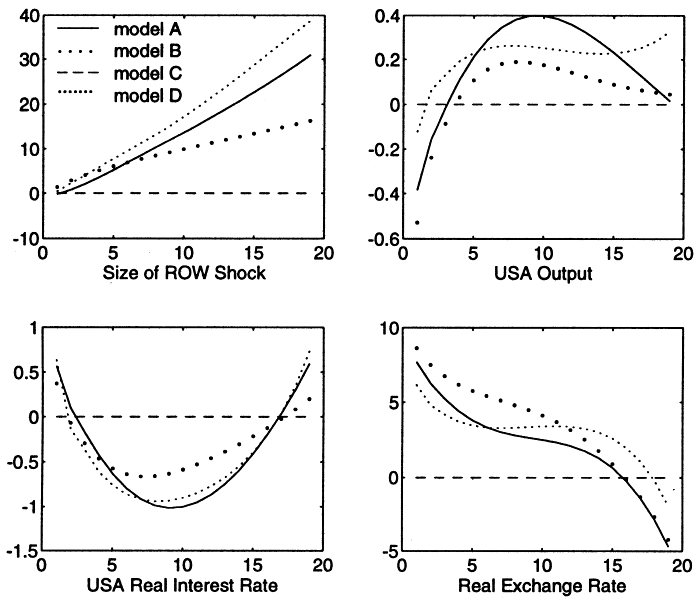

Fig. 6. Foreign monetary shock, fixing foreign GDP at one percent above base for 20 years.

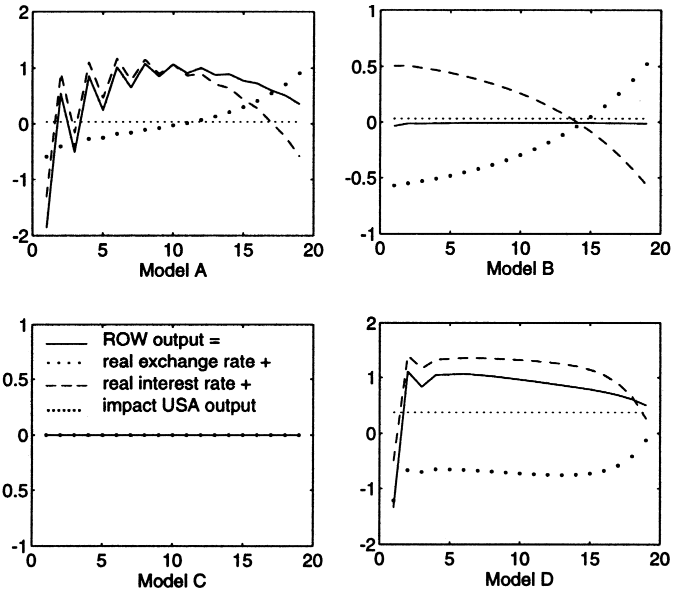

Fig. 7. Domestic monetary shock, fixing domestic GDP at one percent above base for 20 years.

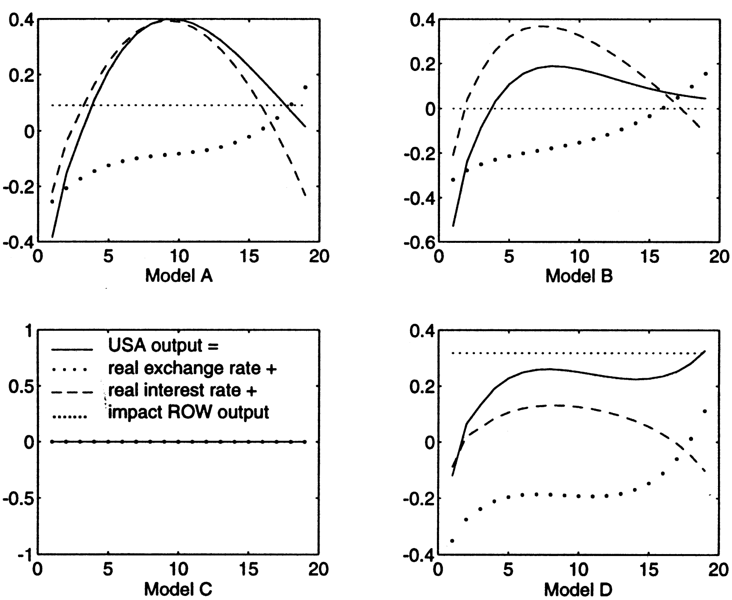

Fig. 8. Foreign monetary shock, fixing foreign GDP at one percent above base for 20 years.

increase in the interest rate. A similar story holds for Fig. 2 and, as explained above, Figs. 1 and 2 should be identical if symmetry holds.

Figs. 3 and 4 show the decomposition of the foreign GDP response. The solid line represents the total foreign GDP response, the dotted line the contribution from the real exchange rate, the dashed line the contribution from real interest rate and the closely dotted line the contribution from the domestic GDP response. In all four models it follows that the real interest rate is quantitatively most important, the real exchange rate comes next and the impact of home GDP is small. This observation can change drastically if dynamic aspects such as the adjustment lags of foreign GDP are included in the aggregate demand equation (see e.g. Douven and Plasmans, 1996).

