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The Specification, Estimation, and Simulation of a Small Global Macroeconomic Model

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Abstract

This report describes the structure and simulation properties of a small global macroeconomic model (SGM). Simulation experiments comparing SGM results with those of other world models suggest that SGM is a viable tool for macroeconomic policy analysis.

Keywords: Forecasting, macroeconomic model, multipliers, simulation

Preface

Earlier versions of this report have been presented to the Seventh International Conference on Mathematical and Computer Modelling, Chicago, August 2-5, 1989, and to the Economic and Social Research Council Macroeconomic Modelling Bureau Conference, University of Warwick, England, July 4-6, 1989. The author thanks the participants from both conferences for their valuable comments.

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Overview of the Small Global Model

The small global model described in this report has been developed as part of a joint international research agreement between U.S. Department of Agriculture's Economic Research Service (USDA-ERS), and the University of Glasgow's Department of Political Economy. ERS uses the model to provide macroeconomic intelligence to a variety of internal and external bodies, including the private, public, and university sectors. In addition, the model is used biannually in conjunction with assumptions from the U.S. Department of Energy and the Council of Economic Advisors to produce forecasts to the year 2000 for the USDA.

In specifying the model, simple, theoretically plausible relationships have been set out to provide a basis for estimation where robust, parameter-constant equation estimates can be derived. The goal is accuracy in forecasting and economically reasonable simulation properties. As far as possible, a similar structural framework has been used in each country, facilitating cross-country comparisons. Differences between countries are viewed as originating in different parameter values, including different zero restrictions.

The model comprises a small number of structural equations together with some reduced-form equations and reaction functions. These describe aggregate demand, supply, and the current account in each of the five included countries. SGM covers only the United States and its four largest trading partners: the United Kingdom (U.K.), Canada, Japan, and West Germany, plus a rest-of-world (ROW) aggregate. The core of SGM is Keynesian in character in the sense that it adopts domestic consumption and investment disaggregation of expenditure and, as in Marris (1987)[1], relies on the Keynesian concept of macroeconomic equilibrium to link the budget, private, and trade balances. The model thus constructed, however, can incorporate ideas from a wide range of schools of thought. For example, there is room for the expression of supply-side influences in the model through exogenous changes in potential output.

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[1]Citations listed in References.

Trade volumes and prices are disaggregated into fuels, manufacturing, primary, and nonfactor services. Trade linkages between countries make use of a combination of time series modeling and a fixed-trade shares matrix for each commodity. This method of determining trade volumes and prices is based on the Samuelson-Kurihara (1980) approach and has also been applied in the LINK, COMPACT, INTERLINK, WHARTON, and FAIR models.

In the present form of SGM, expectations are backward-looking. The private sector thus does not react immediately to policy changes. This is not meant to indicate that we preclude the use of model-consistent expectations but rather that we feel that this may be on the agenda for future research. It is worth noting, however, that examination of the reported fiscal and monetary multipliers in tables 1 and 2 does not provide an easy basis for discrimination between models which use backward-looking and those which use forward-looking expectations.

Equation Specification, Estimation, and Evaluation

Our estimation strategy is broadly based on the London School of Economics methodology described in Spanos (1986).[2] All structural relationships are estimated in logged first differences and contain an error correction mechanism (ECM) if the data permit. Not only does ECM ensure theoretical consistency, but it also goes a long way to meeting the requirements of those who wish to acknowledge the possibility of rational expectations (see Muscatelli for discussion of this equivalence in the context of the demand for money). We generally exclude constant terms in logged first-difference equations except in a few cases where structural change is suspected to have resulted in some residual time trending in the long run.

The model is estimated using annual data, spanning 1960-86, drawn from the world database developed by Wharton Econometric Forecasting Associates. There are 646 equations in the model, including behavioral equations, identities, and trade share matrices. Even though such a model is small by the standards of, for example, the Federal Reserve Board's MCM and the LINK models, it is still a large undertaking which requires a careful strategy to ensure consistency of estimates, solvability, and, perhaps most important, easy access to a wide range of interested researchers and policymakers. The relatively small number of behavioral equations also required that estimated relationships pass a stringent battery of diagnostic tests.

In undertaking model design, we attempted to be as comprehensive as possible in terms of examining a wide range of single-equation diagnostics. The individual equation properties we attempted to obtain included good overall equation fit, plausible parameter values relative to those suggested by economic theory, absence of

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[2]Refer to Malley, Foster, and Bell (1988a), section D, for a detailed discussion of the estimation strategy used in SGM.

residual autocorrelation and heteroscedasticity, and parameter constancy. In addition to the standard diagnostics routinely reported in typical regression packages, we also recorded a selection of relevant diagnostics used in the LSE tradition.[3] The model was solved on the personal computer-based Glasgow University Modelling System (Bell).

Model Structure

Tables 1 and 2 present a stylized version of SGM which highlights the transmission mechanisms of fiscal and monetary policy. The notation has been simplified to exclude country detail, commodity detail, and functional form.

Goods Market

In the goods market, real consumer expenditure (C) is based on the approach of Davidson, Hendry, Srba, and Yeo (1978). Disposable income (Yd) is the difference between gross domestic product (Y) and taxes net of government transfers and subsidies. Nominal interest rates also enter the equation to capture the effects of the cost of borrowing on durable consumption. All consumption functions, with the exception of Japan, were estimated using the ECM specification. The longrun marginal propensities to consume implied for each country, assuming steady-state Yd growth of 2 percent, are U.S.= 0.85, U.K. = 0.82, Canada = 0.77, and West Germany = 0.73. As expected, these estimates indicate the relatively low saving propensities in the United States and high propensities in West Germany. The United Kingdom was the only country in which the inflation variable was accepted by the data. It was decided to opt, however, in the U.K. case for an equation which included an interest-rate term only. We made this decision because there was little to choose in overall equation fit between these two specifications.

