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Andrew T. Levin, John H. Rogers, and Ralph W. Tryon

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Abstract: This paper describes the structure and illustrates the key features of FRB/Global, a large-scale macroeconomic model used in analyzing exogenous shocks and alternative policy responses in foreign economies and in examining the impact of these external shocks on the U.S. economy. FRB/Global imposes fiscal and national solvency constraints and utilizes error-correction mechanisms in the behavioral equations to ensure the long-run stability of the model. In FRB/Global, expectations play an important role in determining financial market variables and domestic expenditures. Simulations can be performed using either limited-information ("adaptive") or model-consistent ("rational") expectations.

Keywords: macroeconometric models; long-run stability; rational expectations; fiscal and monetary policy; European Monetary Union.

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1. Introduction

FRB/Global is a large-scale macroeconomic model developed and maintained by the staff of the Board of Governors of the Federal Reserve System. This model uses the equations of the FRB/US model to represent the macroeconomic structure of the U.S. economy. FRB/Global also contains eleven blocks of equations to represent each of the foreign 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 exogenous shocks and alternative policy responses in foreign economies and in examining the impact of external shocks on the U.S. economy. For example, experiments with FRB/Global provide useful information about the effects of exchange rate movements or oil price fluctuations on U.S. unemployment and inflation under alternative assumptions about foreign monetary policy. 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 incorporated into the structure of FRB/Global. First, the equations have been reformulated to ensure *long-run stability:* in response to an exogenous shock, each economy represented in FRB/Global gradually converges to a balanced growth path in which actual output is equal to potential GDP and every inflation-adjusted variable has a constant ratio to potential GDP. The inflation rate converges to a target determined by monetary policy, and all relative prices converge to constant values. Fiscal solvency is maintained by assuming that a country's tax rate adjusts when the ratio of government debt to GDP deviates from a specified target. National solvency is maintained by assuming that the risk premium on a country's assets responds to the ratio of its net external debt to GDP.

The second feature added to FRB/Global is the *explicit treatment of expectations*. Simulations can be performed under either of two assumptions about expectations formation: (1) limited-information or "adaptive" expectations, under which agents are assumed to have less than complete information about the structure of the global economy, or (2) model-consistent ("rational") expectations, under which agents are assumed to possess all the information

contained in the model.[1] Expected values of future variables directly influence interest rates, consumption and investment expenditures, the aggregate wage rate, and the nominal exchange rate. As seen in Section 5, the method of expectations formation can have important implications for the simulation results.

The remainder of this paper provides a historical perspective on the development of FRB/Global and gives an overview of the foreign blocks of the model. The dynamic properties of FRB/Global are highlighted using three simulation experiments: a reduction in U.S. government purchases; a depreciation of the U.S. dollar; and an increase in the OPEC oil export price. Other uses of FRB/Global are illustrated by examining the spillover effects of fiscal and monetary policy under alternative European monetary policy regimes.

2. A Historical Perspective on FRB/Global

In the mid-1970s, a variety of factors--increased economic interaction among countries, the first oil shock, and the floating of 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 block representing the U.S. economy (with a more detailed external sector than in previous models); four other blocks representing Canada, Germany, Japan, and the United Kingdom; and an aggregate block representing the rest of the world.[2] From 1979 onward, the Board staff used the MCM on a regular basis 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

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[1] To represent limited-information expectations, FRB/US uses a core vector autoregression with auxiliary equations (cf. Brayton and Tinsley 1996; Brayton et al. 1997), while individual regression equations are used to generate each of the expectation variables in the foreign blocks of FRB/Global.

[2] Guy Stevens led the effort to develop the MCM, which was completed in 1979. Stevens et al. (1984) describes the MCM in detail and reports multiplier results and other simulation properties of the model.

rate determination and the capital account of the balance of payments. In particular, equations based on the portfolio balance approach to exchange rate determination were replaced by modified uncovered interest parity relationships, a specification based on interest rate differentials.[3] Empirical considerations also led to the elimination of detailed representations of banking sectors from the individual country blocks. 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.[4] 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, 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/regional block. The resulting arrangement of twelve country/regional blocks with multilateral trade equations has also been used in the current version of FRB/Global.

The staff's most recent reassessment of the MCM began in 1993 and culminated

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[3] This 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 (1976), which incorporated assumptions of open interest parity, nominal price rigidities, and rational expectations.