We conclude that a fiscal policy shock that keeps home GDP at one percent above baseline values shows a constant negative spillover effect on foreign GDP in the neoclassical model. In all sticky price models this spillover is however positive in the short run, negative in the medium run and for some models even very strongly negative in the long run. All models thus show beggar-thy-neighbour-behaviour in both the medium and long run. This result is obtained by a combination of three effects. The first effect is the foreign real interest rate that increases slowly but surely to high positive values in the medium run, suppressing foreign GDP. This effect overrules the second (positive) effect, the depreciation of the real exchange rate which boosts exports and thus foreign GDP. The third effect, the positive transmission (in the sticky price models and the negative transmission in the neoclassical model) of home GDP on foreign GDP, contributes only marginally.

3.2. Monetary policy shock

Fig. 5(1)–(4) and Fig. 6(1)–(4) show the results for a domestic and foreign money demand shock, respectively. From Fig. 5(1) it follows that for Models (A), (B) and (D) a (positive) incremental shock is needed to keep home GDP at one percent above base during 20 years. As the real side of the economy is not affected if prices can adjust fully and instantaneously, a monetary shock is not possible for Model (C) and hence it is zero in Figs. 5–8. Since a change in money is neutral in all the models in the long run, huge incremental shocks in money demand are necessary in order to keep home GDP deviations at the one percent level for 20 years in the sticky price models. Fig. 5(1) shows that these shocks are about 20–50% deviations from base. The only way to offset the accumulating price effects and to keep GDP 1% above base is to print even more money. The spillover effects on foreign GDP are negative in the short run and become positive after about 2 years in all models, see Fig. 5(2). Compared to the fiscal shock experiment quantitative responses seem more realistic. No explosive behaviour is shown as domestic GDP stays between -1 and 1 for a one percent of GDP domestic shock in Fig. 5(2). Interesting results are shown in Fig. 5(3). Foreign real interest rates fall below base in the medium term. Only in the early years of the simulations do positive real interest rate responses exist for some models. The reason is that foreign inflation falls more than the negative response of the foreign nominal interest in the early years following the shock.

This observation corresponds with the Mundell-Fleming beggar-thy-neighbour result as discussed in the previous section. Foreign real interest rates increase and the real exchange rate depreciates from the point of view of the home country, see Fig. 5(4). The initial negative jump in foreign inflation peters out in the medium term and the negative impact of the nominal interest rates becomes more important. This has an ultimate negative impact on real interest rates. In the longer run these results are again reversed.

Figs. 7 and 8 show the precise decomposition of foreign GDP. In Model (A), see Fig. 7(1), the foreign real interest rate response is the main explanatory factor for the foreign GDP outcome, followed by the real exchange rate. In Model (B) and (D), the foreign real interest rate and the exchange rate explain almost an equal amount and mirror each other. Home GDP can have a substantial impact also, as follows from Fig. 8(4).

We conclude that a monetary policy shock that keeps home GDP at one percent above baseline-values shows in the short run a negative impact on foreign GDP in the sticky price models (A), (B) and (D). In the medium term foreign real interest rates show a negative response which results in positive foreign GDP-spillovers in most simulations. The size of the foreign GDP response is on average more realistic than in the fiscal policy case. The foreign real interest rate tends to be the most important component when explaining foreign GDP responses, but this result is not as clear as in the fiscal policy case. As in the fiscal policy experiment, Models (A) and (D) show somewhat larger responses in the domestic monetary shock experiment. Possibly, imposing $\varphi_1 = \varphi_1^* = 1$ in the model of Table 6 is too restrictive. Estimating these parameters might, at least with respect to GDP-spillovers, yield more realistic results.

4. Large multi-country models

The multi-country models discussed here are the MSG2 (version 42) model of McKibbin and Sachs (1991), MULTIMOD of the IMF and NiGEM of the National Institute, all made available to the ESRC Macroeconomic Modelling Bureau. As in the smaller models, spillovers in these large multi-country models occur mostly through trade, the exchange rate and interest rate mechanism. Other potentially important international transmission mechanisms such as foreign investment, labour force migration and knowledge spillover effects are not modelled. The models are however detailed in other respects. They include many countries and an elaborate set of equations per country. Moreover, they have been used by many researchers for many different purposes; e.g. Mitchell et al., 1997 undertake a comparative study. Simulations are performed for three types of shocks, namely a demand shock, a supply shock and a monetary shock. The results of these simulations are investigated for the US, (West-)Germany, France and the United Kingdom. As our interest concerns the spillovers, the responses of GDP, the real interest rate, the real effective exchange rate and the current account are presented in Tables 7–9.

Performing a Type II fix during a long period can give stability problems for some variables, hence we consider only temporary shocks, as in the previous section. As an arbitrary choice a period of 6 years is chosen. Performing a Type II fix is not an option in the software of the models, so a methodology was invented to achieve the same result. A description of the methodology as well as the presentation of the shock sizes can be found in Section 6. The results presented in Tables 7–9 concern only the first five years. The reason for omitting the sixth year is that the abrupt changes after year 6 to zero affect the simulation results in the previous six years because of the forward looking nature of the models. This impact can also be present during the first five years of the shock, but turns out to be negligible in MSG2 and NiGEM.

4.1. MSG2

The MSG2-model is described in McKibbin and Sachs (1991). We use version 42 which models each of the G7 countries, with the rest of the world divided into five regions. The model is calibrated and annual. The basic model is non-linear but the simulations are performed on a linear version of the model.

Three shocks are applied during the first six years for the US and for Germany:

- A demand shock: a government consumption shock;
- A supply shock: a value added shock;
- A monetary shock: a money (M1) stock shock by shocking the money target.