Real fixed investment (IF) is based on the modified-accelerator approach and is driven by the change in GDP with the nominal long-term interest rate acting as a cost of capital add-on. Inventory investment (II) is based on the simple stock adjustment model with inventory change determined as a constant share of the change in GDP.

Total government expenditure (G), which includes consumption (GC) and investment expenditure (GI), is exogenous. Unlike all other countries in SGM, the United States does not disaggregate G in its national income and product accounts into consumption and investment. In order to facilitate comparability across countries in SGM, government spending in the calculation of budget deficits is defined in terms of total G.

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[3]Refer to Malley, Foster, and Bell (1988b) for a discussion of which regression diagnostics were used and the single-equation estimates.

Imports and Exports

Real imports (M) include imports of fuels, manufacturing, primary, and nonfactor services. Each of these commodities is modelled as a function of domestic demand (DY = C+I) and relative import (MP) to overall domestic prices (P). The import price is specific to the particular commodity and the domestic price is the domestic GDP deflator. The ECM was tried for each commodity but with relatively little success. This is hardly surprising since the unit elastic longrun constraint adopted in the ECM is unlikely to hold over a period where world trade as a proportion of GDP has grown consistently.

The kth commodity import price index (MPk) for a particular country is derived by:

(1) solving for the trade-weighted average of nominal dollar valued export prices of all other countries,

(2) rebasing the index to 1980, and

(3) converting the index to local currency units by that country's nominal exchange rate (ER) with the dollar.

The exchange rate is defined in terms of U.S. dollars per local currency units. Commodity-specific export prices (XPk) are driven by domestic prices and commodity specific world prices (WPk).

A 1986 fixed-trade-shares matrix (S) for each good is used to derive a nominal country-by-country trade-flows matrix (T).[4] Matrix S shows the share of total nominal imports for a good that each country imports from each of its trading partners. Matrix T is derived by multiplying a country's nominal commodity imports by its corresponding row vector in S. Each row in S sums to 1 which implies that each row in T equals a country's total imports from all countries.

Nominal dollar-valued commodity-specific exports by country are elements of the column vectors in T. In other words, the imports of country 1 from country 2 must equal the exports of country 2 to country 1. Therefore, total nominal commodity-specific exports for a country can be derived by summing down the columns of T. Local currency exports are then derived by dividing the column sum by that country's nominal exchange rate with the dollar. Real exports (X) are derived as the sum of nominal exports across commodities each divided by their corresponding export price index (XPk).

Monetary Sector

Rather than modelling demand and supplies of money, it was decided that a quasi-reduced form approach would be adopted for the

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[4]The shares were calculated from OECD series C, Foreign Trade by Commodities and have all been converted to a F.O.B. basis.

monetary sector where interest rate equations are estimated directly, using variables suggested by theory but allowing the data to generate dynamic specifications (Malley, Foster, and Bell 1988a). Since these are reduced-form equations of price variables, where expectations are clearly important, we do not adopt the ECM strategy.

The overall strategy in modelling interest rates is to treat the United States, as the largest economy, as determining its interest rates independently of the other economies. The others, to some degree, have their rates influenced by rates prevailing in the United States. Thus, U.S. monetary policy influences other countries' monetary conditions directly. Short-term interest rates (Rs) are driven by monetary growth (MS), demand pressure (Y/PY), and long-term inflation (P). All countries except the United States also contain an argument for the short-term U.S. interest rate. Long-term interest rates (Rl) are driven by the same set of arguments as the short-term interest rates with the exception of MS. A feature of the interest rate estimations worth noting is the relatively low longrun elasticity of U.S. Rs (0.12) and Rl (0.02), with respect to demand pressure. These estimates imply a relatively flat U.S. LM curve. On the other hand, U.S. interest rate responsiveness to money supply growth and inflation is much higher. In Rs, the longrun partial elasticities with respect to these variables are -1.38 and 1.64. In Rl, the longrun elasticity with respect to inflation is 0.55. The slope of the U.S. LM has quite a significant effect on overall model properties.

Inflation is another price variable which is modelled as a quasi-reduced form, without the use of ECM, for the same reasons as in the case of interest rates. The key explanatory variables in the inflation specification are Y/PY and the growth in import prices (MP) (Monaco 1988). In addition, past inflation is used to proxy inflation expectations (Pe). Obviously, this is a key equation where the adoption of forward-looking expectations would affect model properties.

Exchange Rates

Currently, nominal exchange rates (ER) are modelled as reaction functions and include differences in demand (Y-Y'), prices (P-P'), and current accounts CA-(CA'/ER[80]) as explanatory variables (Fair).[5] Since ER is defined in terms of U.S. dollar/local currency units, an increase in this ratio implies a depreciation of the U.S. dollar and an appreciation of the local currency. In SGM there are n-2 exchange rates since the U.S. rate with itself is one and the ROW block is denominated in dollars. The signs on the coefficients are consistent with the following story about exchange rate determination. The relative demand variable should

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[5]The exchange rates were estimated over the 1973-86 period. In future research, we are considering adopting the uncovered interest parity approach to exchange rate determination.

be negative, since a relative increase in non-U.S. GDP leads to an increase in the demand for U.S. goods and, in turn, an increased demand for U.S. dollars. The appreciation of the U.S. dollar implies a depreciation of the non-U.S. currency. The expected sign on relative inflation differences is also negative, since a relative increase in the price on non-U.S. goods leads to lower demand for those goods and, in turn, a lower demand for that currency. Finally, the term for nominal current account differences should have a positive sign. In this case, a relative increase in non-U.S. net external wealth implies a greater overall demand for that country's financial assets and goods. As in Fair (1984), the U.S. current account in the equation is calculated in 1980 local currency units. This calculation avoids having a nominal exchange rate implicitly appearing on the right side of the exchange rate equations. In addition, the dollar/Deutshe Mark rate is an argument in the U.K. and Japanese exchange rate equations. In these cases, the DM is viewed as an important world currency which has influence in exchange rate determination. This argument has a positive sign in both equations, indicating that as the dollar depreciates relative to the DM, agents leave the dollar and move into other safe currencies, for example, the pound and the yen.

