Evaluating International Economic Policy with the Federal Reserve's Global Model

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FRB/Global is a large-scale macroeconomic model developed and maintained by the staff of the Board of Governors of the Federal Reserve System. The model contains the equations of the FRB/US model (discussed in the April 1997 issue of the *Federal Reserve Bulletin*) to represent the macroeconomic structure of the U.S. economy. In addition, FRB/Global contains eleven other blocks of equations to represent each of the foreign Group of Seven (G-7) industrial economies (Canada, France, Germany, Italy, Japan, and the United Kingdom), Mexico, and four other groups of industrial and developing economies.

Simulation experiments conducted with FRB/Global assist the Board in analyzing sudden changes in external macroeconomic variables and alternative policy responses in foreign economies. For example, experiments with FRB/Global provide useful information about the effects of exchange rate movements or oil price changes on U.S. unemployment and inflation. The alternative scenarios studied with FRB/Global also provide a valuable input to forecasts of foreign activity and the U.S. external sector.

Over the past several years, two important features have been added to the structure of FRB/Global. First, the equations have been reformulated to ensure long-run stability: In response to a macroeconomic disturbance, each economy represented in FRB/Global gradually converges to a balanced growth (or equilibrium) path, that is, a path in which actual output is equal to potential gross domestic product and in which every inflation-adjusted variable has a constant ratio to potential GDP. The inflation rate adjusts to a target level determined by monetary policy, and all relative prices reach constant values.

Fiscal solvency (a condition in which the stock of government debt grows no faster than nominal GDP) is maintained by assuming the gradual adjustment of a country's tax rate. Similarly, national solvency (a condition in which the stock of net external debt grows no faster than nominal GDP), is ensured by the assumption that the risk premium on a country's external liabilities rises when net external debt is high relative to nominal GDP.

The second feature added to FRB/Global is the explicit treatment of expectations. In the model, agents' expected values of future variables directly influence interest rates, consumption and investment expenditures, the aggregate wage rate, and the exchange rate. Thus, the way in which agents form expectations can have important implications for the simulation results. In FRB/Global, simulations can be performed under either of two assumptions about the nature of expectations: (1) limited-information expectations, under which agents have incomplete information about the structure of the global economy or (2) model-consistent expectations, under which agents possess all the information contained in the model.

This article provides a historical perspective on the development of FRB/Global and an overview of the model's blocks of equations for foreign countries. We use three simulation experiments to highlight the dynamic properties of FRB/Global: a reduction in U.S. government purchases, a depreciation of the U.S. dollar, and an increase in the price of oil exported by countries in OPEC (the Organization of Petroleum Exporting Countries). The article also illustrates other uses of FRB/Global by examining the spillover effects of fiscal and monetary policy under alternative European monetary policy regimes.

A Historical Perspective on FRB/Global

In the mid-1970s, a variety of factors—increased economic interaction among countries, the first (1973) shock to oil prices, and the floating of

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exchange rates—combined to raise interest in global macroeconomic modeling. Against this background, the Board's staff began the development of a large-scale macroeconometric model called the Multicountry Model (MCM) to provide an empirical framework for analyzing interactions among the major industrial countries. One of the first models of its kind, the MCM consisted of about 1,000 equations divided into six blocks: one representing the U.S. economy (with a more detailed external sector than in previous models); four others representing Canada, Germany, Japan, and the United Kingdom; and an aggregate block representing the rest of the world.[1] From 1979 onward, the Board staff regularly used the MCM to simulate the effects of alternative policy scenarios and external shocks.

In the early 1980s the staff significantly modified the MCM with regard to exchange rate determination and the capital account of the balance of payments.[2] Empirical considerations also led to the elimination of detailed representations of banking sectors from the equation blocks of individual countries. In subsequent versions of the MCM, the monetary authorities were assumed to control either the money stock or the short-term interest rate. Finally, in the wake of the second (1979) OPEC oil price shock, the MCM was extended to provide explicit treatment of the oil sector.

In the mid-1980s, many of the equations in the MCM were re-estimated using methods suggested by David Hendry and other econometricians at the London School of Economics.[3] The re-estimation improved the fit and the dynamic properties of the equations and represented a first step toward ensuring the long-run stability of the model. In the late 1980s, the equations in the Board staff's model of the U.S. economy (the MPS model) were linked with the foreign equation blocks of the MCM. FRB/Global has continued this approach of linking foreign equation blocks with the staff's domestic U.S. model.

Another major restructuring and re-estimation of the MCM came in 1991–92. The model continued to use individual country blocks for the United States, Canada, Germany, Japan, and the United Kingdom, while the rest-of-world block was disaggregated into seven blocks of equations representing France, Italy, Mexico, the smaller industrial countries, the newly industrializing economies, OPEC countries, and other developing countries and economies in transition. A multilateral trade structure replaced the bilateral one, thereby greatly simplifying the data requirements and the analysis of simulation results for each country and region. The resulting arrangement—twelve countries and regions, each with an equation block containing multilateral trade equations—is used in the current version of FRB/Global.

The staff's most recent reassessment of the MCM began in 1993 and culminated in FRB/Global in 1996.[4] Explicit treatment of expectations enabled the model to capture the notion that news about future economic developments can directly affect the current economy; for example, the adoption of a multiyear deficit reduction package can generate an immediate drop in long-term interest rates. To ensure the long-run stability of the model, error-correction mechanisms were incorporated into the behavioral equations, and constraints that preserve fiscal and national solvency were imposed.[5] The long-run stability of FRB/Global permits simulations under either model-consistent or limited-information expectations.[6]

1. Guy Stevens led the effort to develop the MCM; see Guy V.G. Stevens, Richard B. Berner, Peter B. Clark, Ernesto Hernández-Catá, Howard J. Howe, and Sung Y. Kwack, *The U.S. Economy in an Interdependent World: A Multicountry Model* (Board of Governors of the Federal Reserve System, 1984).

2. In particular, equations based on the portfolio balance approach to the determination of exchange rates were replaced by modified uncovered interest parity relationships, a specification based on interest rate differentials. The change was prompted by a lack of empirical support for the portfolio balance model and by the attractive properties of the overshooting model of Dornbusch, which incorporated assumptions of open interest parity, nominal price rigidities, and model-consistent expectations (Rudiger Dornbusch, ''Expectations and Exchange Rate Dynamics,'' *Journal of Political Economy,* vol. 84, December 1976, pp. 1161–76).

3. The results of these and other changes to the MCM are described in Hali Edison, Jaime Marquez, and Ralph Tryon, ''The Structure and Properties of the Federal Reserve Board Multicountry Model,'' *Economic Modelling,* vol. 4 (April 1987), pp. 115–315.

4. This work drew heavily on the experimental multicountry model of Joseph E. Gagnon, ''A Forward-Looking Multi-Country Model: MX-3,'' International Finance Discussion Papers 359 (Board of Governors of the Federal Reserve System, 1989).

5. The constraints of fiscal and national solvency in FRB/Global are similar to those used in the IMF's multicountry model, MULTIMOD; see P. Masson, S. Symansky, R. Haas, and M. Dooley, ''MULTIMOD: A Multi-Region Econometric Model,'' International Monetary Fund, *World Economic Outlook,* July 1988, pp. 50–104.

6. To represent limited-information expectations, FRB/US uses a core vector autoregression with auxiliary equations (see F. Brayton and P. Tinsley, eds., ''A Guide to FRB/US: A Macroeconomic Model of the United States,'' Finance and Economics Discussion Series 1996-42 (Board of Governors of the Federal Reserve System, 1996); see also Flint Brayton, Eileen Mauskopf, David Reifschneider, Peter Tinsley, and John Williams, ''The Role of Expectations in the FRB/US Macroeconomic Model,'' *Federal Reserve Bulletin,* vol. 83 (April 1997), pp. 227–45. Individual regression equations are used to generate each of the expectation variables in the foreign blocks of FRB/Global.

THE STRUCTURE OF FRB/GLOBAL

FRB/Global consists of twelve blocks of equations, with each block describing the economy of a country or a group of countries. The U.S. block of FRB/Global is taken directly from the staff's model of the domestic economy, FRB/US, which consists of about 50 behavioral equations and about 250 accounting identities. Among the FRB/US behavioral equations are 4 that determine foreign aggregate demand, the inflation-adjusted (real) effective exchange rate, the oil import price deflator, and net investment income from abroad. FRB/Global replaces these 4 equations with about 1,400 equations that provide a much more detailed representation of macroeconomic developments outside the United States.

Six blocks of FRB/Global represent the foreign G-7 industrial countries (Canada, France, Germany, Italy, Japan, and the United Kingdom). The equation blocks for the foreign G-7 countries represent medium-sized open economies in which, in the short run, aggregate demand determines output and employment, and wages and prices respond slowly to macroeconomic shocks (a formulation in accord with neo-Keynesian theory). Eventually, however, wages and prices adjust to ensure that the economies return to a balanced growth path, with output at potential and unemployment at the natural rate (a result conforming to neoclassical theory). Gradual movement of the direct tax rate ensures long-run fiscal solvency, while the determination of the risk premium on external liabilities ensures national solvency.[7]

To incorporate these features, the equation block for each foreign G-7 country consists of about 60 behavioral equations and about 100 accounting identities. The specification of these equations is nearly identical for each country. The behavioral differences among the six economies have been derived from estimation and from calibration of the model; the differences in monetary and fiscal policies among the six depend on the assumptions of a particular simulation scenario.

The remaining five blocks of equations in FRB/Global represent Mexico; 16 smaller OECD countries (SOECD); the newly industrializing economies of Hong Kong, Korea, Singapore, and Taiwan (NIEs); the 16 countries with fuel-oriented exports (OPEC); and the rest of the world (ROW), which comprises about 140 developing economies and countries in transition.

The structure of the equation blocks for Mexico, the NIEs, and the SOECD is fairly similar to that of the foreign G-7 country blocks but with somewhat less disaggregation: Each of these blocks consists of about 45 behavioral equations and about 75 accounting identities. The OPEC and ROW blocks are much smaller, with about 15 behavioral equations and 25 accounting identities each.

Each block of equations in FRB/Global may be divided into five sectors: domestic spending, fiscal accounts, the external sector, aggregate supply (production, employment, wage and price determination), and financial markets (interest rates and exchange rates). The remainder of this section outlines the specification of these sectors for the foreign G-7 countries, highlights the role of expectations, and outlines the features that ensure the long-run stability of the model. For more details about the foreign blocks of FRB/Global, see appendixes A and B.

Domestic Spending

In the foreign G-7 equations of FRB/Global, six expenditure variables constitute domestic spending: private consumption expenditures, business fixed investment, residential investment, changes in business inventories, government fixed investment, and other government spending on goods and services (referred to as government consumption). Real private expenditures for consumption and for investment are determined endogenously (that is, by the model) through assumptions and empirical findings embodied in behavioral equations. Real government consumption and investment, on the other hand, are independent variables—they are determined exogenously (that is, outside the model).