The results are presented in Table 7.

The results for the demand shock in the US show that the GDP-spillover in Germany is 0.14 in the first year and −0.63 in the fifth year, in the UK 0.13 and −0.37 and in France 0.01 and −0.54. The demand shock in Germany results in smaller spillovers in the US, being 0.01 in the first year and −0.13 in the fifth year, but larger spillovers in the UK and France, ranging from −0.28 to 0.02 and from −4.89 to 0.52, respectively. In a floating exchange rate regime, these effects are mainly due to an increasing real interest rate effect in the foreign countries. This effect overrules the positive spillovers of the current account inflow and the depreciation of the real exchange rate. The GDP-spillovers are substantial and qualitatively they resemble model (D) in Fig. 1(2) of Section 3. In the German demand shock experiment the different monetary regime of France becomes visible: France pegs its currency to the German mark, which drastically changes the results. In this pegged world, the interest parity condition states that France also has to adjust interest rates.

This results in a huge initial recession. This recession curbs inflation which in turn provides some GDP growth in the medium run.

In comparison with this demand shock, spillovers from the supply shock are much smaller. They range from −0.01 to 0.06 in the European countries after a US supply shock and from 0.00 to 0.02 in the US after a German supply shock. From Table 10 in Section 6 it follows that for fixing domestic GDP 1% above base the supply shock is more suitable than a demand shock. For example the demand

Table 7
Simulations MSG2 (version 42)

	Year	A demand shock				A supply shock				A monetary shock			
		US	GE	UK	FR	US	GE	UK	FR	US	GE	UK	FR
US shock													
GDP	1	1	0.14	0.13	0.01	1	−0.01	−0.01	−0.00	1	−0.01	−0.01	−0.00
	2	1	−0.35	−0.39	−0.39	1	0.02	0.03	0.02	1	0.02	0.03	0.02
	3	1	−0.62	−0.62	−0.59	1	0.05	0.05	0.04	1	0.04	0.05	0.03
	4	1	−0.72	−0.67	−0.64	1	0.06	0.06	0.04	1	0.05	0.06	0.03
	5	1	−0.63	−0.37	−0.54	1	0.05	0.04	0.03	1	−0.02	−0.05	−0.04
RR	1	3.66	−0.11	−0.35	0.04	0.70	0.01	0.04	0.01	0.35	0.00	0.03	−0.00
	2	2.40	0.06	−0.11	0.19	−0.20	−0.01	0.01	−0.01	0.31	−0.00	0.02	−0.01
	3	2.26	0.34	0.27	0.46	−0.22	−0.03	−0.02	−0.03	0.22	0.00	0.02	0.00
	4	3.52	0.70	0.59	0.79	−0.28	−0.04	−0.03	−0.04	−0.16	0.02	0.09	0.03
	5	6.44	1.28	1.47	1.35	−0.41	−0.07	−0.06	−0.06	−1.98	−0.07	−0.07	−0.06
RE	1	19.5	−2.15	−3.62	−2.47	−2.17	0.18	0.33	0.20	−2.24	0.13	0.30	0.15
	2	16.7	−2.10	−3.20	−2.50	−1.88	0.18	0.30	0.20	−1.99	0.14	0.27	0.15
	3	15.8	−2.01	−2.91	−2.48	−1.74	0.17	0.26	0.20	−1.87	0.12	0.23	0.14
	4	15.6	−1.88	−2.74	−2.38	−1.63	0.16	0.23	0.18	−1.75	0.10	0.18	0.10
	5	14.9	−1.70	−2.27	−2.13	−1.52	0.14	0.19	0.15	−1.34	0.03	−0.00	0.01
CA	1	−1.94	1.30	1.44	1.31	0.05	−0.07	−0.07	−0.07	−0.08	0.03	0.04	0.01
	2	−1.98	0.96	1.16	1.25	0.06	−0.05	−0.05	−0.07	−0.12	0.08	0.10	0.04
	3	−2.14	0.81	1.07	1.31	0.06	−0.03	−0.04	−0.07	−0.16	0.12	0.15	0.07
	4	−2.44	0.79	1.13	1.47	0.07	−0.02	−0.03	−0.07	−0.18	0.15	0.18	0.08
	5	−2.84	0.91	1.35	1.69	0.08	−0.02	−0.03	−0.08	−0.10	0.08	0.10	0.04
GE shock													
GDP	1	0.01	1	0.02	−4.89	0.00	1	0.01	0.31	0.00	1	0.01	0.98
	2	−0.15	1	−0.28	−2.35	0.02	1	0.04	0.18	0.02	1	0.06	0.89
	3	−0.21	1	−0.27	−0.81	0.02	1	0.05	0.08	0.02	1	0.07	0.80
	4	−0.18	1	−0.13	0.03	0.02	1	0.04	0.02	0.02	1	0.05	0.74
	5	−0.13	1	0.01	0.52	0.01	1	0.02	−0.02	0.00	1	−0.01	0.64
RR	1	−0.29	3.48	−0.83	6.08	0.03	0.65	0.11	−0.28	0.04	0.26	0.18	0.19
	2	0.03	2.31	0.27	4.31	0.01	−0.12	0.02	−0.25	−0.01	0.24	0.01	0.11
	3	0.23	1.71	0.69	2.99	−0.01	−0.11	−0.03	−0.19	−0.04	0.24	−0.08	0.09
	4	0.32	1.78	0.77	2.47	−0.02	−0.11	−0.05	−0.14	−0.08	−0.10	−0.14	0.00
	5	0.37	2.66	0.84	2.86	−0.03	−0.13	−0.06	−0.13	−0.12	1.44	−0.22	0.23
RE	1	−3.85	8.58	−7.26	2.16	0.29	−1.54	0.64	0.10	0.56	−0.95	1.35	−0.62
	2	−2.55	8.64	−3.62	−0.32	0.23	−1.55	0.43	0.26	0.49	−0.96	1.08	−0.50
	3	−1.75	8.93	−1.95	−1.73	0.18	−1.56	0.31	0.35	0.43	−1.01	0.92	−0.42
	4	−1.32	9.11	−1.30	−2.44	0.14	−1.57	0.26	0.39	0.37	−1.08	0.84	−0.36
	5	−1.04	8.93	−0.91	−2.81	0.12	−1.53	0.23	0.41	0.32	−1.05	0.75	−0.34
CA	1	0.16	−3.60	0.95	0.15	−0.01	0.27	−0.06	−0.01	−0.01	0.29	−0.13	0.04
	2	0.15	−3.36	0.67	0.37	−0.01	0.26	−0.04	−0.03	−0.01	0.30	−0.12	0.01
	3	0.13	−3.28	0.52	0.47	−0.01	0.25	−0.03	−0.03	−0.01	0.32	−0.12	−0.00
	4	0.11	−3.23	0.44	0.51	−0.01	0.24	−0.02	−0.03	−0.00	0.33	−0.11	−0.02
	5	0.10	−3.06	0.38	0.49	−0.00	0.22	−0.02	−0.03	0.00	0.41	−0.13	−0.05