The nominal current account (CA) is the sum of nominal exports less imports plus net factor services (NF), which include net interest, profits, and dividend flows. The change in NF is, in turn, driven by a distributed lag of the CA.

Model Simulation

This section places the model results of SGM in perspective by comparing them with the results of the world models who took part in the 1986 Brookings Institution workshop on applied macro-economic modelling (Bryant, Henderson, Holtham, Hooper, and Symansky). In the discussion which follows, I will concentrate on U.S. own-country responses and selected foreign responses to U.S. policy changes. Model multipliers are derived in the usual way from dynamic simulations over a 5-year period.[6]

The monetary and fiscal shocks applied to SGM are the same as those applied in the Brookings workshop. The monetary shock consists of a phased-in expansion of the nominal money supply of 2 percent over base levels in the first year and a 4-percent sustained shock for the remaining years of the simulation. The fiscal shock takes the form of a decrease in Federal Government spending equal to 1 percent of base GNP. In SGM, we shock total government spending by a sustained 1 percent of base GDP.

[6]The use of dynamic simulation is not without its critics (see, for example, Pagan, 1987a). For the moment, however, we proceed in the usual fashion.

After considerable effort to obtain a uniform baseline across models in the Brookings workshop, the workshop organizers eventually had to abandon this goal and assume that their models were approximately linear. In other words, the derived model multipliers are assumed to be independent of the starting-solution value. Producing a common baseline was a problem for the EEC, LINK, and WHARTON models. In addition, those models using forward-looking, model-consistent expectations (LIVERPOOL, MINIMODR, MSG, and TAYLOR models) also had trouble producing a common baseline. (Refer to table 9 for a list of the models participating in the Brookings workshop). We also apply the assumption that the SGM model is approximately linear and, therefore, run our multiplier analysis over history. Preliminary sensitivity analysis on SGM suggests that this is not an inappropriate assumption.

In the Brookings workshop, the models disagreed considerably about the effect on foreign output resulting from a monetary expansion and the effect on exchange rates resulting from a fiscal contraction.[7]

Monetary Shocks

Standard macroeconomic theory suggests that in the short run a monetary expansion should cause a fall in domestic interest rates, a rise in domestic GDP and prices, and a depreciation of the domestic currency. SGM results follow this pattern, as do most of the models in the Brookings workshop. Table 3 presents results in terms of deviations between shocked and baseline values. There are considerable differences, however, in the magnitude of response of Rs in the short run to a change in the money supply. The average decline in Rs, over all models in the Brookings workshop, in the first year is approximately -2 percentage points (%pts.). The MCKIBB, DRI, and OECD models displayed extremely large impacts with declines of 6.7, 4.4 and 3.6 %pts. respectively. SGM'S impact multiplier on Rs, of -1.3 %pts., is either half a point higher or lower than the following models: EEC model (-1.2 %pts.), MINIMODR (-1.9 %pts.), VAR (-1.8 %pts.), LINK (-0.7 %pts.). In the last 2 years of the simulation, Rs in SGM starts to rise. This is because the upward pressure on RS via demand pressure and inflation dominates the downward pressure on RS via the monetary expansion. Inflation is increasing because of higher income and import prices resulting from the lower-valued dollar.

The average U.S. GDP response to the money shock across all models participating in the Brookings workshop was 0.75 percent from base in the first year, 1.25 percent by the third year and approximately 0.85 by the fifth year. The dissimilar interest rate responses in the MCKIBB, DRI, and OECD models naturally led to GDP responses which were also quite different than the averages in the Brookings workshop. For example, the MCKIBB model predicts high initial changes in GDP (2.5 percent), which is about 1.75

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[7]See Frankel, chapter 2 and Bryant, chapters 3 and 4.

%pts. higher than the average. Other models producing unusual GDP results include the LIVERPOOL model, which actually predicted falling GDP relative to base in the last 3 years of the simulation, and EPA, which predicted falling GDP in the last year. The SGM results for U.S. GDP were most like those of Project LINK. Both models predicted GDP to be 2.5 percent higher than the base by the fifth year of the simulation. Both models also start with small initial differences in GDP from the base, with these effects growing through the run and slowing by the end of the simulation.

Besides DRI in the first year and LINK in all 5 years, all models produce price level increases. LIVERPOOL clearly has the greatest impact multiplier on P (1.8 percent). This result, in conjunction with LIVERPOOL'S GDP impact results (0.6 percent), suggests that the LIVERPOOL model has a very steep aggregate supply (AS) curve. The LIVERPOOL results are certainly not standard since an increase in the MS in the first year leads to higher Rs, GDP, and P. This is explained by the fact that LIVERPOOL has very strong wealth effects. Their results might be characterized as follows: increase the MS, the LM and aggregate demand (AD) curves shift out, GDP and P increase; initial lower Rs leads to higher bond prices and a simultaneous shift out in the IS and AD curves due to higher consumption; and the net result being higher Rs, GDP, and P.

All models essentially report a depreciation of the U.S. dollar with respect to the U.K. pound, Canadian dollar, German mark, and Japanese yen. SGM reports very small impact multipliers across all countries for exchange rates. SGM shows the most depreciation against Japan and the United Kingdom with virtually no change relative to Canada. For the most part, SGM exchange rate responses are between the upper and lower bounds of the other model results. In the fifth year, the range of currency movement is as follows: U.K. pound, -0.3 percent (WHARTON) to 8.6 percent (EPA), with SGM at 7.3 percent; Canadian dollar, 0.6 percent (MCM) to 6.6 percent (DRI), with SGM at -0.1 percent; German mark 1.2 percent (WHARTON) to 14.5 percent (DRI), with SGM at 4.2 percent; and Japanese yen 2.4 percent (MCKIBB) to 15.3 percent (VAR), with SGM at 10.9 percent.