The behavioral equation for each component of private expenditure incorporates an error-correction mechanism that permits realistic short-run dynamics while ensuring that the level of expenditure gradually adjusts to a long-run equilibrium growth path—that is, a stable ratio of expenditures to real GDP. The equilibrium path of each expenditure variable can be shifted by a permanent change in real interest rates or other specific macroeconomic variables. For example, the equilibrium path of real private consumption depends on real disposable income and the labor force participation rate as well as the long-term real interest rate (see box "Determining Private Con-

7. The risk premium on external liabilities (also known as the sovereign risk premium) refers to the extra rate of return demanded by creditors to compensate them for holding government bonds that have some degree of credit risk. Credit risk is the risk that the government, or sovereign, will not fully redeem the bonds at maturity. In the model, the risk premium on the net foreign holdings of a country's government bonds rises when those holdings are rising relative to that country's GDP.

Determining Private Consumption Expenditures

The equilibrium level of real private consumption expenditures, *C*, depends on real disposable income, *Y;* the ex ante long-term real interest rate, R_L; and the labor force participation rate, *L/POP*.[1] An accounting identity relates nominal disposable income to nominal GDP, net investment income from abroad, and taxes less government subsidies and transfers to households; then *Y* is computed by deflating nominal disposable income by the consumption price index. The determination of R_L is described below. The labor force participation rate is exogenously determined.

For each foreign G-7 country, statistical analysis has been used to verify that the ratio of private consumption to disposable income, *C/Y,* has a stationary long-run relationship with R_L and *L/POP,* and to estimate the short-run and long-run characteristics of this relationship.[2] The table below summarizes the response of private consumption to changes in disposable income and the long-term real interest rate. In Germany, for example, a permanent 1 percentage point increase in R_L is estimated to reduce private consumption 0.23 percent within one quarter and 0.76 percent in the long run.

In the short run, *C* exhibits partial adjustment in response to permanent changes in *Y* and R_L because of liquidity constraints, information lags, and other factors. In Germany, for example, a permanent 1 percent change in *Y* generates an immediate 0.73 percent change in *C*, so that the consumption–income ratio temporarily falls. The gap between the actual consumption–income ratio and its equilibrium value subsequently shrinks at a rate of 30 percent per quarter (not shown in table).

1. In the foreign G-7 equation blocks of FRB/Global, private consumption expenditures depend on current and past income so that consumption is sensitive to movements in temporary as well as permanent income. In FRB/US, consumption expenditures also depend on financial wealth and the present discounted value of expected future labor and transfer income so that consumption is less sensitive to fluctuations in temporary income; in future work, we plan to investigate specifications in the foreign-country equations of FRB/Global that are comparable to those in FRB/US.

2. The labor force participation rate is highly significant in explaining long-term changes in private saving rates in Germany, Japan, and the United Kingdom, perhaps because the private saving rate tends to decline as a higher fraction of the population reaches retirement age. The labor force participation rate is not, however, statistically significant in explaining the private saving rate in Canada. For Italy, the relationship between the private saving rate and the rates of long-term interest and labor force participation appears to be nearly nonstationary; for France, no satisfactory estimates of the relationship could be obtained, so the relationship in Germany was used for France as well.

Determinants of private consumption expenditures

	Canada	France	Germany	Italy	Japan	U.K.
Y						
Short run …	.58	.73	.73	.10	.62	.29
Long run …	1.0	1.0	1.0	1.0	1.0	1.0
R_L						
Short run …	–.13	–.23	–.23	–.05	–.23	–.19
Long run …	–.37	–.76	–.76	–2.4	–1.5	–.65

NOTE. The first two rows indicate the elasticity of private consumption expenditures, *C*, with respect to a permanent change in real disposable income, *Y*. The last two rows indicate the percentage change in *C* arising from a permanent 1 percentage point increase in the ex ante long-term real interest rate, R_L. The "short run" is the first quarter; the "long run" is the steady-state.

sumption Expenditures"). The equilibrium paths of real business fixed investment and residential investment are each determined by real GDP, the long-term real interest rate, and the corresponding depreciation rate. Finally, the equilibrium path of real inventory investment depends on domestic sales and the short-term real interest rate (see box "Determining Business Inventory Investment").

The determination of business fixed investment provides a useful example of the long-run stability and flexible dynamics associated with an error-correction mechanism. In each period, the business capital stock changes by the amount of business fixed investment less depreciation. Assuming competitive markets for inputs (land, labor, and capital) and output, microeconomic theory holds that the marginal product of capital should equal the real rental rate on capital, which is the sum of the real interest rate and the depreciation rate. In FRB/Global, the marginal product of capital is inversely proportional to the ratio of capital to GDP (the Cobb–Douglas production function). Therefore, in the model's long run, business fixed investment is determined in a manner that will maintain the capital–output ratio at a level consistent with the long-term real interest rate and the depreciation rate.

In the short run, however, fluctuations in the growth of real GDP strongly influence business fixed investment through an accelerator effect. Business fixed investment also incorporates a partial adjustment mechanism: For each of the foreign G-7 economies, the gap between current fixed investment and its equilibrium level shrinks at an estimated rate of about 25 percent per quarter.

For an illustration of these properties in the determination of business fixed investment, consider a permanent 1 percent increase in real GDP (both actual and potential) for Germany, with no change in the real rental rate on capital (chart 1, top panel). The dynamic accelerator generates a 3.5 percent increase in business fixed investment during the first year and an additional 0.75 percent increase over the subse-

Determining Business Inventory Investment

In the equations for each foreign G-7 country, real inventory investment depends on domestic sales, the stock of business inventory, and the ex ante short-term real interest rate. Domestic sales include all private and government consumption and fixed investment expenditures. The equilibrium ratio of the inventory stock to domestic sales depends on the cost of holding inventories, which is mainly determined by the ex ante short-term real interest rate. Thus, with domestic sales held unchanged along a constant growth path, an increase in the short-term real interest rate reduces the target stock of business inventories and thereby depresses the equilibrium level of inventory investment.

In the very short run, an increase in the level of domestic sales generates negative inventory investment as firms use inventories as a buffer against sudden changes in sales. The target inventory–sales ratio remains unchanged, assuming a constant short-term real interest rate. Thus, over the medium term, the increase in domestic sales stimulates higher inventory investment until the stock of business inventories eventually rises in proportion to the increase in domestic sales.

quent two years. These changes in investment represent a small fraction of the existing stock of business fixed capital, so that the capital stock rises gradually in response to the output shock. With a constant real rental rate, the equilibrium value of the capital–output ratio remains unchanged, so that the capital stock eventually stabilizes at 1 percent above its initial level. Given the constant depreciation rate, fixed investment also rises 1 percent in the long run.

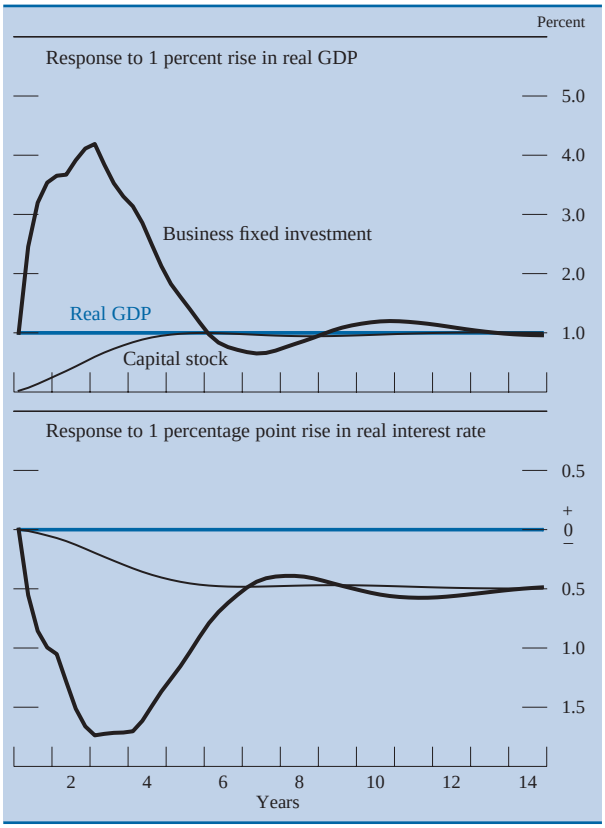
A permanent 1 percentage point increase in the real rental rate on capital in Germany, with no change in actual or potential output, also illustrates the model's adjustment properties (chart 1, bottom panel). The drop in the equilibrium capital–output ratio leads to a 1.8 percent reduction in business fixed investment over the first several years. The stock of business fixed capital gradually falls about 0.4 percent, to its new equilibrium level, with a similar long-run drop in the level of business fixed investment.

Fiscal Accounts

The model's representation of the fiscal accounts of the foreign G-7 countries is relatively straightforward: Government expenditures consist of consumption, investment, subsidies, transfers to households, and interest payments; government revenues come from direct taxes, social security payroll taxes, fuel taxes, and other indirect taxes. The most important feature of this sector is that the direct tax rate is determined endogenously to prevent a shock from causing a continuous rise or fall in the ratio of real government debt (nominal debt deflated by the GDP price deflator) to potential GDP. That is, each country's block of equations has a specified target path for the debt–GDP ratio; if a shock causes the ratio to deviate from that path, the direct tax rate is adjusted to ensure that the ratio gradually returns to its target.

For an illustration of this mechanism, consider the effects of a permanent reduction in government consumption expenditures under two different fiscal policy assumptions. Under the first assumption, the target ratio of government debt to GDP is unchanged. In this case, the direct tax rate will gradually move downward so that the drop in government spending is matched by a similar drop in direct tax revenue and by a corresponding increase in disposable income. As already noted, the equilibrium level of private consumption expenditures moves in proportion to real disposable income. Thus, in the long run, the drop in

1. Illustration of error correction in FRB/Global: Business fixed investment in Germany



government consumption is offset by a roughly equal increase in private consumption.

Under the second assumption, the debt–GDP target ratio gradually adjusts downward toward a new value, so that the direct tax rate remains constant over the first twenty-five years of the experiment. During this period, lower real interest rates stimulate private expenditures to keep real output at potential and avoid deflationary pressures, and potential GDP itself gradually rises in response to the higher level of private investment. Eventually, however, the downward trajectory of the debt–GDP ratio must be halted by reducing the direct tax rate, so that the long-run effects are the same as those described for the previous experiment.

The External Sector

For each foreign G-7 country, exports and imports are divided into three components: fuel, nonfuel merchandise, and services.

The volume of net fuel imports equals the difference between domestic fuel production and domestic fuel consumption, in which fuel production is determined exogenously, and fuel consumption depends on domestic nonfuel output and the relative price of fuel.

The imports of services and nonfuel merchandise are determined as follows. Under the assumption of worldwide balanced growth in the long run, the equilibrium ratio of real nonfuel merchandise imports to real domestic spending is set by the ratio of the import price deflator for nonfuel goods to the price deflator for nonfuel domestic output. In the short run, real nonfuel merchandise imports adjust at a rate of 30 percent per quarter toward the equilibrium level. The determination of imports of services involves the relative price of such imports and follows essentially the same error-correction mechanism as nonfuel merchandise.