GDP, gross domestic product, percentage deviation from base.
RR, real short term interest rate, in percentage point deviation from base.
RE, real effective exchange rate, in percentage deviation from base.
CA, real current account, percentage point deviation from base.

shock in Germany has to increase government expenditure by more than 5% of GDP. Since deviations in real GDP are kept constant at 1%, the remaining differences are almost completely absorbed by the current account which is around −3.5% of GDP. The inflationary pressures in Germany are suppressed by high interest rates, and as a result the German currency appreciates. All these effects are much stronger than in the case of the German supply shock and therefore spillovers are significantly larger.

The monetary shock in the US hardly spills over to the European countries, and the same holds for the spillovers to the US and the United Kingdom after a monetary shock in Germany. For both shocks the same story holds as explained for the German supply shock. Domestic effects are modest, and therefore we only find small real interest rate effects in the foreign countries, generating small spillovers. The small negative response of the current account and the small appreciation of the foreign currency after a supply shock does not seem to feed through substantially to GDP. The same holds for the German monetary shock where the small appreciation of the real effective exchange rate and the positive current account effect in the foreign countries is too small to feed through to foreign GDP.

The spillovers of a German monetary shock to France are again high; in the first year they almost equal the domestic GDP-response. This is due to the fact that the Franc is pegged to the German Mark. For example, a higher German money supply improves international competitiveness by depreciating the German currency. In Table 7, this is indicated by the negative real effective exchange rate numbers, and since the French currency is pegged we also see negative real effective exchange rate numbers for France.

In all regimes, after a German shock, French output is significantly larger than in the other two countries. This reflects the finding of Helliwell and Padmore (1985) and Whitley (1992b) that the type of monetary policy regime seems to be more important for the size and sign of the spillovers than the type of shock. The simple reason is that the foreign country which is pegging its currency has to give an additional internal shock, normally by adjusting interest rates, which in general enhances the internal effects.

4.2. MULTIMOD

MULTIMOD is described in Masson et al. (1990) and has since been updated. The version used here includes each of the G7 countries separately and small industrial countries and developing countries each as a block. The model is estimated by pooled regression and is annual.

Two shocks are applied during the first 6 years for the US and Germany:

- A demand shock: a government consumption shock;
- A supply shock: a private investment shock.

As value added (used in MSG2) again does not appear in MULTIMOD, private investment is shocked instead. Private investment directly affects GDP so one should be careful when comparing the outcomes with those of MSG2. A comparable money demand shock (as in MSG2) proved difficult to implement as the money demand equation in MULTIMOD (like in NiGEM) is dynamic, unlike in MSG2, with a low impact multiplier, resulting in problems of instrument instability. Results for the first two shocks are presented in Table 8.

The results for the demand shock in the US show that the GDP-spillover in Germany is 0.15 in the first year and −0.08 in the fifth year, in the UK −0.51 and 1.18 and in France −0.18 and 0.24. The demand shock in Germany results in smaller spillovers in the US, 0.04 in the second year to −0.01 in the fourth year, but larger spillovers (in absolute values) in the UK and France, ranging from −1.54 to 0.96 and −1.09 to 0.15, respectively. Whereas the magnitude of the demand and supply shocks differ (see Table 11, Section 6) the outcomes in Table 8 for both shocks are strikingly similar. So, concerning GDP spillovers it does not make much difference in MULTIMOD if government consumption or private investment is shocked. The MULTIMOD results differ in some respects from the MSG2 demand shock results. MULTIMOD clearly shows more asymmetries between the US and Germany. A German demand shock yields very small, positive spillovers for the US economy whereas a US demand shock produces negative spillovers for European economies. The main difference is that the real short-term interest rate of the country generating the shock is negative the first two years after the shock. This indicates that nominal interest rate adjustments in response to price increases are slower in MULTIMOD than in MSG2. This difference is reflected in the dynamics of the money demand equations which ensure that interest rates in MULTIMOD adjust more slowly to suppress inflation than in MSG2 (see also Mitchell et al. (1997)). This inflation is passed through to foreign countries which yields smaller negative GDP-spillovers for Germany in the medium term than in MSG2. This inflation effect, which in turn raises interest rates in foreign countries, is stronger than the impact on foreign GDP obtained by the expected positive effect of the depreciation of the real effective exchange rate.