The other area in the monetary set of results which produced considerable disagreement in the Brookings workshop concerned the effects of a U.S. monetary expansion on foreign output. Standard theory suggests that there should be both foreign output-enhancing effects due to increased domestic GDP and M (income effects) and foreign output-reducing effects due to dollar depreciation, which increases foreign P and lowers foreign X (substitution effects). The answer to this question is clearly an empirical issue and depends on whether the domestic income absorption effects dominate the domestic expenditure switching or substitution effects.

Model results from the Brookings workshop are quite mixed on this question and nothing approaching consensus seems to come from the simulations. Some models predict positive GDP results for some countries and negative results for others. SGM uniformly reports positive foreign output results, with Canada and Germany clearly the biggest winners in terms of GDP gains. In SGM, by the fifth year of the simulation, Canadian GDP is 2.9 percent higher and German GDP is 2.3 percent higher than base.

Other models which produce positive foreign output results for most years of the simulation include MCKIBB (Japan is the only foreign country), VAR (Japan is the only foreign country), and WHARTON (all countries). Models that predict falling output for a majority of the years in the simulation are EPA (all countries except Canada), MCM (all countries), and TAYLOR (all countries, but the effects are very small).

DRI does not produce a consensus of countries predicting output changes in the same direction. In the DRI model, Japan and Germany experience falling output and Canada and the United Kingdom rising output. LINK reports the same direction of output changes for the set of same countries. LIVERPOOL predicts essentially no change in foreign output for any country. The foreign output changes in the OECD model are very small and alternate from positive to negative in each year for each country.

Fiscal Shocks

As mentioned above, the ambiguous area both theoretically and empirically concerns the effects on the domestic currency of a fiscal policy change. Theoretically (Mundell-Fleming basic two-country model), depending on one's assumptions regarding the degree of capital mobility, a contractionary fiscal policy produces either an exchange rate depreciation (high capital mobility) or a depreciation (low capital mobility).

In the Brookings workshop, all the models except LINK, WHARTON, and OECD for some countries predicted that the U.S. dollar would depreciate in the face of a fiscal contraction (table 4). The LINK exchange rate appreciation effects are small, and WHARTON are much larger. SGM falls into the appreciation camp, with its exchange rate paths looking very much like WHARTON. WHARTON interestingly employs a reaction function approach which tends to find little role for interest rates in annual exchange rate equations. The reaction function approach usually concentrates on relative GDP, P, and trade balances as the important underlying determinants of the exchange rate. In SGM, we experimented with poorer fitting exchange rate equations containing relative interest rate terms, and we still did not predict a depreciating U.S. dollar. In the context of SGM, this latter finding is most likely explained by the fact that we have a very flat U.S. LM curve. Even without interest rates in our exchange rate equation, a steeper LM curve would lead to less appreciation because of the second round depreciation pressure on the exchange rate. This pressure is due to higher GDP, resulting from relatively lower interest rates.

For further evidence on the response of SGM to fiscal disturbances, we substituted WHARTON longrun and shortrun interest rate responses into SGM and found that our exchange rate did, in fact, appreciate less (table 5). These findings also suggest that SGM and WHARTON probably have fairly similar IS curves.

The shape of the LM curve is an interesting feature of SGM, and besides the single-equation evidence, its steepness can also be implied from the impact responses in table 4 by looking at the GDP, Rs, and Rl results. The shape of this curve also explains why SGM continues to experience a fall in GDP throughout the simulation. In other words, SGM experiences very little crowding-in by the private sector in response to reduced government spending. Again, when we approximately substituted WHARTON LM into SGM, the GDP effects look more like the other model results in Brookings workshop (table 5). By year 5 of the simulation, SGM GDP was 1.6 percent lower than base compared with 3.9 percent lower in table 4.

Starting with a very diffuse prior at the estimation stage, our unconstrained U.S. interest rate equations exhibit very strong Keynesian properties. While these results certainly differ from the results of the Brookings workshop, we cannot infer from the available evidence that our interest rate specifications are incorrect. Other studies, in particular Leamer's (1986) study on inflation, support this conclusion. Using formal Bayesian analysis, Leamer's study suggests that inferences from the data are fragile and are unable to discriminate between implicit vertical (monetarist) or horizontal (Keynesian) LM's. At a later stage, we will experiment with altering the interest rate specifications in SGM to examine, for example, how sensitive international policy coordination results are to differing LM curves.

Implications of Multipliers for Policy Coordination

Tables 3 and 6 reveal that money, in the long run, is nonneutral. In other words, the monetary expansion invokes both price and quantity responses. As expected, in the short run, higher money growth in the United States leads to lower Rs, higher GDP, higher P, and a lower dollar. The short-term and medium-term effects on U.S. net exports depend on the net global income and substitution effects. In table 6, we can see that the U.S. real net export balance deteriorates for the first 3 years of the simulation and then improves by the last year. The initial worsening of the U.S. external deficit is due to the greater GDP and M in the United States relative to its trading partners and small initial declines in the value of the dollar relative to each country. As the dollar depreciates further throughout the simulation, however, there is pressure for U.S. net exports to improve. By the end of the simulation, the U.S. external balance improves because U.S. prices denominated in foreign currency continue to fall.

All other countries experience an improvement in their net export balance and GDP, with this improvement slowing toward the end of the simulation. The exception in this case is Japan, whose net export balance improves in the second year and deteriorates in the third and fourth years. The biggest winners in terms of GDP and net exports are Canada and West Germany. The relatively higher gains in GDP are probably explained by the fact that these countries' currencies appreciated the least against the dollar. Their relatively larger net export gains are due to their domestic and export prices rising more slowly than U.S. prices. In the Japanese case, the effects of higher U.S. GDP, which tends to increase Japanese net exports, are canceled out by the effects of the yen appreciation.