Exports of services and nonfuel merchandise are determined by error-correction mechanisms (see box ''Determining Export Volumes'').

Determining Export Volumes

For each foreign G-7 country, the volume of nonfuel merchandise exports, X_g, is determined by foreign trade-weighted imports, M^*, and relative prices, RP_{xg}. We use the equation block for Germany to illustrate the construction of the variables for foreign demand and relative prices.

Foreign demand for German exports is the weighted average of nonfuel goods imports by Germany's trading partners, in which the weights are constructed using the bilateral export data for Germany. The relative-price variable measures German competitiveness in each of its export markets. For example, the share of German exports in total French imports depends on the relative price of German exports compared with other exporters to France. Thus, in constructing the relative-price measure for Germany, RP_{xg}, the French component is defined as the ratio of the German nonfuel goods export price deflator to the weighted average of foreign export prices, in which the weights are constructed using bilateral import data for France. Finally, the overall measure of German competitiveness, RP_{xg}, is computed as a weighted average across German export markets, using bilateral export weights for Germany.

Using these measures of foreign demand and relative prices, an error-correction mechanism determines the volume of nonfuel merchandise exports. With constant relative prices, the ratio of X_g to M^* remains on its baseline path; that is, each country exports a fixed share of world imports. If relative prices change, the ratio of X_g to M^* gradually adjusts toward its new equilibrium value at a rate of 15 percent per quarter. Real exports of services are determined by a similar error-correction mechanism involving foreign trade-weighted service imports and the relative price of service exports.

Aggregate Supply

For each foreign G-7 country, wage and price determination causes the rates of inflation and unemployment to move inversely in the short run (a downward-sloping Phillips curve); in the long run, unemployment settles on its ''natural'' rate, the point at which the inflation rate is constant (a vertical Phillips curve). For example, a monetary stimulus initially generates a drop in the unemployment rate and a relatively small increase in wage and price inflation; as wages and prices rise further, unemployment gradually returns to its natural rate.

In particular, real GDP is determined by aggregate demand, which is the sum of domestic spending and net exports. The employment level (and hence the unemployment rate) adjusts to equate aggregate supply to aggregate demand. Potential GDP is determined by the size of the labor force, the natural unemployment rate, the stocks of business fixed capital and residential capital, and net fuel imports. When output exceeds potential (unemployment is below the natural rate), wages initially move little but gradually rise in response to pressures generated by excess aggregate demand. An error-correction mechanism

ensures that the price deflator for domestic output gradually moves toward its equilibrium path, which is a markup over the aggregate wage rate and the domestic fuel price index.

The specific formulation of aggregate wage behavior depends on how expectations are formed. Under limited-information expectations, the aggregate wage inflation rate is a function of past wage inflation rates, current and past output gaps, consumer price inflation rates, and short-term interest rates.[8] Under model-consistent expectations, the aggregate wage rate is determined by the overlapping nominal wage contract specification of Taylor. In this case, the new wage contracts signed each period depend on expectations about future aggregate wages and deviations of unemployment from its natural rate; the aggregate wage rate is defined as the average value of the wage contracts currently in effect.[9]

Financial Markets

The financial-market equations for the foreign countries cover short- and long-term interest rates, expected inflation, and exchange rates. For countries whose currencies are assumed to be pegged to the German mark, interest rates and expected inflation move in parallel with the corresponding variables in Germany, apart from an endogenously determined risk premium on each country's external liabilities. The premium is related to the ratio of net external debt to GDP and helps avoid continuously rising or falling levels of net external debt.

For the countries with independent monetary policies, the monetary policy regime and the method of expectations formation are crucial in the determination of long-term interest rates, expected inflation, and the bilateral U.S. dollar exchange rate.

Short-Term Interest Rates

In a typical FRB/Global simulation, Canada, Germany, Japan, and the United Kingdom follow independent monetary policies using a rule of the form proposed by Henderson and McKibbin and by Taylor.[10] Under this form of rule, the short-term interest rate is adjusted in response to the current output gap and to the current deviation of consumer price inflation from an exogenously specified target. France and Italy are usually assumed to maintain fixed exchange rates with respect to the German mark. Although these are typical monetary policy assumptions, FRB/Global has been designed so that they can be modified easily from one simulation to the next, a feature that will be highlighted later in this article.

Long-Term Interest Rates

Under limited-information expectations, the long-term nominal interest rate is specified as a function of current and past short-term interest rates, inflation rates, and output gaps. The long-term interest rate also exhibits partial adjustment, so that the spread between short-term and long-term rates initially widens and then gradually shrinks in response to a shock to the short-term interest rate. Under model-consistent expectations, the long-term interest rate is determined as a geometrically declining weighted average of future short-term interest rates.

Expected Inflation

Under limited-information expectations, short-term expected inflation is equal to the current inflation rate; long-term expected inflation is a moving average of current and past short-term inflation rates, with a relatively slow adjustment of 5 percent per quarter in response to a persistent change in the inflation rate. Under model-consistent expectations, short-term expected inflation is equal to the actual one-step-ahead inflation rate, while long-term expected inflation is determined as a weighted average of future short-term inflation rates (using the same geometrically declining weights as in the long-term interest rate equation).

Exchange Rates

For those countries with independent monetary policies, the bilateral exchange rate under both limited-

8. Regression analysis has been used to estimate the parameters of this relationship for each foreign G-7 country.

9. John Taylor, "Aggregate Dynamics and Staggered Contracts," *Journal of Political Economy,* vol. 88 (February 1980), pp. 1–23. This specification of wage determination under model-consistent expectations is highly simplified; alternative specifications of wage determination for the foreign G-7 countries will be considered in subsequent research.

10. In *Carnegie–Rochester Conference Series on Public Policy,* vol. 39 (June 1993), see Dale Henderson and W. McKibbin, "A Comparison of Some Basic Monetary Policy Regimes for Open Economies: Implications of Different Degrees of Instrument Adjustment and Wage Persistence," pp. 221–318; and John Taylor, "Discretion versus Policy Rules in Practice," pp. 195–214.

information and model-consistent expectations is determined by real interest parity (the bilateral differential in real interest rates) and the risk premium on external liabilities, which depends on the ratio of net external debt to GDP, both measured in U.S. dollars (see box ''Determining Exchange Rates under Alternative Types of Expectations''). Thus, an increase in the relative magnitude of U.S. net external debt puts downward pressure on the real value of the dollar, thereby preventing explosive paths for the net stock of external debt.

Under either method of expectations formation, an unanticipated temporary increase in U.S. interest rates generates an initial rise in the exchange value of the U.S. dollar, followed by depreciation back toward its equilibrium value, a point referred to as purchasing power parity. For example, under limited-information expectations, the bilateral exchange rate depends on the corresponding differential in long-term interest rates as adjusted for long-term expected inflation. In this case, a 1 percentage point increase in the differential between U.S. and German long-term real interest rates generates a 0.08 percent real appreciation of the dollar against the German mark.

Under model-consistent expectations, the exchange rate is determined by short-term real interest parity. If the U.S. three-month real interest rate temporarily exceeds the German three-month real interest rate by 1 percentage point, then investors are willing to hold assets denominated in German marks only if the U.S. dollar is expected to depreciate 1 percent against the mark over the subsequent quarter. Thus, the temporary interest rate differential generates an immediate 1 percent jump in the value of the dollar, followed by depreciation back to its long-run value in the subsequent period.

Determining Exchange Rates under Alternative Types of Expectations

Limited-information expectations:

$$RER_t = 0.08[(RL_t^{US} - \hat{\Pi}_t^{US}) - (RL_t - \hat{\Pi}_t)] - 0.1\frac{NXDEBT_t^{US} - NXDEBT_t}{GDPVD_t^{US} + GDPVD_t}$$

Model-consistent expectations:

$$RER_t - \hat{RER}_{t+1} = (RS_t^{US} - \hat{\pi}_t^{US}) - (RS_t - \hat{\pi}_t) - 0.1\frac{NXDEBT_t^{US} - NXDEBT_t}{GDPVD_t^{US} + GDPVD_t}$$

Definitions

RER_t = the natural logarithm of the bilateral real exchange rate as adjusted by consumer prices, where the exchange rate is defined in units of local currency per U.S. dollar

RL_t = the current long-term interest rate

RS_t = the current short-term interest rate

$NXDEBT_t$ = the net external debt position in U.S. dollars

$GDPVD_t$ = nominal GDP in U.S. dollars

Long-term expected inflation, Π_t, is computed using limited-information expectations. The one-step-ahead inflation rate, π_{t+1}, and the one-step-ahead real exchange rate, RER_{t+1}, are computed using model-consistent expectations. The *US* superscript indicates the corresponding variable in the U.S. block of equations. Each equation includes an intercept and a residual term (not shown).

The Dynamic Properties of FRB/Global

The dynamic properties of FRB/Global are described here through three simulation experiments, each featuring a different type of shock: an exogenous reduction in U.S. government spending, an exogenous depreciation of the exchange value of the U.S. dollar, and an exogenous increase in the OPEC oil export price. In each experiment, expectations are assumed to be formed with limited information.

The effects of each shock are evaluated under two alternative U.S. monetary policy rules: ''active'' and ''passive.'' Under the active rule, the nominal federal funds rate adjusts in response to the output gap and to the deviation of consumer price inflation from the target rate. Thus, for each percentage point that output exceeds potential, the short-term nominal interest rate rises 50 basis points. For each percentage point increase in average annual inflation (based on the current and previous three quarters), the short-term nominal interest rate rises 150 basis points. Under the passive monetary policy rule, the nominal federal funds rate is held constant throughout the simulation.

In each simulation experiment, Canada, Germany, Japan, and the United Kingdom follow independent monetary policies under the same active monetary policy rule just described for the United States. Meanwhile, the French franc, Italian lira, and SOECD currencies remain fixed to the German mark. The Mexican peso and the OPEC and ROW currencies are assumed to be pegged to the U.S. dollar, while the NIE currencies are assumed to be pegged to a trade-weighted basket of foreign currencies.

The results of each experiment are reported in terms of deviations from the baseline path; the construction of the baseline is described in appendix C.

Experiment 1: A Reduction in U.S. Government Spending

In this experiment, real U.S. government purchases of goods and services are permanently reduced by 1 percent of the baseline path of U.S. GDP, starting in the first quarter of year 1, while U.S. tax rates are held constant through year 14. During year 1, the spending reduction amounts to about $70 billion. Because the spending shock originates within the United States, where foreign trade is a fairly small part of the economy, the experiment also serves as a useful benchmark for comparing the simulation results from FRB/Global with those from FRB/US.