[4] Edison, Marquez, and Tryon (1989) describe the results of these and other changes to the MCM.

in FRB/Global in 1996.[5] 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 multi-year 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 fiscal and national solvency constraints were imposed.[6] The long-run stability of FRB/Global permits simulations under either model-consistent ("rational") or limited-information ("adaptive") expectations.[7]
The method of expectations formation plays a crucial role in determining the extent to which a pre-announced policy measure has contemporaneous effects on the economy; the implications of this choice are explored in Section 5.

3. The Structure of FRB/Global

FRB/Global consists of twelve blocks of equations, with each block describing the economy of an individual country or a specific 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. FRB/US utilizes four behavioral equations to determine foreign aggregate demand, the real effective exchange rate, the oil import price deflator, and net factor income from abroad. FRB/Global replaces these four 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). Each foreign G-7 country block represents a

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[5] This work drew heavily on the experimental multi-country model of Gagnon (1989).

[6] The fiscal and national solvency constraints in FRB/Global are similar to those used in the IMF's multi-country model, MULTIMOD; see Masson, Symansky, Haas, and Dooley (1988).

[7] To represent limited-information expectations, FRB/US uses a core vector autoregression with auxiliary equations (see Brayton and Tinsley 1996; see also Brayton, Mauskopf, Reifschneider, Tinsley, and Williams 1997). Individual regression equations are used to generate each of the expectation variables in the foreign blocks of FRB/Global.

medium-sized open economy with neo-Keynesian features in the short run and neoclassical properties in the long run. Under these assumptions, output and employment are determined by aggregate demand, and wages and prices respond slowly to macroeconomic shocks. Eventually, however, wages and prices adjust to ensure that the economy returns to a balanced growth path with output at potential and unemployment at the natural rate. Gradual movement of the direct tax rate ensures long-run fiscal solvency, while the determination of the sovereign risk premium ensures national solvency.

To incorporate these features, each foreign G-7 country block is comprised of about 60 behavioral equations and about 100 accounting identities. The specification of these equations is nearly identical for each country block, and the differences between the six economies are captured by country-specific parameter values: the behavioral coefficients have been obtained from estimation and calibration of the model, while the monetary and fiscal policy parameters depend on the assumptions of a particular simulation scenario.

The remaining five blocks of FRB/Global represent Mexico; the 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), comprised of 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. Thus, each block is comprised 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.

The equations in each block of FRB/Global may be grouped into five sectors: domestic spending; fiscal accounts; the external sector; aggregate supply (i.e., production, employment, wage and price determination); and financial markets (i.e., interest rates and exchange rates). The remainder of this section outlines the specification of these sectors for the foreign G-7 country blocks, and highlights the role of expectations and the features that ensure the long-run stability of the model. Further details about the foreign blocks

of FRB/Global are provided in Appendices A and B. The model variables are defined in Appendix D, and the equations of the prototypical foreign G-7 block are listed in Appendix E.

A. Domestic Spending

In the foreign G-7 blocks of FRB/Global, six expenditure variables contribute to 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 consumption and investment expenditures are determined by behavioral equations, while real government consumption and investment are exogenously determined.

The behavioral equation for each private expenditure variable incorporates an error-correction mechanism, which permits realistic short-run dynamics while ensuring that the level of expenditures gradually adjusts toward a long-run balanced growth path; i.e., 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 *ex ante* long-term real interest rate. The equilibrium paths of real business fixed investment and residential investment are each determined by real GDP, the *ex ante* long-term real interest rate, and the corresponding depreciation rate. Finally, the equilibrium path of real inventory investment depends on domestic sales and the *ex ante* short-term real interest rate.

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 ($\boldsymbol{R}_L$), and the labor force participation rate (***L/POP***).[8] An accounting identity relates nominal disposable income to nominal GDP, net factor income from abroad, and taxes less government

[8] In the foreign G-7 country blocks of FRB/Global, private consumption expenditures depend on current and past income, so that consumption is sensitive to temporary as well as permanent income movements. In FRB/US, consumption expenditures also depend on financial wealth and the present discounted value of expected future labor income, so that consumption is less sensitive to temporary income fluctuations. In future work, we plan to investigate similar specifications for the foreign country blocks of FRB/Global.

subsidies and transfers to households; then ***Y*** is computed by deflating nominal disposable income by the consumption price index. The determination of $\boldsymbol{R}_{\mathrm{L}}$ will be described later.
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 $\boldsymbol{R}_{\mathrm{L}}$ and ***L/POP***, and to estimate the short-run and long-run parameters of this relationship.[9] Table 1 displays a summary of how private consumption responds to changes in disposable income and the long-term real interest rate. In Germany, for example, a permanent one percentage point increase in $\boldsymbol{R}_{\mathrm{L}}$ is estimated to reduce private consumption by 0.23 percent within one quarter and by 0.76 percent in the long-run.