There are also differences in the size of GDP-spillovers across countries. This is especially true for the UK and France. Both countries are modelled as ERM members, pegging German rates, which yields rather strong GDP-spillovers. This, again, stresses the fact that in floating regimes GDP-spillovers seem to be modest but in the case of pegged exchange rate regimes GDP-spillovers can be even stronger than the GDP-response in the country where the shock originates.

4.3. NiGEM

The NiGEM model is described in NIGEM (1996). The version used here is May 1996 which includes each of the G7 countries, in slightly less detail Spain, The Netherlands, Belgium and the rest of the world (in several blocks). In contrast to MSG2, the model is estimated and is quarterly. The results presented are the averages of the four quarters for each year.

Two shocks are implemented during the first 6 years for both the US and Germany:

Table 8
Simulations MULTIMOD (MARK II)

	Year	A demand shock				A supply shock			
		US	GE	UK	FR	US	GE	UK	FR
US shock									
GDP	1	1	0.15	− 0.51	− 0.18	1	0.14	− 0.51	− 0.19
	2	1	− 0.16	− 0.73	− 0.31	1	− 0.15	− 0.71	− 0.30
	3	1	− 0.14	− 0.25	− 0.20	1	− 0.17	− 0.26	− 0.22
	4	1	− 0.07	0.41	− 0.03	1	− 0.13	0.36	− 0.07
	5	1	− 0.08	1.18	0.24	1	0.01	1.09	0.17
RR	1	− 2.03	− 0.29	1.40	0.16	− 1.89	− 0.29	1.38	0.16
	2	− 1.48	0.01	1.18	0.39	− 1.39	0.01	1.18	0.39
	3	0.67	0.75	1.55	0.84	0.05	0.71	1.51	0.82
	4	4.54	1.88	2.20	1.21	0.04	1.74	2.09	0.15
	5	10.41	3.71	2.76	2.10	0.09	3.34	2.49	1.91
RE	1	7.99	− 1.41	− 2.09	− 1.26	7.92	− 1.41	− 2.08	− 1.27
	2	9.85	− 1.53	− 3.53	− 1.63	9.65	− 1.52	− 3.49	− 1.61
	3	11.9	− 1.71	− 4.71	− 1.96	11.64	− 1.68	− 4.65	− 1.94
	4	12.7	− 1.82	− 5.21	− 2.05	12.45	− 1.79	− 5.18	− 2.05
	5	11.0	− 1.45	− 5.20	− 1.43	11.12	− 1.50	− 5.26	− 1.52
CA	1	− 0.18	− 0.06	0.13	− 0.01	− 0.18	− 0.06	0.13	− 0.01
	2	− 0.96	0.38	− 0.08	0.03	− 0.93	0.37	− 0.07	0.03
	3	− 1.31	0.72	0.14	0.04	− 1.28	0.70	0.14	0.04
	4	− 1.71	1.10	0.34	0.08	− 1.67	1.06	0.33	0.08
	5	− 2.08	1.28	0.27	0.13	− 2.05	1.25	0.25	0.13
GE shock									
GDP	1	0.02	1	− 0.85	− 0.50	0.02	1	− 0.79	− 0.46
	2	0.04	1	− 1.54	− 1.09	0.04	1	− 1.43	1.00
	3	0.03	1	− 0.99	− 0.90	0.02	1	− 0.90	− 0.84
	4	− 0.01	1	− 0.11	− 0.51	− 0.03	1	− 0.09	− 0.51
	5	0.00	1	0.96	0.15	− 0.03	1	0.89	0.07
RR	1	0.05	− 0.40	2.78	1.55	0.05	− 0.30	2.67	1.45
	2	0.20	− 0.37	2.66	1.91	0.19	− 0.26	2.52	1.78
	3	0.38	0.15	2.41	2.13	0.36	0.16	2.23	1.93
	4	0.55	1.68	2.46	2.15	0.50	1.36	2.22	1.87
	5	0.71	3.94	1.62	1.78	0.62	3.13	1.36	1.48
RE	1	− 2.60	2.62	0.75	0.65	− 2.44	2.44	0.70	0.61
	2	− 2.21	4.39	− 0.84	0.21	− 2.05	4.03	− 0.82	0.23
	3	− 1.78	6.33	− 2.32	− 0.38	− 1.63	5.75	− 2.22	− 0.30
	4	− 1.38	7.83	− 3.51	− 1.00	− 1.27	7.08	− 3.33	− 0.85
	5	− 0.73	8.06	− 4.44	− 1.34	− 0.72	7.41	− 4.23	− 1.16
CA	1	− 0.02	− 0.82	0.41	0.08	− 0.02	− 0.78	0.39	0.04
	2	0.14	− 1.58	0.14	0.09	0.14	− 1.47	0.13	0.15
	3	0.22	− 1.94	− 0.22	0.10	0.21	− 1.80	− 0.22	0.11
	4	0.23	− 1.97	− 0.45	0.09	0.21	− 1.82	− 0.45	0.07
	5	0.23	− 1.90	− 0.55	0.08	0.06	− 1.79	− 0.99	0.06

GDP, gross domestic product, percentage deviation from base.
RR, real short term interest rate, in percentage point deviation from base.
RE, real effective exchange rate, in percentage deviation from base.
CA, real current account, percentage point deviation from base.