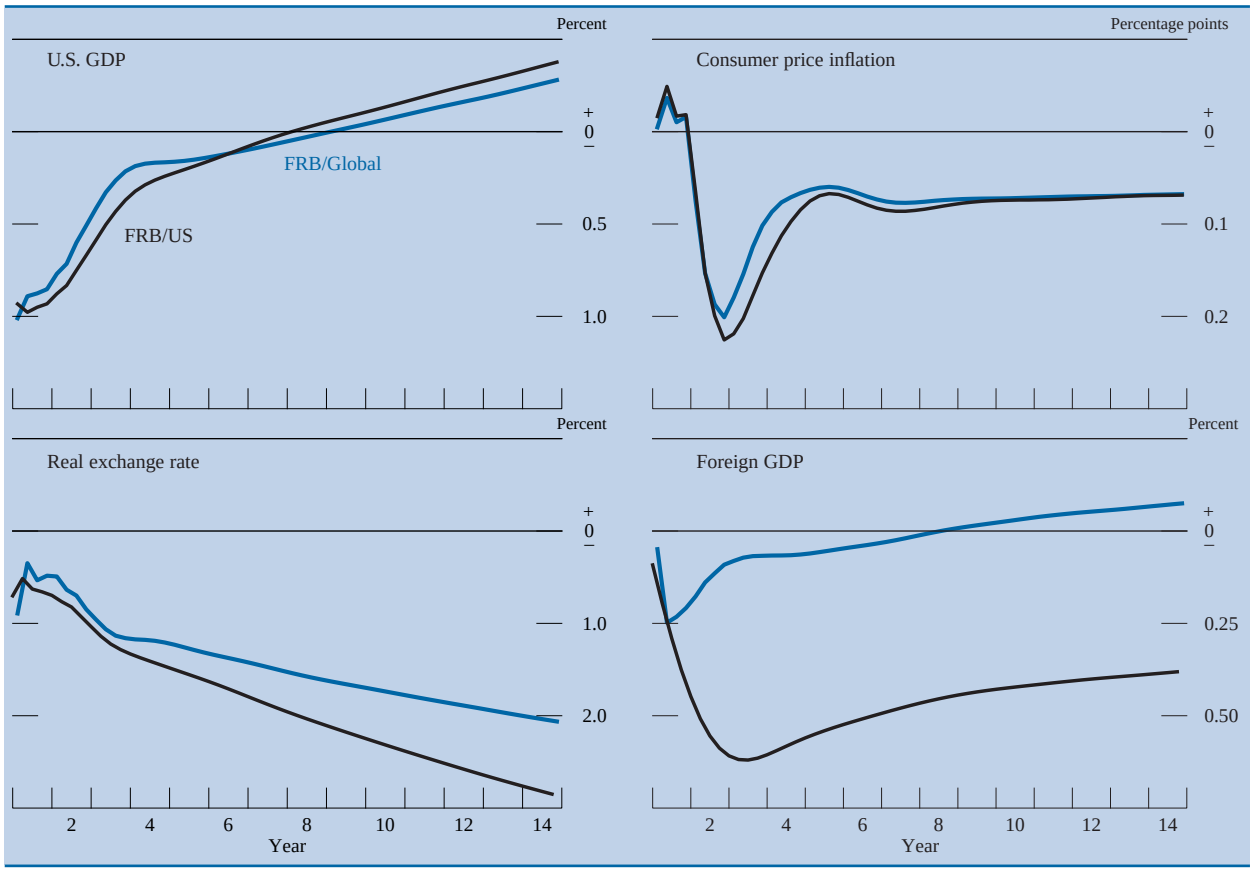
The two models generate nearly identical paths for U.S. real GDP and consumer price inflation (chart 2, top panels). In FRB/US, the two foreign variables that enter into the determination of U.S. net exports—the trade-weighted real exchange rate and foreign trade-weighted GDP—are each determined by a single equation; in FRB/Global, they are jointly determined by 1,400 equations. Yet, in the case of the real exchange rate, the paths generated by the two models are quite close, especially over the first three years of the simulation (chart 2, bottom-left panel). The differences in the paths for foreign GDP are slightly larger (bottom-right panel), but the effect on U.S. exports (not shown) is small.

This example illustrates the general result that, for domestic shocks, FRB/Global produces essentially the same results as FRB/US. Thus, the natural role for FRB/Global is in analyzing the effects of U.S. shocks on foreign economies and the effects of external shocks on the U.S. economy as well as foreign economies.

Active U.S. Monetary Policy Rule

Examining the U.S. government spending shock over its first three years provides a good comparison

2. Comparison of FRB/Global and FRB/US: A shock in U.S. government spending



NOTE. For definition of shock, see note to table 1.

of its effects on four of the countries with independent monetary policies—the United States, Canada, Germany, and Japan—under both active and passive U.S. monetary rules (chart 3, sections A and B). In the active-policy experiment, real GDP in Canada closely tracks the contraction and recovery in U.S. output (chart 3.A, top-left panel), inasmuch as exports from Canada to the U.S. comprise a relatively large share of aggregate demand in Canada. The U.S. contraction has a much smaller effect on Japan and Germany.

The active monetary policy rule prescribes a cut in short-term interest rates in each country (chart 3.A, bottom-left panel). The short rate in Canada falls a full percentage point, whereas the Japanese and German short rates fall only about 20–40 basis points.

Long-term real interest rates in all three foreign countries fall less than in the United States (chart 3.A, bottom-right panel). Thus, each foreign currency exhibits real appreciation relative to the U.S. dollar (see the equations for determining exchange rates), accounting for the depreciation in the trade-weighted U.S. real exchange rate (chart 2, bottom-left panel).

The U.S. fiscal shock under an active U.S. monetary policy improves the U.S. trade balance by about $15 billion (table 1.A); the improvement arises from a combination of the depreciation in the real exchange rate and lower domestic spending. The U.S. current account improves even more as lower rates of profit and interest reduce the rates of return paid on direct investment and portfolio liabilities. The rise in U.S. net exports is reflected in a fairly even drop in net exports among the other eleven blocks. The rest-of-world (ROW) trade balance is determined by the constraint that the global trade deficit remain at its baseline value. Nevertheless, the decline of about $5 billion in ROW net exports seems to be reasonable in light of the fact that the ROW block accounts for about 30 percent of U.S. imports.

Passive U.S. Monetary Policy Rule

When the United States maintains a constant federal funds rate, U.S. real GDP remains stagnant, at about 1 percent below baseline, during the first three years of the simulation (chart 3.B, top-left panel), while consumer price inflation falls because of the downward-sloping short-run Phillips curve (top-right panel). Thus, expected long-term inflation falls, and the long-term real interest rate gradually increases (bottom-right panel). Meanwhile, falling foreign real interest rates in response to the active monetary policy rules in Canada, Germany, and Japan lead to real appreciation of the U.S. dollar. As long as the U.S. federal funds rate remains constant, these contractionary influences will grow in magnitude,

1. Effects of selected shocks on the trade balances and current accounts of countries and country groups in FRB/Global, years 1 through 3

U.S. dollars

A. U.S. government spending shock

Country or region	Trade balance			Current account		
	Year			Year		
	1	2	3	1	2	3
United States	15.1	16.9	11.8	24.3	27.8	23.7
Germany	.1	.2	.1	–.8	–.8	–1.3
Japan	–.6	–1.4	–1.6	–5.3	–7.4	–9.0
Canada	–1.5	–1.3	–1.2	–1.0	–.9	–.9
France	.1	–.3	–.7	–.4	–1.0	–1.7
Italy	.1	–.3	–.4	.0	–.7	–.9
United Kingdom	–.8	–.6	–.4	–1.6	–1.8	–1.8
Smaller OECD	–1.0	–1.7	–1.1	–.8	–1.6	–1.1
Mexico	–.3	–.5	–.6	–.2	–.4	–.6
NIEs	–1.6	–1.2	–.4	–1.1	–1.2	–.8
OPEC	–4.4	–3.0	–1.0	–4.9	–4.1	–2.8
ROW	–5.1	–6.8	–4.3	–8.3	–7.9	–2.9

B. U.S. currency shock

United States	–2.8	23.8	34.7	–3.6	18.1	28.2
Germany	2.2	4.3	2.8	–2.4	–2.0	–4.3
Japan	–1.1	–5.6	–10.5	–1.4	–3.8	–10.6
Canada	.5	1.2	.6	.3	.8	.5
France	3.7	2.3	–1.6	1.6	–1.2	–5.9
Italy	2.4	.4	–1.1	3.1	–1.9	–3.5
United Kingdom	–3.0	–4.0	–4.1	–3.1	–10.0	–10.0
Smaller OECD	3.3	–.9	–2.4	5.8	2.1	.8
Mexico	.4	1.4	1.8	–.5	.0	.5
NIEs	–12.1	–14.2	–13.5	–5.3	–6.4	–6.7
OPEC	–7.1	–2.1	–.2	–9.7	–5.2	–3.5
ROW	13.5	–6.7	–6.4	15.1	9.6	14.5

C. OPEC oil export price shock

United States	–13.1	–4.0	–1.8	–14.2	–3.1	–1.0
Germany	–4.7	–3.3	–3.0	–4.6	–3.8	–3.8
Japan	–12.3	–7.9	–5.7	–11.4	–10.1	–9.3
Canada	1.3	.3	.2	.9	.5	.5
France	–2.7	–2.1	–1.9	–2.6	–2.5	–2.6
Italy	–3.0	–2.6	–2.3	–3.2	–3.1	–2.9
United Kingdom	.5	–.2	–.2	.0	–1.0	–1.1
Smaller OECD	–1.2	.2	1.7	–1.1	.1	1.6
Mexico	1.4	1.4	1.4	1.4	1.6	1.5
NIEs	–3.2	–4.4	–4.8	–2.5	–3.0	–3.7
OPEC	34.5	26.8	21.8	35.3	30.7	28.0
ROW	2.7	–4.1	–5.5	2.0	–6.1	–7.2