Table 1

Determinants of Private Consumption Expenditures

	Canada	France	Germany	Italy	Japan	U.K.
Y						
Short-Run	0.58	0.73	0.73	0.1	0.62	0.29
Long-Run	1.0	1.0	1.0	1.0	1.0	1.0
$\boldsymbol{R}_{\mathrm{L}}$						
Short-Run	-0.13	-0.23	-0.23	-0.053	-0.23	-0.19
Long-Run	-0.37	-0.76	-0.76	-2.4	-1.5	-0.65

Notes: 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 percent change in ***C*** from a permanent one percentage point increase in the *ex ante* long-term real interest rate ($\boldsymbol{R}_{L}$). "Short-Run" indicates the effect during the first quarter, and "Long-Run" indicates the steady-state effect.

[9] The labor force participation rate is crucial in explaining long-term changes in private savings rates in Germany, Japan, and the U.K, but is not statistically significant in the case of Canada. For Italy, the relationship between the private savings rate and the long-term interest rate and labor force participation rate appears to be nearly non-stationary. For France, no satisfactory estimates could be obtained, so the parameters of the French consumption function were calibrated to those of Germany.

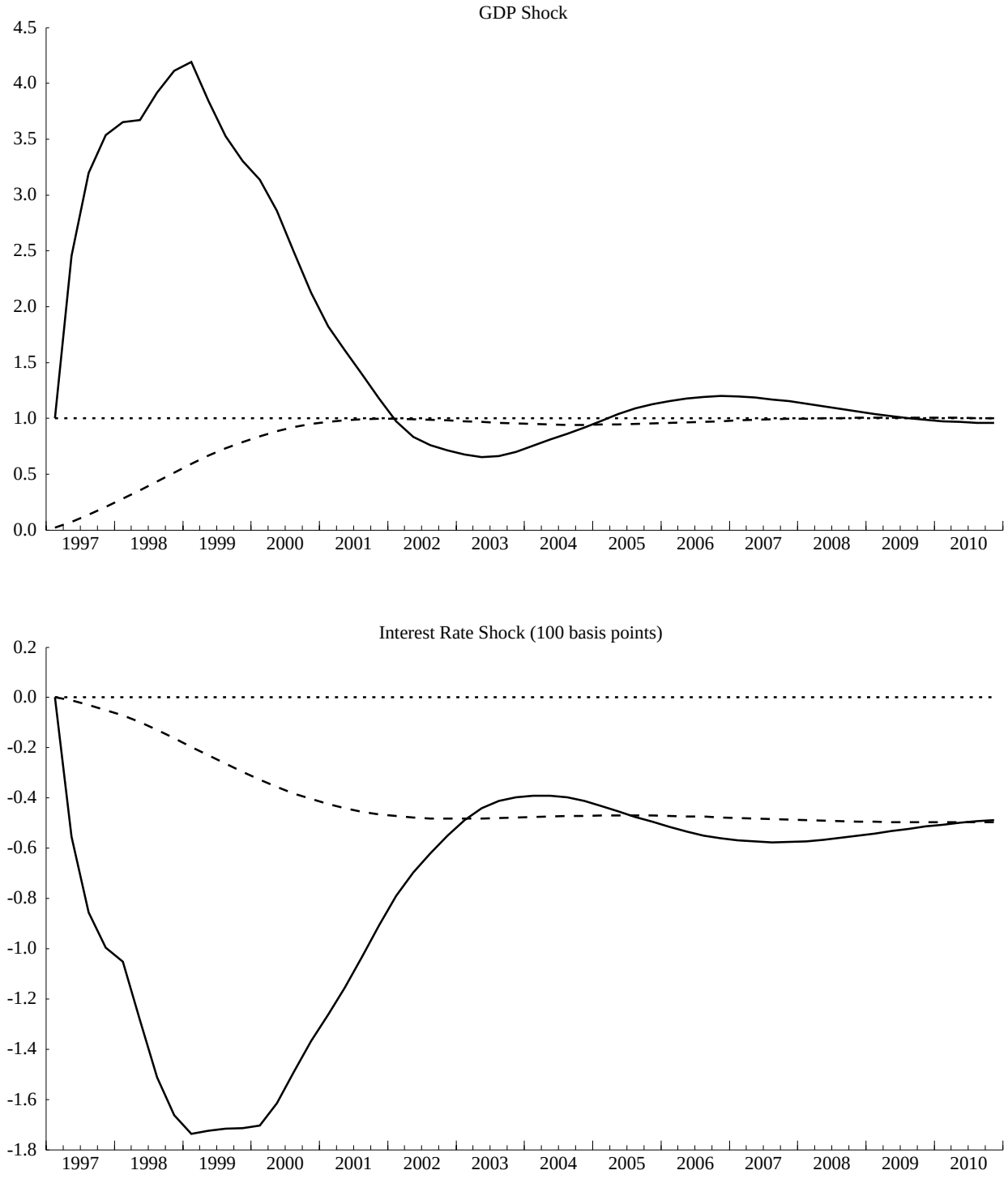
In the short run, ***C*** exhibits partial adjustment in response to permanent changes in ***Y*** and $\boldsymbol{R}_{\mathbf{L}}$, due to liquidity constraints, information lags, and other factors. In Germany, for example, a permanent one percent change in ***Y*** generates an immediate 0.73 percent 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).