- A demand shock: a government consumption shock;
- A supply shock: a business investment shock.

As value added (used in MSG2) does not appear in NiGEM business investment is shocked instead. Business investment directly affects GDP, allowing comparison with MULTIMOD. The money demand shock again proved impossible to implement for the same reasons as with MULTIMOD. The results for the demand and supply shocks are presented in Table 9.

The results for the demand shock in the US show that the GDP-spillovers in Germany, the UK and France are positive. The GDP-spillovers are strongest in Germany. A demand shock in Germany generates negative spillovers, except for the first year in the US. As in MULTIMOD, spillovers from the supply shock are qualitatively similar to the demand shock. Although Germany, the UK and France are modelled in an ERM, the size of GDP-spillovers are always within range and do not show any extreme outliers (as was the case in MSG2 and MULTIMOD).

The mechanisms at work seem to be largely the same as the ones described in the previous sections. In case of a fiscal shock or supply shock, the nominal interest rate increases. As inflation is higher than the interest rate increase, the real interest rate can decrease in the short run. After a US fiscal shock the US real interest rate decreases by 0.98%-point, but after a German fiscal shock this rate in Germany increases by 0.23%-point. The dollar appreciates much more after the US-shock than the German Mark after the German shock, and the spillovers to Germany are much higher (see upper part of Table 9) than the spillovers to the US (see lower part of Table 9). After the fiscal shock the US current balance deteriorates. But again, this deterioration is less than the decrease in the current balance of Germany after the German shock.

The results are similar for MULTIMOD that show a −0.19%-point decrease for the US and a −0.82%-point decrease for Germany. The NiGEM-results differ in some respects from the MSG2-results. First, NiGEM clearly shows asymmetries between the US and Germany. For both shocks, the GDP-spillovers in Germany have the opposite sign to the GDP-spillovers in the US. Spillovers in Germany are also much stronger than the spillovers in the US. Secondly, spillovers due to the supply shock in NiGEM are close to those due to the demand shock, whereas in MSG2 spillovers are smaller. This difference might be due to the fact that in MSG2 the supply side is modelled in more detail, whereas in NiGEM it is not. The NiGEM-results resemble the MULTIMOD in that the demand and supply shocks are similar in signs and sizes. Again, this is due to the fact that the government expenditure shock as well as a business investment shock instantaneously affects GDP. It would have been preferable to perform a value added shock, as carried out in MSG2, but this is (unfortunately) not possible as the supply side is not modelled in great detail. A major difference between NiGEM and MULTIMOD is that spillovers from the USA to Germany (and UK and France) are locomotive in the former whereas they become negative after the first year in the latter. The appreciation of the dollar is stronger in MULTIMOD, but the trade-advantage for Germany, France and the UK is longer lasting in NiGEM. This is probably due to the stronger dynamics in NiGEM.

Table 9
Simulations NiGEM (May 1996)

	Year	A demand shock				A supply shock			
		US	GE	UK	FR	US	GE	UK	FR
US shock									
GDP	1	1	0.18	0.10	0.08	1	0.20	0.12	0.09
	2	1	0.22	0.10	0.12	1	0.22	0.11	0.12
	3	1	0.24	0.11	0.14	1	0.22	0.09	0.13
	4	1	0.28	0.11	0.17	1	0.23	0.07	0.14
	5	1	0.32	0.13	0.20	1	0.25	0.06	0.15
RR	1	−0.98	0.01	−0.03	−0.03	−0.89	0.01	−0.03	−0.05
	2	−0.76	0.00	−0.02	−0.02	−0.67	−0.00	−0.03	−0.02
	3	−0.44	−0.01	−0.02	−0.02	−0.35	−0.02	−0.03	−0.03
	4	−0.16	−0.02	−0.02	−0.02	−0.06	−0.03	−0.03	−0.03
	5	−0.01	−0.03	−0.02	−0.02	0.10	−0.03	−0.03	−0.03
RE	1	1.24	−0.17	−0.2	−0.11	1.70	−0.24	−0.29	−0.15
	2	1.69	−0.23	−0.27	−0.14	2.08	−0.28	−0.34	−0.18
	3	1.49	−0.18	−0.24	−0.12	1.79	−0.22	−0.29	−0.14
	4	1.12	−0.10	−0.18	−0.08	1.34	−0.13	−0.22	−0.09
	5	0.68	−0.01	−0.12	−0.02	0.85	−0.04	−0.15	−0.03
CA	1	−0.19	0.04	0.09	0.06	−0.17	0.04	0.09	0.07
	2	−0.22	0.06	0.12	0.08	−0.21	0.06	0.13	0.09
	3	−0.25	0.08	0.14	0.10	−0.24	0.08	0.15	0.11
	4	−0.28	0.09	0.16	0.11	−0.28	0.09	0.17	0.12
	5	−0.31	0.11	0.17	0.13	−0.31	0.11	0.19	0.14
GE shock									
GDP	1	0.01	1	−0.10	−0.03	0.00	1	−0.16	−0.07
	2	−0.03	1	−0.28	−0.08	−0.07	1	−0.43	−0.17
	3	−0.05	1	−0.36	−0.08	−0.11	1	−0.59	−0.21
	4	−0.06	1	−0.38	−0.04	−0.14	1	−0.66	−0.2
	5	−0.06	1	−0.32	0.04	−0.16	1	−0.65	−0.14
RR	1	−0.12	0.23	0.30	0.31	0.25	0.03	0.35	−0.03
	2	−0.11	0.12	0.32	0.29	0.14	0.37	0.32	−0.01
	3	−0.09	0.05	0.35	0.30	0.07	0.40	0.34	0.00
	4	−0.07	0.00	0.37	0.32	0.01	0.44	0.36	0.02
	5	−0.07	−0.03	0.40	0.34	−0.02	0.47	0.39	0.02
RE	1	−0.46	0.19	0.27	0.15	−0.72	0.32	0.43	0.23
	2	−0.32	0.32	0.10	0.05	−0.57	0.45	0.22	0.11
	3	−0.15	0.68	−0.16	−0.11	−0.36	0.83	−0.12	−0.08
	4	0.05	1.11	−0.49	−0.29	−0.10	1.29	−0.54	−0.30
	5	0.25	1.51	−0.83	−0.45	0.15	1.73	−0.98	−0.52
CA	1	−0.01	−0.39	0.10	0.04	−0.03	−0.41	0.11	0.03
	2	−0.00	0.44	0.13	0.05	−0.01	−0.49	0.14	0.05
	3	0.01	−0.49	0.15	0.07	0.00	−0.54	0.17	0.06
	4	0.02	−0.52	0.18	0.07	0.02	−0.58	0.20	0.07
	5	0.02	−0.55	0.20	0.08	0.02	−0.62	0.24	0.08