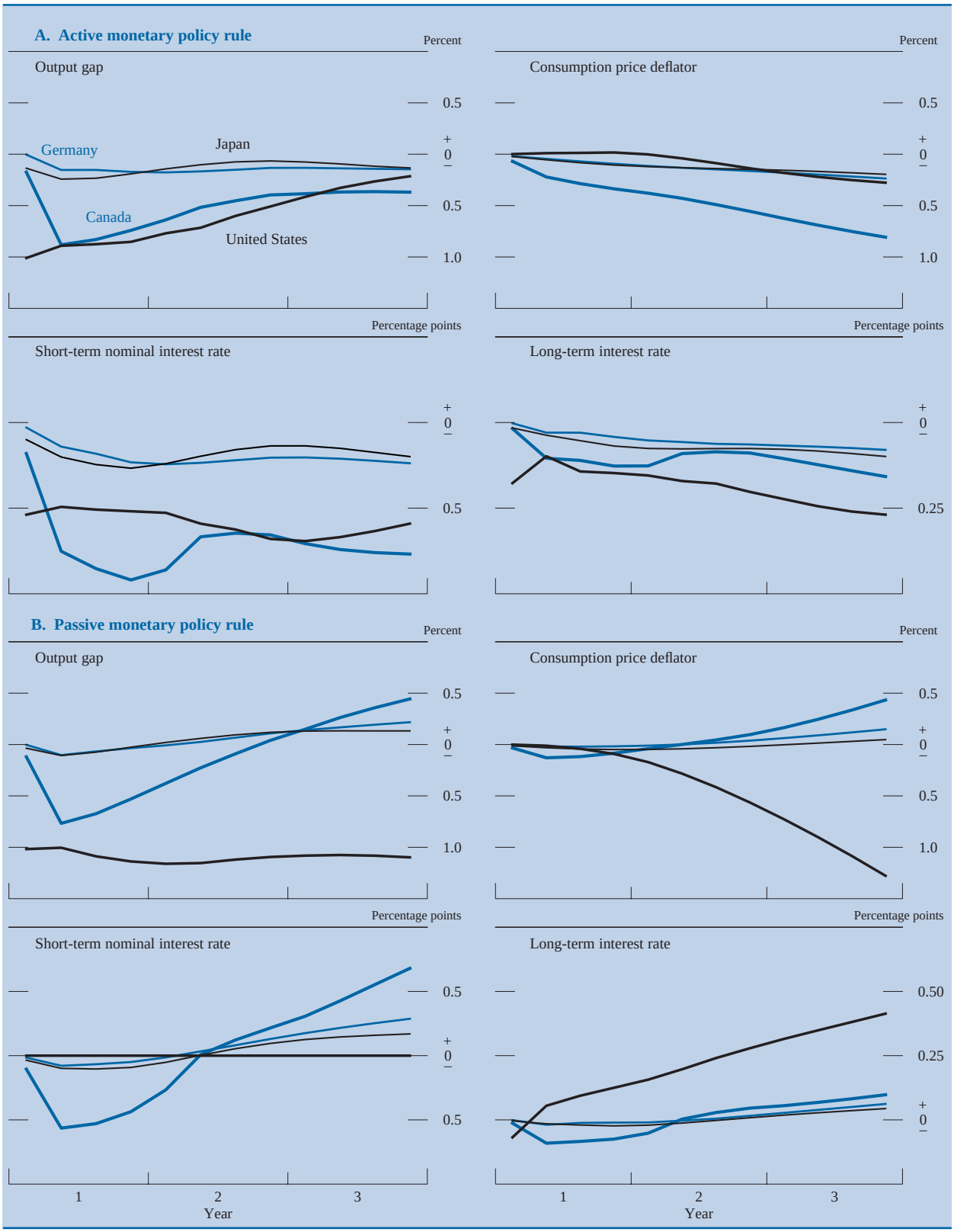
NOTE. Each shock begins at the start of year 1. In each simulation, the U.S. monetary authorities follow the active monetary policy rule, in which the federal funds rate is adjusted to counteract movements in the output gap and in deviations of consumer price inflation from the target rate.

The U.S. government spending shock is a permanent reduction in spending equal to 1 percent of the baseline path of U.S. GDP.

The U.S. currency shock is a 5 percent depreciation in the exchange value of the U.S. dollar versus the Canadian dollar and a 10 percent depreciation versus the currencies of the rest of the G-7, the smaller OECD countries, and the newly industrializing economies (NIEs).

The OPEC oil export price shock is an increase of $5 per barrel above the baseline path.

3. U.S. government spending shock under active and passive U.S. monetary policy rules



NOTE. For definitions of shock and active monetary policy rule, see note to table 1.

generating an explosive downward spiral for U.S. output and prices.[11]

Experiment 2: A Depreciation in the Exchange Value of the U.S. Dollar

In this simulation, the exchange value of the U.S. dollar depreciates 5 percent against the Canadian dollar and 10 percent against the currencies of the other foreign G-7 countries, the SOECD, and the NIEs. After the depreciation in year 1, these exchange rates remain fixed at the new level throughout the simulation period. Because the depreciation is not triggered by a change in expectations about future interest rates, it may be viewed as arising from an exogenous downward shift in preferences for holding dollar-denominated assets.

Under the active as well as the passive monetary policy regime, the exchange rate depreciation improves U.S. external competitiveness and stimulates net exports, thereby raising real GDP about 0.6 percent within about a year (charts 4.A and 4.B, top-left panels). The exchange rate depreciation also passes gradually into U.S. import prices and ultimately into higher consumer price inflation (top-right panels). The active monetary policy rule prescribes an increase of almost 150 basis points in the federal funds rate by the middle of year 2 and gradually pushes up the long-term real interest rate (chart 4.A, top-right panel).

Under the active U.S. monetary policy rule, the U.S. trade balance displays a standard J-curve response to the exchange rate depreciation, with a small initial deterioration yielding to an improvement of $35 billion by the end of year 3 (table 1.B). The U.S. current account improves a smaller amount as higher rates of interest and profit generate higher net factor payments. Japan and the NIEs bear the brunt of the increase in U.S. net exports. The ROW is not severely affected—its price level adjusts fairly quickly to maintain a constant trade-weighted real exchange rate.

Experiment 3: An Increase in OPEC Oil Export Prices

In this case, the export price of OPEC oil increases $5 per barrel above its baseline path in year 1 and remains fixed at $5 above the baseline thereafter (chart 5 and table 1.C). This shock roughly corresponds to a 25 percent rise in the fuel import prices faced by all countries and regions in the model. Under the active monetary policy rule, the U.S. consumer price level rises about 0.3 percent by the end of year 1 (chart 5.A, top-right panel).

To push inflation back toward its target rate, the active policy raises the federal funds rate 20 basis points, causing a mild contraction in which U.S. real GDP falls about 0.3 percent (chart 5.A, top-left panel). As inflationary pressures subside, the federal funds rate returns to baseline, and by year 3 the output gap is almost closed. By contrast, U.S. output remains close to the baseline under a constant federal funds rate (chart 5.B, top-left panel), but consumer prices rise about 0.5 percent (chart 5.B, top-right panel), nearly twice as much as under the active policy rule.

Illustrative Applications of FRB/Global

FRB/Global can be used to analyze the spillover effects of fiscal and monetary policy under alternative European monetary policy regimes, an area of interest given the movement toward a European monetary union. Simulations inform the forecasts of the Board's staff regarding foreign activity and the U.S. external sector. This section discusses three examples of such simulations.

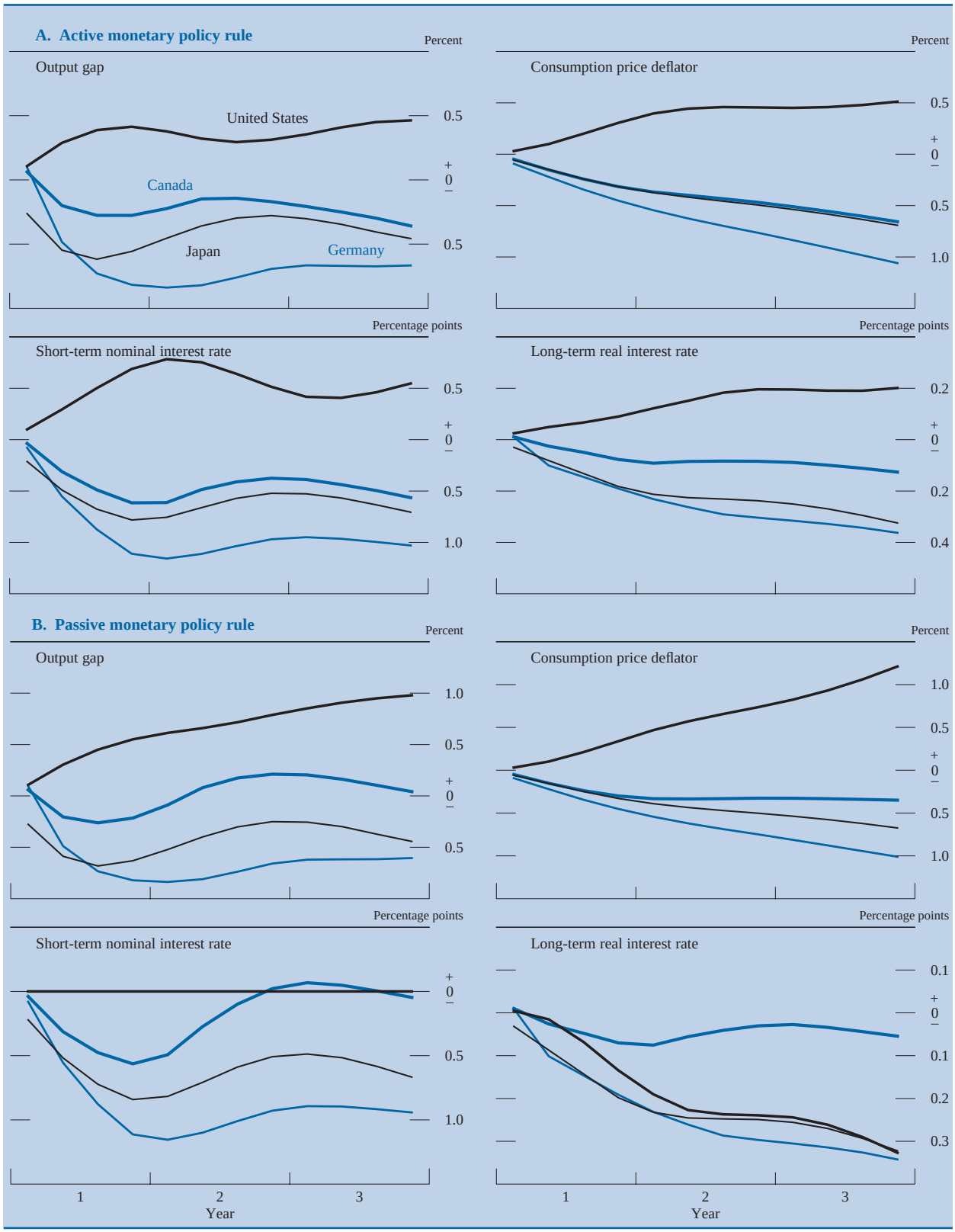
A Comparison of EMS and EMU

The first scenario highlights the effects of different monetary policy regimes on simulations for France and Germany of a fiscal shock originating in Germany. The shock is a permanent increase in German government spending equal to 1 percent of German GDP beginning at the outset of year 1. Although hypothetical, this shock is comparable to the fiscal expansion in Germany that followed reunification in 1990.