Business Fixed Investment. Assuming competitive input and product markets, microeconomic theory indicates that the marginal product of capital should equal the real rental rate, which is the sum of the *ex ante* long-term real interest rate and the depreciation rate. With a Cobb-Douglas production function, the marginal product of capital is inversely proportional to the capital-output ratio. Thus, in the long run, business fixed investment maintains the capital-output ratio at a level consistent with the *ex ante* long-term real interest rate and the depreciation rate. In the short run, business fixed investment is strongly influenced by fluctuations in real GDP growth through an accelerator effect. Business fixed investment also incorporates a partial adjustment mechanism, in which the gap between current fixed investment and its equilibrium level shrinks by about 25 percent per quarter.

To illustrate these properties, Chart 1 exhibits the partial equilibrium behavior of German business fixed investment and the business fixed capital stock. The upper panel of Chart 1 shows the effects of a permanent one percent increase in real GDP (both actual and potential), with no change in the real rental rate. 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 subsequent 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 equibrium value of the capital-output ratio remains unchanged, so that the capital stock eventually stabilizes at one percent above its initial level. Given the constant depreciation rate, fixed investment also rises by one percent in the long run.

The lower panel of Chart 1 displays the partial equilibrium effects of a permanent one percentage point change in the real rental rate on capital, with no change in actual or potential output. The drop in the equilibrium capital-output ratio leads to a 1.8 percent reduction in

Chart 1
The Dynamics of German Business Fixed Investment
Absolute (+/-) and Relative (%) Deviations from Baseline, in Percentage Points



Solid: Business Fixed Investment (%)
Dashed: Capital Stock (%)
Dotted: Real GDP (%)

business fixed investment over the first several years. The stock of business fixed capital gradually falls by about 0.4 percent to its new equilibrium level, with a similar long-run drop in the level of business fixed investment.

Inventory Investment. For each foreign G-7 country block, 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, holding domestic sales 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, reflecting the use of inventories as a buffer against sudden changes in sales. However, 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 by the same proportion as the increase in domestic sales.[10]

B. Fiscal Accounts

The fiscal accounts of the foreign G-7 country blocks are relatively straightforward: government expenditures are comprised of consumption, investment, subsidies, transfers to households, and interest payments, while government revenues are obtained 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 endogenously determined to ensure a stationary path for the ratio of government debt to GDP. In particular, each country block has a specified target path for the ratio of real government debt (deflated by the GDP price deflator) to potential

[10] The current specification of the inventory investment equation does not distinguish between expected and unexpected changes in domestic sales; it would be useful to incorporate such a distinction in future work.

GDP. If a shock causes the actual debt-GDP ratio to deviate from target, the direct tax rate is adjusted nonlinearly to ensure that the debt-GDP ratio gradually returns to its target.

To illustrate this mechanism, consider the effects of a permanent reduction in government consumption expenditures under two different fiscal policy assumptions. First, suppose that the debt/GDP target is left 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 previously indicated, the equilibrium level of private consumption expenditures moves in proportion to real disposable income. Thus, in the long run, the drop in government consumption expenditures is offset by a roughly equal increase in private consumption expenditures.

Alternatively, suppose that the debt-GDP target is gradually adjusted downward toward a new value, so that the direct tax rate remains constant over some time horizon (e.g., 25 years). 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.