These results suggest that in any policy coordination exercise, Japan should attempt to minimize exchange rate fluctuations when the United States is undergoing a monetary expansion and maintain moderate growth in GDP and P. For Japan, a stable exchange rate avoids output loss due to a rapidly appreciating domestic currency. Maintaining lower relative GDP and P growth than the United States will also help Japan realize an improvement in its net export balance.

With less dollar depreciation, the United States should encourage its trading partners to expand their economies. Higher relative foreign income and prices will both lead to greater U.S. exports and income. The United States also seems to have some scope for altering the timing of its net export gains by pushing for greater dollar depreciation early in any potential coordination exercise. Although this type of move would lower foreign gains, it could be viewed as the cost to be paid by these countries for expanding as a result of higher U.S. demand.

Tables 7 and 8 show the effects of the U.S. fiscal contraction on U.S. and foreign net exports and government balances as a share of GDP. As expected, in the face of a fiscal contraction, the U.S. Government balance improves and then levels off by the end of the simulation (table 8). The U.S. foreign balance initially improves and then progressively worsens. All other countries' government and foreign balances deteriorate with the exception of Japan, whose balances steadily improve. Canada's and Germany's balances worsen the most, which is most likely explained by the large share of their trade accounted for by the United States and their small relative depreciations against the dollar. Even though the U.K. depreciation was large relative to the dollar, the effects on its government and external balances were small, since the United States comprises a small share of U.K. trade. In the Japanese case, substantial trading links and a large depreciation of the yen explain a better foreign balance, strong GDP effects, greater tax revenue, and, hence, a better government balance.

Contrary to the monetary shock, in the fiscal shock, the Japanese would lose GDP and their foreign and government balances would worsen if they did not let the yen decline against the dollar. The Canadians and Germans would obviously like to see their currencies fall more relative to the dollar to offset the effects of lower U.S. GDP. On the other hand, the United States would like to see the dollar fall throughout the coordination period to help offset its policy-induced decline in demand.

As mentioned earlier, the above results only pertain to policy changes initiated by the United States. To more thoroughly conduct policy analysis, the own-country and cross-country effects of policy changes in the other countries of SGM would need to be considered simultaneously. In addition, it would also be necessary to explicitly define the desired state that each country might hope to realize through macroeconomic policy cooperation. In SGM, cooperation could be simulated by altering the monetary and fiscal policy instruments in order to obtain some desired state in the target variables. For example, the desired targets might be zero or very low inflation, zero budget and trade balances, and annual GDP growth from 3.5 to 4 percent per annum. In addition, some mechanism would have to be defined which penalized any one country for breaking the rules set up in a cooperation exercise.

The above general requirements regarding quantifying the gains from international policy coordination contain elements of control and game theory. An explicit optimization framework for examining these issues which incorporates both these elements has been developed by Oudiz and Sachs (1986) and has been more recently extended by Hughes-Hallet (1988). The Hughes-Hallet framework could be extended by considering the welfare implications of any one government's attempt to alter the discount rate that it uses when assessing its welfare gains from cooperation. Another possibility would be to assess the implications of each country employing a different discount rate to its gains from policy cooperation.

Conclusions and Future Research

This report has demonstrated the building and use of a small, semistructural world macroeconomic model. Multiplier experiments suggest that SGM is a viable tool for the analysis of policy effects. SGM has the advantage of being smaller and more manageable than many other macroeconometric models, and comparisons of model results suggest that reduction in size has cost virtually nothing in analytical capacity.

We are developing the software which will enable us to formally analyze and measure the welfare effects of policy coordination both at the individual country and global levels. Once this work is completed, we plan to examine how the gains from cooperation change when key parts of the model structure or the optimization algorithm are altered. For example, we intend to experiment with implementing different LM curves, model-consistent expectations for inflation and exchange rates and altering the rate of time preference that a country or countries use when assessing their gains from cooperation.

Table 1--Stylized country structure in the small global model

Goods market:		
(1)	C = C(Yd, Rs)	Consumption
(2)	Yd = (1-a)*Y	Personal disp. income
(3)	IF = I(Y-Y[t-1], Rl)	Investment
(4)	II = b*(Y-Y[t-1])	
(5)	M = M(DY, MP/P)	Imports
(6)	X = ((M'*MP'*ER')/ER)/XP	Exports
(7)	Y = C + IF + II + G + (X-M)	Gross domestic product (GDP)
Money market:		
(8)	Rs = Rs($\dot{MS}$, $\dot{P}$, Y/PY)	Short-term interest rate
(9)	Rl = Rl(A(L)Rs, $\dot{P}$, Y/PY)	Long-term interest rate
Prices:		
(10)	$\dot{P}$ = P(Y/PY, $\dot{MP}$, $\dot{Pe}$)	Inflation
(11)	$\dot{Pe}$ = B(L)$\dot{P}$[t-1]	Expected inflation
(12)	MP = (XP'*ER')/ER	Import price
(13)	XP = XP(P, WP)	Export price
Exchange rates and current account:		
(14)	ER = ER(Y-Y', P-P', CA-(CA'/ER[80])	Exchange rate
(15)	CA = (X*XP - M*MP) + NF	Current account
(16)	NF = NF(C(L)CA[t-1]) + NF[t-1]	Net factor services