The scenario covers two monetary policy regimes: the current arrangements (the European Monetary System, or EMS) and those envisioned under the Economic and Monetary Union (EMU). Under the EMS regime, monetary policy in Germany follows an active rule (German short rates respond to deviations of German output and inflation from target), while France, Italy, and the SOECD countries peg

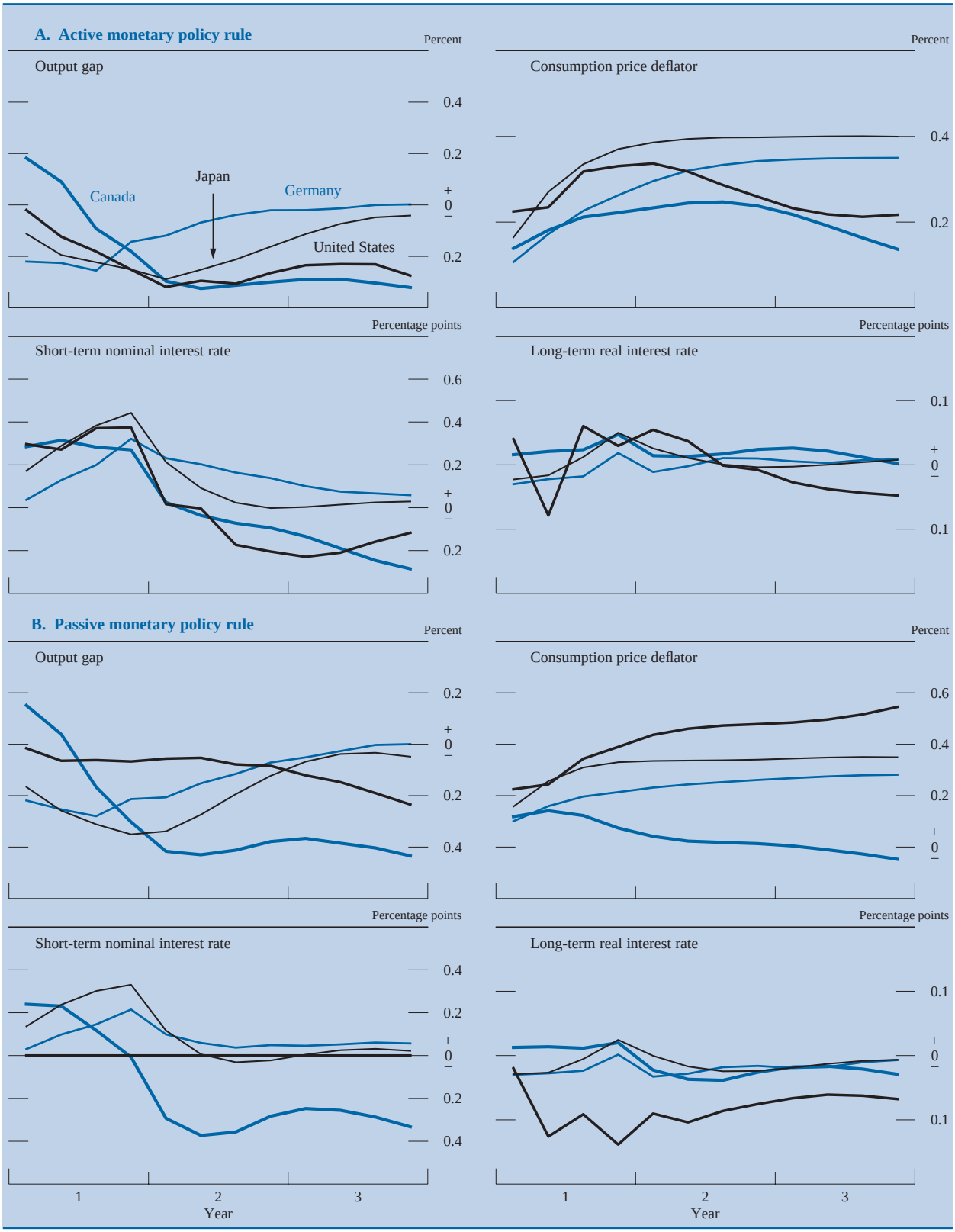
11. These results are consistent with standard economic theory, which holds that the domestic price level is indeterminate (that is, not tied down by macroeconomic fundamentals) under a fixed nominal interest rate.

4. U.S. currency shock under active and passive U.S. monetary policy rules



NOTE. For definitions of shock and active monetary policy rule, see note to table 1.

5. Shock to the export price of OPEC oil under active and passive U.S. monetary policy rules



NOTE. For definitions of shock and active monetary policy rule, see note to table 1.

their currencies to the German mark.[12] In this experiment, the United States, Canada, Japan, and the United Kingdom follow independent monetary policies under the EMS.

Under the model's EMU regime, the European Central Bank would implement monetary policy for the member countries; it would use an active monetary policy rule in which the interest rate on the common currency (the euro) responds to the weighted average of the output gaps and inflation deviations of all member countries. This rule highlights the contrast between the EMU and the EMS regimes; in the latter, short-term interest rates in all member countries are determined by the output and inflation gap in Germany (apart from a risk premium on external liabilities).

The actual composition of the EMU and the relative influence of its members remain open issues. For this experiment, all members of the European Union except the United Kingdom are assumed to join the EMU, and the influence of specific countries in the equation governing the European Central Bank's simulated response are represented by weights calculated from the relative dollar values of GDP of the member states. On that basis, Germany's weight is slightly more than ¼, France and Italy each have a weight of about ⅕, and the SOECD weight is about ⅓.

Under the EMS, the fiscal expansion in Germany has a direct positive effect on German GDP and prices (chart 6.A, top panels). The German central bank responds to the shock by raising short-term interest rates substantially (about 75 basis points) (chart 6.A, bottom-left panel). France must raise interest rates by a similar magnitude in order to maintain the exchange rate peg (chart 6.B, bottom-left panel). The interest rate hike in France has strongly contractionary effects on real GDP and prices in France (chart 6.B, top panels), which are only partially offset by higher net exports to Germany.

Under the EMU regime, the same fiscal shock produces a rise in the interest rate in each country (about 60 basis points) that is somewhat smaller than under the EMS (as noted, about 75 basis points) (chart 6.A and 6.B, bottom-left panels). The smaller rise in interest rates reflects the fact that the European Central Bank adjusts interest rates according to the effects of a shock on the output gaps and inflation rates of all member countries. Under the EMU, the effects of a German-specific fiscal expansion on the rates of GDP and inflation in all member countries are much smaller than the effect on Germany; therefore, interest rates rise less than they do under the EMS, in which interest rates target only the German output and inflation gaps.

In addition, output and prices in Germany rise more under the EMU than they do under the EMS in response to the fiscal expansion (chart 6.A, top panels). These results highlight the point that relative to the EMS, the EMU will tend to generate somewhat higher variability of output and inflation in Germany because German short-term interest rates will reflect economic conditions in all member countries and not just those in Germany, as they do under the EMS.

Likewise, under the EMU, the contractionary effects in France arising from fiscal expansion in Germany are much smaller than they are under the EMS (chart 6.B). In particular, the variability of French output and inflation are markedly lower. These results illustrate the general point that, as modeled by FRB/Global, a country that currently pegs its currency to the German mark will tend to reduce the volatility of its output and inflation by joining EMU.

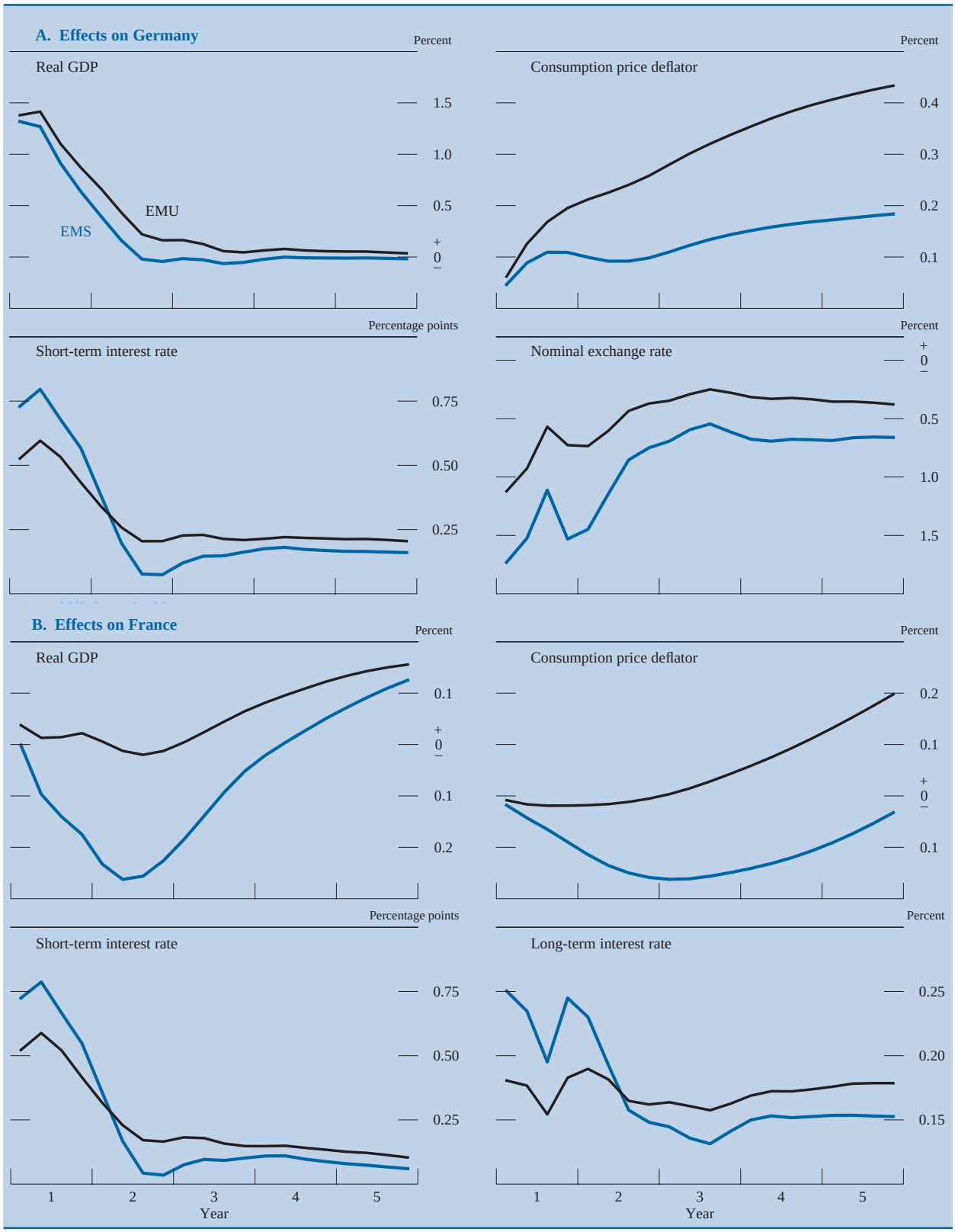
A Comparison of Independent Monetary Policy and Participation in EMU

Although countries that currently participate in the EMS (other than Germany) may experience a reduced volatility of inflation and output under the EMU, a non-EMS country joining the EMU presumably would sacrifice some control over domestic macroeconomic outcomes by giving up its independent monetary policy. To test the latter proposition, we analyze a fiscal shock similar to that considered above—a permanent increase in fiscal spending of 1 percent of GDP—but this time within the United Kingdom instead of Germany. We consider its effects on the United Kingdom under each of two monetary policy scenarios: U.K. membership in the EMU and an independent monetary policy in the United Kingdom.