GDP, gross domestic product, percentage deviation from base.
RR, real short term interest rate, in percentage point deviation from base.
RE, real effective exchange rate, in percentage deviation from base.
CA, real current account, percentage point deviation from base.

5. Conclusions

In global economic modelling there is a growing interest in 'spillovers', defined as the disturbances in foreign countries that result from policy actions in a home country. The theoretical Mundell-Fleming model with sticky wages and prices provides the foundation of most empirical models, and its predictions are well known: fiscal policy tends to be 'locomotive', with positive spillovers, whereas monetary policy is 'beggar-thy-neighbour', with negative spillovers. However studies of empirical dynamic models show wide variation in the sign and sizes of spillovers. A particular difficulty is that a precise way to measure spillovers over more than one period has never been given.

In this paper a new measure for determining GDP-spillovers is proposed. This measure is the response of foreign GDP when GDP of the country in which the shock originates is fixed at a 1% level above base for a certain number of years. It is calculated using a diagnostic Type II fix. The advantage of the proposed spillover measure is that specific variables of interest can be compared precisely over a longer simulation period.

Simulations are performed on small static models, small dynamic models and three large-scale calibrated or estimated models: MSG2,MULTIMOD and NiGEM. In the small Mundell-Fleming type models under floating exchange rates, fiscal policy yields a positive GDP-spillover in the first year but increasingly negative spillovers in subsequent years. These results are confirmed by MSG2 and MULTIMOD. In general it was found that in the empirical models under floating exchange rates GDP spillovers tend to be small, whereas under pegged exchange rates GDP spillovers can sometimes be huge. Under pegged exchange rates these spillovers sometimes exceed in size the GDP response of the country where the shock originates.

In the theoretical models under floating exchange rates monetary policy, effected by changing the money base, yields a negative GDP-spillover in the first year but positive spillovers in subsequent years, eventually returning to base. These results are confirmed by the calibrated MSG2 model, although the responses are weak. Attempts to carry out a similar experiment on the two estimated models, MULTIMOD and NIGEM, ran into difficulties, since the monetary base is not an effective instrument to keep GDP at a certain percentage above base during more than one period in these models.

In general, in all types of models the foreign real interest rate is found to represent an important transmission mechanism; the contribution to GDP-spillovers arising from trade effects is found to be small. In empirical models it was found that under floating exchange rates spillovers are much smaller than under pegged exchange rates. These results confirm the analysis of Roubini (1991), using an older version of the MSG model, that structural spillover effects are small and that most spillover effects are rather policy-induced. For example, strong policy induced spillover occur if the foreign country follows a policy to peg parities with the country where the shock originates. We also found some indication that under floating exchange rate regimes spillovers in small (dynamic) models tend to be larger than in large empirical models.

To summarize, the overall results confirm economic intuition that spillovers are non-negligible and throw a different light on existing studies with multi-country models that show only tiny spillovers.

6. Construction of Type II fixes

The MULTIMOD-Type-II-fixes have been carried out by optimal control, i.e. an additional equation is added to the model by which GDP-deviations from a one percent deviation from base of GDP are punished. This is easy to perform with MULTIMOD. For MSG2 and NiGEM carrying out a Type II fix is more cumbersome as these models run in their own software and for this reason are carried out as follows.