Table 2--Variable and symbol definitions

A(L),	B(L) and C(L) are polynomials in the lag operator	
.	percentage change	
'	Foreign trading partner	
a	Net taxes as a share of gross domestic product (GDP)	(Exogenous)
b	Change in inventory investment as a share of GDP	(Exogenous)
C	Real consumption expenditure	
CA	Nominal current account balance	
DY	Domestic demand (C+I)	
ER	Nominal exchange rate in U.S. dollars/local currency	
G	Real public expenditure	(Exogenous)
I	Real private investment	
M	Real imports of goods and nonfactor services	
MP	Import price deflator	
MS	Nominal money supply	(Exogenous)
NF	Nominal net exports of factor services	
P	Implicit GDP price deflator	
Pe	Price expectations	
PY	Real potential gross domestic product	(Exogenous)
Rs	Nominal short-term interest rate	
Rl	Nominal long-term interest rate	
Y	Real gross domestic product	
Yd	Real disposable income	
WP	World price of exports	(Exogenous)

Table 3--U.S. monetary shock, increased MS by 2 percent over base initially and 4 percent thereafter

Model	U.S. GNP - percentage difference from base				
	1	2	3	4	5
DRI	0.6	1.8	2.2	1.6	0.5
EEC	.6	1.0	1.0	1.0	.9
EPA	1.2	1.2	.9	.4	-.1
LINK	.1	1.0	2.1	2.5	2.5
LIVERPL	.6	.1	-.1	-.2	-.2
MCM	.4	1.5	2.2	2.0	1.4
MINIMODR	.6	1.0	1.0	1.0	.9
MSG	2.5	.3	.3	0	-.2
OECD	1.0	1.6	.4	.2	.4
SGM	.3	1.1	1.6	2.2	2.5
TAYLOR	1.0	.6	.5	.3	.2
VAR	.6	3.0	2.9	2.3	2.4
WHARTON	.4	.7	.8	.9	.9
	U.S. P - percentage difference from base				
	1	2	3	4	5
DRI	-0.1	0.2	0.9	1.6	2.4
EEC	.3	1.1	1.4	1.6	1.9
EPA	.1	.7	1.0	1.0	.8
LINK	-.1	-.6	-1.1	-1.2	-.9
LIVERPL	1.8	3.7	3.9	4.1	4.4
MCM	0	.3	.8	1.4	2.1
MINIMODR	.1	.4	.7	1.1	1.4
MSG	.5	1.5	2.1	2.7	3.1
OECD	0	.4	1.0	1.3	1.5
SGM	0	.1	.3	.8	1.4
TAYLOR	.3	1.2	1.9	2.4	2.7
VAR	0	.4	1.1	1.3	1.4
WHARTON	0	.1	.2	.3	.4
	U.S. Rs - percentage difference from base				
	1	2	3	4	5
DRI	-4.4	-2.3	-1.5	-1.1	-1.2
EEC	-1.2	-2.4	-2.3	-2.1	-1.6
EPA	-3.2	-2.2	-2.6	-3.1	-3.9
LINK	- .7	-1.4	-1.3	-1.3	-1.3
LIVERPL	.4	-.3	-.1	-.1	0
MCM	-2.6	-2.2	-1.4	-.9	-.8
MINIMODR	-1.9	-1.8	-1.4	-1.2	-1.1
MSG	-6.7	-.8	-1.2	-.7	-.5
OECD	-3.6	-.8	-.3	-.9	-.7
SGM	-1.3	-.7	-.2	.1	.4
TAYLOR	-.5	-.4	-.2	-.2	-.2
VAR	-1.8	-1.9	-1.1	-1.2	-1.2
WHARTON	-2.2	-2.1	-2.1	-2.1	-2.2

Continued--

Table 3--U.S. monetary shock, increased MS by 2 percent over base initially and 4 percent thereafter--Continued

Model	U.S. Rl - percentage difference from base				
	1	2	3	4	5
DRI	-1.8	-1.6	-1.2	-0.9	-0.9
EEC	-.4	-1.2	-1.6	-1.8	-1.3
EPA	-1.0	-1.6	-2.2	-2.7	-3.1
LINK	-.6	-1.5	-1.5	-1.5	-1.6
LIVERPL	.1	0	0	0	.1
MCM	-.7	-1.5	-1.5	-1.0	-.7
MINIMODR	-.3	-.3	-.2	-.2	-.2
MSG	-.5	-.1	0	.1	.2
OECD	-1.0	-1.5	-.9	-.8	-.8
SGM	0	-.6	-.5	-.2	.1
TAYLOR	-.3	-.2	-.2	-.2	-.2
VAR	-	-	-	-	-
WHARTON	-1.0	-1.6	-2.0	-2.3	-2.5
	U.K. ER - percentage difference from base				
	1	2	3	4	5
DRI	5.6	13.6	15.3	13.6	7.5
EEC	-	-	-	-	-
EPA	2.0	5.4	7.7	8.0	8.6
LINK	.3	1.5	3.1	4.9	7.0
LIVERPL	2.4	4.2	4.3	4.5	4.6
MCM	4.8	7.5	7.8	7.9	8.1
MINIMODR	-	-	-	-	-
MSG	-	-	-	-	-
OECD	2.3	3.0	2.2	2.5	2.7
SGM	.1	.7	2.4	4.8	7.3
TAYLOR	7.3	5.2	4.6	4.4	4.4
VAR	-	-	-	-	-
WHARTON	0	.2	.3	0	.3
	Canadian ER - percentage difference from base				
	1	2	3	4	5
DRI	3.2	5.1	5.6	6.0	6.6
EEC	-	-	-	-	-
EPA	.4	.5	1.3	2.8	4.1
LINK	.2	.7	.9	.9	.9
LIVERPL	2.5	4.3	4.3	4.4	4.5
MCM	1.7	1.5	1.7	1.3	.6
MINIMODR	-	-	-	-	-
MSG	-	-	-	-	-
OECD	2.2	2.8	2.2	2.6	2.8
SGM	0	0	-.1	0	-.1
TAYLOR	7.6	5.6	5.1	4.9	4.9
VAR	-	-	-	-	-
WHARTON	.1	.4	.8	1.2	1.5