Under the EMU scenario, the European Central Bank is assumed to adjust interest rates using the active monetary policy rule discussed above, except that the United Kingdom is now included in the set of member countries. In this simulation, the United Kingdom receives a relatively small GDP-based weight of ⅛. Under an independent monetary policy, the United Kingdom uses a variant of the active monetary policy rule, in which the short-term interest rate is adjusted to keep U.K. output at its target level.

12. Because the SOECD block includes Australia and New Zealand, the simulations are intended to only approximately represent both EMS and EMU.

6. German fiscal shock under EMS-style and EMU-style monetary policies



NOTE. The shock begins at the start of year 1 and consists of a permanent increase in German central government spending equal to 1 percent of GDP. See text for definition of monetary policy alternatives.

After the fiscal expansion in the United Kingdom, output there initially rises sharply (to 1 percent above baseline) if the country is in the EMU (chart 7, top-left panel); in contrast, an independent U.K. monetary policy could basically target output at baseline. The monetary tightening and the resulting rise in U.K. interest rates under an independent policy is considerably more aggressive than that which would be taken by the ECB if the United Kingdom were one of its members (bottom-left panel).

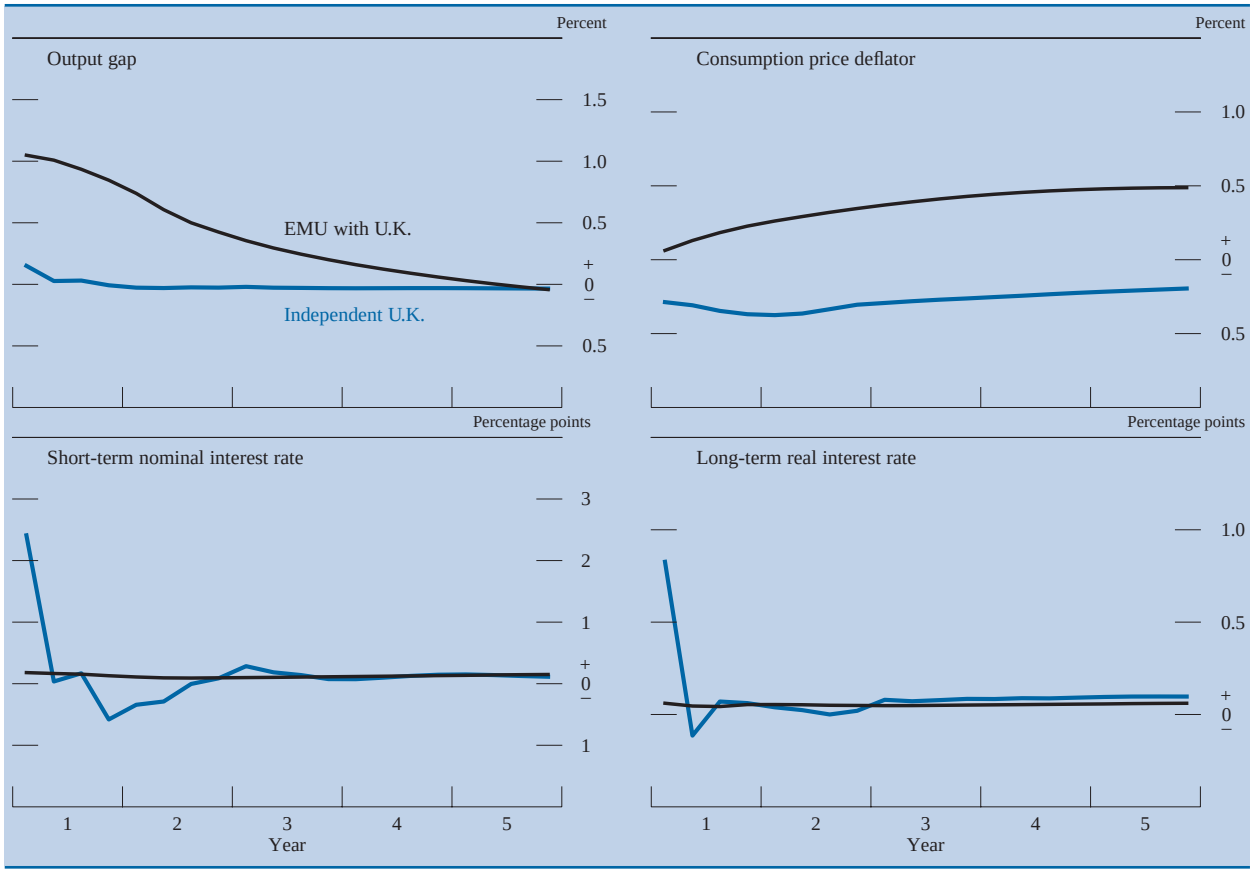
The simulation just described illustrates how a country such as the United Kingdom stands to incur some increase in the variability of output and inflation by forgoing an independent monetary policy. Although the FRB/Global simulations help to assess these costs, the simulations do not take into account some potential benefits of joining EMU, including the microeconomic benefits of lower transaction costs that come with a common currency. Another potential benefit is the "credibility effects" that could reduce the risk premium on a country's external liabilities. That is, choosing to link its economy to a common monetary policy could enhance a country's status as an inflation fighter, which would tend to lower the risk premium on its external liabilities.

The Formation of Expectations

The final scenario examines the implications of alternative assumptions about expectations. The implications are most apparent in the case of shocks whose effects arise after the start of the simulation. We compare the results obtained from expectations that are formed with limited information to the results obtained with model-consistent expectations—those formed with the benefit of all the information contained in the model.

Limited-information expectations depend exclusively on past information; hence, shocks are unforeseen. By contrast, with model-consistent expectations, agents are assumed to have perfect foresight about the shock, meaning that they know the entire

7. U.K. fiscal shock: Effects on the United Kingdom under independent and EMU-style monetary policies



NOTE. The shock begins at the start of year 1 and consists of a permanent increase in U.K. central government spending equal to 1 percent of GDP. See text for definition of the monetary policy alternatives.

future path of the variable whose value is being exogenously changed in the simulation. The assumption of such foresight enables the model to capture the notion that news about future economic developments can affect the current economy.

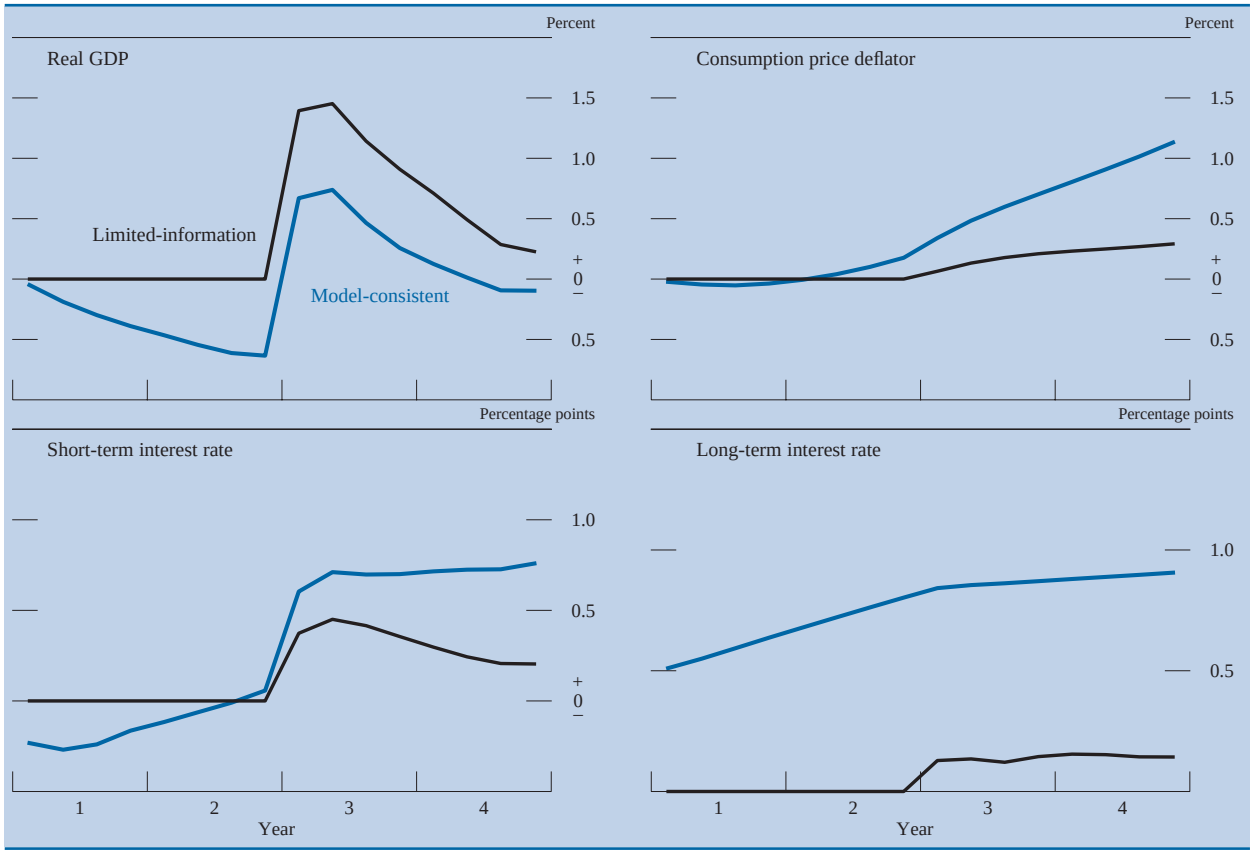
Under each variant of the model, we consider the short- and medium-term response of agents to an announcement by the German government at the beginning of year 1 that, at the beginning of year 3, it will permanently add to its spending an amount equal to 1 percent of GDP. The monetary policy regime in years 1 and 2 is assumed to be the EMS; in year 3, the EMU. (The United Kingdom conducts an independent monetary policy throughout these simulations.)

In Germany, limited-information expectations produce no response until the spending rise is implemented in year 3 (chart 8). Even long-term interest rates fail to respond (bottom-right panel), an indication that, until the shock is implemented, agents do not expect future short-term rates to rise. From year 3 forward, however, the limited-information dynamics are like those in the previous simulation of the effects on Germany of a German fiscal expansion (chart 6.A) because that simulation was also conducted under limited-information expectations.

Under model-consistent expectations, agents in year 1 can use the information that the European Central Bank will be in operation as of the beginning of year 3: As soon as the forthcoming year-3 shock is announced, agents realize that the central bank will have to raise short-term interest rates beginning in year 3 to restrain the effects of the projected fiscal expansion on output and prices. The expectation of the rise in future short rates (chart 8, bottom-left panel) causes an immediate rise in long-term rates (bottom-right panel). The rise in long rates in turn causes real activity to contract somewhat in years 1 and 2, so in this simulation, a future fiscal expansion has a contractionary effect in the short run.

Thus, FRB/Global accommodates two different, and somewhat extreme, perspectives on the formation of expectations. The degree of divergence in the results produced by each perspective in a given scenario depends on whether the effects of the shock are anticipated by economic agents.