To perform a Type II fix for n periods, first a shock is applied for each of the n periods. The partial derivative is then calculated by which the size of the shock needed for the Type II fix can be determined. To give an example, assume $n = 2$, and a shock g with response y. Shocking g by a_1 in the first period gives a certain response in y, say b_{11} in the first period and b_{12} in second period, and subsequently shocking g in the second period by a_2 gives b_{21} and b_{22} in the first and second period. This can be formalized as

$$\begin{aligned} (a_1\ 0)g &\quad\rightarrow\quad (b_{11}\ b_{12})y, \\ (0\ a_2)g &\quad\rightarrow\quad (b_{21}\ b_{22})y, \end{aligned} \tag{3}$$

where g and y are two-dimensional vectors. From this follows

$$\begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix}^{-1} \begin{pmatrix} a_1 & 0 \\ 0 & a_2 \end{pmatrix} g \rightarrow y. \tag{4}$$

The shock size ensuring a one percent increase in y then is

$$\frac{a_1(b_{22} - b_{21})}{b_{11}^{*} b_{22} - b_{12}^{*} b_{21}} \quad \text{and} \quad \frac{a_2(b_{11} - b_{12})}{b_{11}^{*} b_{22} - b_{12}^{*} b_{21}} \tag{5}$$

in the first and second period, respectively.

If there is no forward looking behaviour, $b_{21} = 0$. If a temporary shock only has a temporary (instantaneous) effect, also $b_{12} = 0$. In the case where $b_{21} = b_{12} = 0$, the shock size for a one percent Type II fix is thus a_1/b_{11} in the first period and a_2/b_{22} in the second period. However, in the case of forward looking behaviour or responses that last longer than only the current period the calculation of the shock is evidently more complicated; it is no longer possible to divide merely the vector on the left hand side of the arrow in Eq. (4) by the vector on the right hand side of this arrow[6]. This shows that obtaining a Type II fix is not a straightforward procedure in models with rational expectations and/or dynamic specifications. This also shows that the comparison of GDP responses of two countries, say country A and B, is not merely possible by a division of the GDP-responses of country A by those of country B. A one percent increase in GDP as a deviation from base is constructed in our analysis, and hence can be directly compared across countries.

Our objective is a 6 years Type II fix in GDP. Thus first six shocks are performed in MSG2, and then the size of the shock that gives a one percent increase in GDP during the first 6 years is calculated. As MSG2 is linearized and behaves well, no problems were encountered when carrying out this exercise. NiGEM is a quarterly model, so 24 shocks need to be performed to achieve the objective. For the government consumption and business investment shock no problems arose. For the money demand shock, on the other hand, some insurmountable problems occurred. First, the equation is dynamic by which a one percent increase in the first year is not achievable. Second, the money multiplier turns out to be very small for the US as well as for Germany. So very large shocks are necessary to obtain a one percent increase in GDP. This seems to lead to stability problems, in particular for Germany (see also Turner et al. (1989)).

Tables 10–12 report the sizes of the exogenous shock performed in Tables 7–9, respectively.

Acknowledgements

This research was undertaken at the ESRC Macroeconomic Modelling Bureau at the University of Warwick with the support of the Leverhulme Trust and HCM

Table 10
The shocks in MSG2 (as percentage of GDP) resulting in 1% increase in GDP during 6 years

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Years 7–50
US							
A demand shock	5.39	5.37	5.68	6.17	6.59	7.06	0
A supply shock	1.00	0.64	0.68	0.70	0.72	0.69	0
A monetary shock	0.94	1.95	3.52	5.74	9.25	21.3	0
Germany							
A demand shock	5.69	5.33	5.24	5.26	5.20	4.67	0
A supply shock	1.01	0.66	0.70	0.74	0.75	0.84	0
A monetary shock	1.01	1.94	3.24	5.00	6.23	21.4	0

[6] This would only be possible if the division is by the same amount in each period.

Table 11
The shocks in MULTIMOD (as a percentage of GDP) resulting in a 1% increase in GDP during 6 years

	Year 1	Year 2	Year 3	Year 4	Year 5	Years 6–50
US						
A demand shock	13.57	25.55	40.10	52.37	59.79	0
A supply shock	11.21	22.31	28.96	32.96	34.33	0
Germany						
A demand shock	17.38	32.37	42.07	50.12	53.79	0
A supply shock	5.02	7.46	10.18	11.93	12.21	0

Table 12
The shocks in NiGEM (as a percentage of GDP) resulting in a 1% increase in GDP during six years

Quarter	US		GE	
	Demand	Supply	Demand	Supply
1.1	6.39	10.03	15.23	5.45
1.2	7.35	11.42	16.14	6.23
1.3	8.26	12.53	16.67	6.94
1.4	9.45	13.86	17.68	7.76
2.1	10.69	14.88	18.66	8.62
2.2	11.57	15.59	19.46	9.48
2.3	12.39	16.13	19.80	10.22
2.4	13.19	16.58	19.96	10.89
3.1	13.93	16.88	20.25	11.57
3.2	14.61	17.02	20.55	12.25
3.3	15.33	17.16	20.82	12.94
3.4	15.96	17.18	20.96	13.56
4.1	16.58	17.08	21.30	14.21
4.2	17.15	16.93	21.49	14.79
4.3	17.73	16.83	21.92	15.42
4.4	18.24	16.58	22.21	15.98
5.1	18.73	16.38	22.62	16.60
5.2	19.26	16.16	23.04	17.20
5.3	19.70	15.91	23.43	17.80
5.4	20.09	15.62	23.86	18.38
6.1	20.50	15.35	24.37	19.00
6.2	20.90	15.12	24.79	19.55
6.3	21.26	14.87	25.27	20.14
6.4	21.70	14.70	25.61	20.66
7.1–23.1	0	0	0	0

Research Fellowships from the European Community. For comments on the paper we thank Kenneth Wallis. For help and advice on the simulation results of the macroeconomic models we gratefully acknowledge Pete Mitchell and Joanne Sault.

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