Continued--

Table 3--U.S. monetary shock, increased MS by 2 percent over base initially and 4 percent thereafter--Continued

Model	German ER - percentage difference from base				
	1	2	3	4	5
DRI	6.9	20.2	24.8	23.2	14.5
EEC	-	-	-	-	-
EPA	5.8	15.3	19.9	16.6	10.7
LINK	.6	2.3	3.5	4.5	5.8
LIVERPL	2.6	4.4	4.4	4.6	4.8
MCM	3.8	5.8	6.3	6.4	6.6
MINIMODR	-	-	-	-	-
MSG	-	-	-	-	-
OECD	2.3	3.1	2.6	2.9	3.2
SGM	0	.5	2.0	3.7	4.2
TAYLOR	7.0	4.6	3.9	3.8	3.8
VAR	-	-	-	-	-
WHARTON	.1	.4	.9	1.0	1.2
	Japanese ER - percentage difference from base				
	1	2	3	4	5
DRI	6.6	19.0	23.0	20.2	11.1
EEC	-	-	-	-	-
EPA	7.6	11.5	13.1	11.7	7.5
LINK	1.3	4.5	5.7	6.5	7.5
LIVERPL	2.4	4.3	4.3	4.4	4.6
MCM	6.1	5.9	5.6	6.4	7.0
MINIMODR	-	-	-	-	-
MSG	7.7	1.9	2.5	2.2	2.4
OECD	2.2	3.1	2.6	2.9	3.2
SGM	.2	1.5	4.6	8.7	10.9
TAYLOR	8.1	5.7	4.8	4.3	4.2
VAR	5.8	14.9	14.4	15.1	15.3
WHARTON	.3	2.2	5.1	8.5	12.7

Table 4--U.S. fiscal shock, decreased G by 1 percent of base GNP

Model	U.S. GNP - percentage difference from base				
	1	2	3	4	5
DRI	-2.0	-2.1	-1.4	-1.0	-0.9
EEC	-1.3	-1.2	-1.0	-.8	-.6
EPA	-1.6	-1.7	-1.6	-1.6	-1.6
LINK	-1.2	-1.2	-1.0	-.7	-.5
LIVERPL	-.7	-.6	-.5	-.5	-.5
MCM	-1.6	-1.8	-1.4	-.9	-.5
MINIMODR	-1.1	-1.0	-.8	-.6	-.4
MSG	-.8	-.9	-.8	-.7	-.6
OECD	-1.5	-1.1	-.6	-.5	-.3
SGM	-1.9	-2.3	-2.9	-3.5	-3.9
TAYLOR	-1.6	-.6	-.6	-.7	-.6
VAR	0	-.4	-.6	-.7	-.7
WHARTON	-1.7	-1.4	-1.4	-1.4	-1.4
	U.S. P - percentage difference from base				
	1	2	3	4	5
DRI	-0.3	-0.7	-1.2	-1.7	-2.3
EEC	-.2	-.4	-1.0	-1.3	-1.5
EPA	-.7	-1.4	-2.1	-2.8	-3.7
LINK	-.2	-.5	-1.0	-1.5	-2.0
LIVERPL	-.1	-.2	-.2	-.3	-.3
MCM	-.1	-.6	-1.1	-1.6	-2.2
MINIMODR	-.2	-.5	-.9	-1.3	-1.8
MSG	0	-.1	-.3	-.7	-1.2
OECD	-.2	-.7	-1.2	-1.7	-2.2
SGM	-.1	-.4	-1.0	-1.9	-2.9
TAYLOR	-.2	-.5	-.8	-.9	-1.1
VAR	.3	.9	1.1	1.1	1.1
WHARTON	.2	-.3	-.6	-.8	-.8
	U.S. Rs - percentage difference from base				
	1	2	3	4	5
DRI	-0.7	-1.6	-1.8	-2.2	-2.5
EEC	-1.0	-1.5	-1.7	-1.8	-1.9
EPA	-1.5	-2.2	-3.0	-3.7	-4.7
LINK	-.1	-.2	-.3	-.5	-.6
LIVERPL	-.3	-.4	-.4	-.5	-.5
MCM	-1.0	-1.7	-2.0	-2.2	-2.4
MINIMODR	-.9	-1.1	-1.3	-1.5	-1.6
MSG	-.7	-.9	-1.4	-1.9	-2.5
OECD	-1.0	-1.7	-1.7	-1.9	-2.2
SGM	-.1	-.2	-.4	-.7	-1.0
TAYLOR	-.4	-.3	-.3	-.3	-.4
VAR	-.1	-.1	-.1	0	0
WHARTON	-1.0	-1.1	-1.4	-1.6	-1.7