8. Future German fiscal shock: Model-consistent vs. limited-information expectations



NOTE. The shock, of the magnitude given in chart 6, is announced in year 1 for implementation in year 3. See text for definition of expectations alternatives.

Appendix A: The Foreign G-7 Equation Blocks

The equation blocks for the foreign G-7 countries cover government expenditures, tax revenue, net factor income, potential output, aggregate wages, and domestic prices.

Government Expenditures

Total government expenditures are divided into five components: consumption, investment, subsidies, transfers to households, and interest payments. Real government consumption and investment expenditures on goods and services are exogenously determined; the corresponding nominal values are obtained using price deflators for government consumption and investment. The nominal value of government subsidies moves proportionally with the level of nominal GDP. In contrast, real transfers to households are assumed to be acyclical, depending only on potential GDP; nominal transfers are obtained using the GDP price deflator. Finally, interest payments are computed by multiplying the stock of government debt by the average rate of return on outstanding government securities. The average rate of return is assumed to be a weighted average of two components: the current short-term Treasury bill rate and a moving average of past long-term bond rates.[13]

Tax Revenue

Total government revenues are divided into four components: direct taxes, social security payroll taxes, fuel taxes, and other indirect taxes.[14] Direct tax revenue consists mainly of personal and corporate income taxes and is computed by multiplying the direct tax rate by nominal net national product (nominal GDP plus net factor income from abroad, less depreciation allowances). The direct tax rate is endogenously determined to stabilize the ratio of real government debt to potential GDP.

Payroll taxes are assumed to vary proportionally with labor income, which is the product of the hourly wage rate and total employment.[15] The fuel tax rate is specified on a per-barrel basis, and the value of the tax per barrel is indexed to the GDP price deflator but not to the current price of fuel. Other indirect taxes (for example, the value-added tax) are assumed to vary proportionally with the value of private consumption and investment expenditures.

Net Investment Income from Abroad

Net investment income from abroad is divided into four components: direct investment payments and receipts and portfolio investment payments and receipts. Each of the four is computed by multiplying the outstanding stock of claims or liabilities by the appropriate rate of return. The rate of return on direct investment liabilities varies with the domestic output gap, while the rate of return on direct investment claims varies with a weighted average of foreign output gaps in which the weights are computed using bilateral export data. The rate of return on portfolio liabilities is assumed to be a weighted average of two components: the current short-term interest rate and a moving average of past long-term interest rates. Finally, the rate of return on portfolio investment claims is a weighted average of foreign rates of return on portfolio investment liabilities, adjusted for exchange rate movements.

Potential Output

Potential domestic nonfuel output is determined by a Cobb–Douglas production function exhibiting constant returns to scale with respect to labor, the business fixed capital stock, the residential capital stock, and domestic fuel consumption.[16] Potential GDP is defined as potential nonfuel output less net fuel imports, a formula that reflects the concept of GDP as a measure of value added (gross output less raw materials).

Aggregate Wages

Under limited-information expectations, the inflation rate of aggregate wages is specified as a function of

13. In all foreign G-7 country blocks, the weights on the short-term and long-term components are 10 percent and 90 percent respectively. The long-term component assigns weights of 0.05 to the current long-term bond rate and 0.95 to the previous period's long-term component. In future work, we intend to construct new weights that reflect cross-country differences in the maturity structure of government debt.

14. Strictly speaking, payroll taxes are a subcategory of direct taxes, so direct taxes in this discussion should be understood as referring to the nonpayroll component of direct tax revenue.

15. Hours of work are assumed to be constant in the current version of FRB/Global; this variable will be determined endogenously in future work.

16. These four inputs have output elasticities of 0.7, 0.15, 0.1, and 0.05 respectively. Future work on FRB/Global will incorporate country-specific production parameters and will relax the assumption that the industrial sector uses a constant fraction of total domestic fuel consumption.

past wage inflation rates as well as current and past output gaps, consumer price inflation rates, and short-term interest rates. Under model-consistent expectations, the aggregate wage rate is determined by overlapping nominal wage contracts, as formulated by Taylor.[17] At the beginning of each quarter, one-fourth of the work force is assumed to sign new wage contracts of annual duration. When unemployment remains at its natural rate, each contract specifies a wage rate equal to the average expected aggregate wage rate over the subsequent year. In addition, the wage contract is adjusted to account for the average expected deviation of unemployment from its natural rate over the subsequent year. In particular, for a given value of the average expected aggregate wage, a 1 percentage point increase in unemployment throughout the coming year reduces the current contract wage rate 0.02 percent. Finally, the aggregate wage rate is defined as the average of the four wage contracts currently in effect.

Domestic Prices

The price deflator for domestic nonfuel output is determined as a markup over the aggregate wage rate and the domestic fuel price index.[18] The markup rate is assumed to be mildly procyclical: Given employment and fuel costs, a persistent 1 percentage point increase in the output gap generates a 0.36 percent rise in the domestic nonfuel output price deflator. The gap between the markup rate and its equilibrium value shrinks about 33 percent per quarter. Given prices for fuel imports and exports and the price deflator for nonfuel output, nominal GDP is computed as nominal domestic nonfuel output less net fuel imports, and nominal domestic spending is computed as nominal GDP plus net nonfuel imports. The GDP price deflator is then determined by the ratio of nominal to real GDP, and the domestic spending deflator is determined as the ratio of nominal to real domestic expenditures. The private and government price deflators for consumption and investment move proportionally with the domestic spending deflator, so that the relative prices of the components of domestic spending are held constant. Finally, the domestic fuel price depends on the price of imported fuel and the fuel tax rate.

17. Taylor, "Aggregate Dynamics and Staggered Contracts."

18. The relative weights are identical to those in the production function: 0.92 on labor and 0.08 on fuel.

Import and Export Prices

The import price deflators for services and nonfuel goods are determined by a weighted average of foreign export prices converted into local currency units, with the weights constructed from bilateral import data.

The export price deflators for services and nonfuel goods are determined by the price of domestic nonfuel output and a weighted average of foreign output prices converted into local currency, with the weights constructed from bilateral export data.

The price deflators for fuel exports and imports are determined by the local-currency equivalent of the OPEC oil export price, which is expressed in U.S. dollars per barrel.

Appendix B: Other Foreign-Country Equation Blocks of FRB/Global

Three blocks of equations represent Mexico, the NIEs, and the SOECD. These three blocks have a structure similar to that of the foreign G-7 blocks but with no disaggregation of private investment, government revenue, and the capital account. The currencies of the SOECD are assumed to be pegged to the German mark, so that SOECD interest rates and expected inflation move in parallel with the corresponding German variables, apart from differences in risk premiums on external liabilities. Similarly, the Mexican peso is assumed to be pegged to the U.S. dollar, and the NIE currencies are assumed to be pegged to a trade-weighted basket of foreign currencies.

The OPEC block is intended to represent fuel-export-oriented developing economies with no inertia in their nominal macroeconomic variables. The OPEC currencies are assumed to be fixed to the U.S. dollar, and the OPEC nonfuel output price level adjusts in a flexible way to maintain a stable trade-weighted real exchange rate. OPEC imports adjust gradually to maintain a constant ratio of net external assets to nominal GDP. The OPEC oil export price is endogenously determined by world fuel consumption and a trade-weighted index of foreign prices converted into U.S. dollars. For example, a 1 percent increase in world fuel consumption generates a 1 percent increase in the equilibrium OPEC oil export price, with an adjustment rate of 40 percent per quarter toward the new equilibrium price level.

The ROW block of FRB/Global plays a crucial role in ensuring that all global adding-up constraints are satisfied. Thus, all ROW variables related to the

current account and capital account are defined by accounting identities; for example, ROW net nonfuel merchandise exports are determined by the sum of net nonfuel merchandise imports of the other eleven blocks.

At the same time, the ROW block is intended to be representative of small open developing economies with no nominal inertia. Thus, the ROW nonfuel output price index adjusts fairly quickly in response to changes in the ratio of net external debt to nominal GDP. Since the ROW currencies are assumed to be fixed with respect to the U.S. dollar, these movements in the ROW price level translate directly into the trade-weighted real exchange rate, which in turn influences the net exports of the other eleven blocks and contributes to the long-run stability of the global model.

Appendix C: Construction of the FRB/Global Baseline

The data used to construct the FRB/Global baseline come from a variety of sources (table C.1). The FRB/Global baseline (tables C.2 and C.3) is extrapolated to the fourth quarter of 2025 under the assumption of a gradual transition to a balanced growth path. Thus, all output gaps in the model are closed within about ten years, and each component of aggregate demand converges to a constant fraction of real GDP. Consumer price inflation gradually converges to a constant rate of 3 percent, and each wage and price deflator eventually becomes constant relative to the consumer price index. Finally, tax rates are adjusted so that fiscal balance is achieved within about twenty years. □

C.1. Sources of baseline data for FRB/Global variables

Variables	Sources
United States	
Domestic	FRB/US baseline
External sector	Baseline of a Federal Reserve international transactions model
Foreign industrial countries	
National accounts, fiscal and trade data	BIS database
Foreign direct and portfolio investment	IMF balance of payments statistics
Bilateral export and import shares	IMF direction of trade statistics
Fiscal data, stocks of government debt	IMF government finance statistics
Oil production, consumption, and trade	OECD–IEA oil and gas statistics
Oil prices and tax rates	OECD–IEA energy prices and taxes
Real capital stocks, depreciation rates	Penn world tables
Developing countries	
Mexico and NIEs data	IMF international finance statistics
Additional data for NIEs	DRI database
OPEC and ROW data	IMF World Economic Outlook

BIS Bank for International Settlements
IMF International Monetary Fund
OECD–IEA Organisation for Economic Cooperation and Development–International Energy Agency

C.2. Highlights of the FRB/Global baseline

Percent

Country or region	Share of world GDP	Ratio to country's or region's GDP		
		Exports	Net external assets	Government debt
United States	24	11	−14	49
Germany	8	24	11	77
Japan	15	10	20	59
Canada	2	38	−43	107
France	5	24	−1	44
Italy	4	24	−5	119
United Kingdom	4	29	7	56
SOECD	12	27	16	63
Mexico	1	32	−65	n.a.
NIEs	3	56	16	n.a.
OPEC	2	31	125	n.a.
ROW	20	20	−20	n.a.

Note. Averages for 1995.
n.a. Not available.

C.3. Merchandise imports of the United States, Germany, and Japan in the FRB/Global baseline, distributed by exporter

Percent

Exporter	United States	Germany	Japan
United States	. . .	5	19
Germany	5	. . .	4
Japan	15	5	. . .
Canada	18	.5	3
France	2	11	2
Italy	2	8	2
United Kingdom	3	6	2
SOECD	6	39	15
Mexico	8	.1	.4
NIEs	10	4	12
OPEC	4	2	13
ROW	27	20	27
Total	**100**	**100**	**100**

Note. Averages for 1995. Imports measured in U.S. dollars.
. . . Not applicable.