Continued--

Table 4--U.S. fiscal shock, decreased G by 1 percent of base GNP--Continued

Model	U.S. Rl - percentage difference from base				
	1	2	3	4	5
DRI	-0.5	-1.1	-1.4	-1.7	-1.9
EEC	-.5	-1.0	-1.2	-1.3	-1.5
EPA	-.5	-1.2	-2.0	-2.9	-3.7
LINK	-.1	-.2	-.4	-.5	-.7
LIVERPL	-.3	-.3	-.3	-.2	-.2
MCM	-.3	-.9	-1.4	-1.7	-1.9
MINIMODR	-.1	-.1	-.2	-.2	-.2
MSG	-2.6	-2.8	-2.9	-2.9	-2.9
OECD	-.3	-.8	-1.2	-1.5	-1.7
SGM	0	-.1	-.2	-.4	-.7
TAYLOR	-.4	-.4	-.4	-.4	-.5
VAR	-	-	-	-	-
WHARTON	-.5	-.9	-1.3	-1.7	-1.9
	U.K. ER - percentage difference from base				
	1	2	3	4	5
DRI	0.8	3.0	3.9	4.6	5.8
EEC	-	-	-	-	-
EPA	.7	1.7	3.1	4.1	5.6
LINK	0	-.2	-.5	-.6	-.7
LIVERPL	.6	.4	.3	.2	.1
MCM	1.6	2.9	3.6	4.0	4.3
MINIMODR	-	-	-	-	-
MSG	-	-	-	-	-
OECD	.3	.7	.4	0	-.3
SGM	-.6	-3.0	-7.4	-12.7	-17.0
TAYLOR	4.5	3.9	3.6	3.6	3.6
VAR	-	-	-	-	-
WHARTON	-.2	-.9	-1.2	-2.0	-2.7
	Canadian ER - percentage difference from base				
	1	2	3	4	5
DRI	0	-0.9	-1.7	-1.1	0.2
EEC	-	-	-	-	-
EPA	.3	.4	1.0	2.2	3.6
LINK	0	.1	.1	.2	.2
LIVERPL	1.8	2.1	2.1	2.2	2.2
MCM	1.9	3.5	3.9	4.1	4.3
MINIMODR	-	-	-	-	-
MSG	-	-	-	-	-
OECD	.3	.8	.8	.7	.6
SGM	0	0	0	.1	.3
TAYLOR	5.7	5.1	5.0	5.1	5.2
VAR	-	-	-	-	-
WHARTON	-.8	-1.9	-2.9	-3.7	-4.3

Continued--

Table 4--U.S. fiscal shock, decreased G by 1 percent of base GNP--Continued

Model	German ER - percentage difference from base				
	1	2	3	4	5
DRI	0.9	4.0	5.2	5.6	6.6
EEC	-	-	-	-	-
EPA	2.1	6.4	11.1	14.6	15.7
LINK	-.1	-.3	-.6	-.7	-.6
LIVERPL	.5	.2	-.1	-.3	-.5
MCM	1.4	2.8	3.4	3.6	3.6
MINIMODR	-	-	-	-	-
MSG	-	-	-	-	-
OECD	0	0	-.4	-.7	-.9
SGM	0	-2.7	-6.4	-9.0	-9.4
TAYLOR	4.1	3.4	3.0	2.7	2.5
VAR	-	-	-	-	-
WHARTON	-.4	-1.0	-1.5	-2.5	-3.1
	Japanese ER - percentage difference from base				
	1	2	3	4	5
DRI	0.9	3.7	4.6	4.8	5.6
EEC	-	-	-	-	-
EPA	.8	1.7	3.3	5.3	8.0
LINK	0	-.2	-.3	-.3	-.1
LIVERPL	1.4	1.6	1.6	1.6	1.7
MCM	2.0	2.8	3.0	3.3	3.7
MINIMODR	-	-	-	-	-
MSG	3.2	2.9	3.1	3.2	3.1
OECD	0	0	-.3	-.6	-1.0
SGM	-1.9	-6.5	-11.9	-17.4	-18.9
TAYLOR	6.5	5.4	4.8	4.6	4.6
VAR	.3	.8	.7	.6	.6
WHARTON	-1.8	-4.9	-9.0	-13.0	-17.3

Table 5--SGM multipliers with WHARTON interest rate results, U.S. fiscal shock decreased government spending by 1 percent of base GDP

Item	U.S. domestic variables				
	1	2	3	4	5
Variable					
Y	-1.7	-1.7	-1.7	-1.8	-1.6
P	-.1	-.4	-.8	-1.4	-1.9
Rs	-1.0	-1.1	-1.4	-1.6	-1.7
Rl	-.5	-.9	-1.3	-1.7	-1.9
	Exchange rates - percentage difference from base				
	1	2	3	4	5
Country					
United Kingdom	-.5	-2.6	-6.1	-9.7	-12.2
Canada	0	0	0	.1	.1
West Germany	0	-2.4	-5.3	-6.7	-5.9
Japan	-1.8	-5.6	-9.5	-12.5	-11.5

* Y and P: percentage difference from base, and
Rs and Rl: percentage point difference from base.

Table 6--Response to monetary shock: Net exports as a share of GDP (percentage point difference from base)

Country	1	2	3	4	5
United States	-0.1	-0.2	-0.2	0	0.3
United Kingdom	.1	.1	.2	.4	.4
Canada	.1	.4	.5	.7	1.0
West Germany	0	.1	.4	.6	.9
Japan	0	.1	-.1	-.1	0

Table 7--Response to fiscal shock: Net exports as a share of GDP (percentage point difference from base)

Country	1	2	3	4	5
United States	0.1	0	-0.4	-0.7	-0.9
United Kingdom	-.1	-.2	-.1	-.1	0
Canada	-.3	-.5	-.8	-1.4	-1.8
West Germany	-.2	-.3	-.5	-1.0	-1.4
Japan	0	.2	.4	.5	.5

Table 8--Response to fiscal shock Government deficit as a share of GDP (percentage point difference from base)

Country	1	2	3	4	5
United States	0.6	0.5	0.5	0.3	0.2
United Kingdom	-.1	0	-.1	-.1	0
Canada	-.1	-.2	-.4	-.5	-.8
West Germany	-.1	-.1	-.2	-.4	-.7
Japan	0	.2	.4	.5	.5

Table 9--List of models participating in the 1986 Brookings workshop

DRI International Model, Data Resources Inc.
COMPACT - EEC Commission Model
EPA - Japanese Economic Planning Agency World Model
LINK Project World Model, University of Pennsylvania
LIVERPOOL Model, University of Liverpool
MCM - Multicountry Model of Federal Reserve Board Staff
MINIMODR - Haas/Masson Simulation Model
MSG - McKibbin/Sachs Global Simulation Model
OECD INTERLINK Model
TAYLOR Multicountry Model, Stanford University
VAR - Minneapolis World Vector Autoregression Model, University of Minnesota and Federal Reserve Bank of Minneapolis
WHARTON - World Model of Wharton Econometric Associates

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