C. The External Sector

Trade Volumes. In each foreign G-7 country block, exports and imports are disaggregated into three components: non-fuel merchandise, non-factor services, and fuel. Under the assumption of long-run balanced growth, the equilibrium ratio of real non-fuel merchandise imports to real domestic spending is determined by the ratio of the non-fuel goods import price deflator to the non-fuel domestic output price deflator. In the short run, real non-fuel merchandise imports exhibit partial adjustment at a rate of 30 percent per quarter toward the equilibrium level. Service imports follow essentially the same error-correction mechanism, involving the relative price of service imports. The volume of net fuel imports equals the difference between domestic fuel production and consumption, where fuel production is

exogenously determined, and fuel consumption depends on domestic non-fuel output and the relative price of fuel.

For each foreign G-7 country block, the volume of non-fuel merchandise exports ($\boldsymbol{X}_g$) is determined by foreign trade-weighted imports ($\boldsymbol{M}^*$) and relative prices ($\boldsymbol{RP}_{xg}$). It is helpful to use the German country block to illustrate how these foreign demand and relative price variables are constructed. Foreign demand for German exports is computed as the weighted average of non-fuel goods imports by Germany's trading partners, where the weights are constructed using German bilateral export data. 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 German relative price measure, $\boldsymbol{RP}_{xg}$, the French component is defined as the ratio of the German non-fuel goods export price deflator to the weighted average of foreign export prices, where the weights are constructed using French bilateral import data. Finally, the overall measure of German competitiveness, $\boldsymbol{RP}_{xg}$, is computed as a weighted average across German export markets, using German bilateral export weights.

Using these measures of foreign demand and relative prices, an error-correction mechanism is used to determine the volume of non-fuel merchandise exports. With constant relative prices, the ratio of $\boldsymbol{X}_g$ to $\boldsymbol{M}^*$ remains constant; i.e., each country exports a fixed share of world imports. If relative prices change, the ratio of $\boldsymbol{X}_g$ to $\boldsymbol{M}^*$ gradually adjusts toward its new equilibrium value at a rate of 15 percent per quarter. Real non-factor service exports are determined by a similar error-correction mechanism involving foreign trade-weighted service imports and the relative price of non-factor service exports.

Trade Prices. The non-fuel goods and non-factor service import price deflators are determined by a weighted average of foreign export prices converted into local currency units, where the weights are constructed using bilateral import data. The non-fuel goods and non-factor service export price deflators are determined by the domestic non-fuel output price and a weighted average of foreign output prices converted into local currency, where the weights are constructed using bilateral export data. The fuel export and import price deflators are

determined by the local currency equivalent of the OPEC oil export price, which is expressed in U.S. dollars per barrel.

D. Aggregate Supply

In each foreign G-7 country block, wage and price determination generates a Phillips curve that is downward-sloping in the short run and vertical in the long run. Real GDP is determined by aggregate demand, which is the sum of domestic spending and net exports. Thus, 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 and unemployment is below the natural rate, wages are initially sticky, but gradually rise in response to pressures generated by excess aggregate demand. An error-correction mechanism ensures that the domestic output price deflator gradually adjusts toward its equilibrium path, which is a markup over the aggregate wage rate and the domestic fuel price index.

The particular formulation of aggregate wage behavior depends on whether expectations are assumed to be limited-information (or "adaptive") or model-consistent (also referred to as "forward-looking" or "rational"). Under limited-information expectations, the aggregate wage inflation rate is specified as a function of past wage inflation rates as well as current and past output gaps, consumer price inflation rates, and short-term interest rates.[11] Under model-consistent expectations, the aggregate wage rate is determined by overlapping nominal wage contracts, as formulated by Taylor (1980). 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, and the aggregate wage rate is defined as the average value of the wage contracts currently in effect.[12]

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

[12] This specification of wage determination under model-consistent expectations is highly stylized; alternative specifications of wage determination for the foreign G-7 countries will be considered in subsequent research.

E. Financial Markets

Short-Term Interest Rates. In a typical FRB/Global simulation, Canada, Germany, Japan, and the United Kingdom follow independent monetary policies using the short-term nominal interest rate as the intermediate target, while France and Italy maintain fixed exchange rates with respect to the German mark. Although these are typical monetary policy assumptions, FRB/Global has been designed so that these monetary policy assumptions can be modified easily from one simulation to the next, a feature that will be highlighted later.

For country blocks with independent monetary policies, the short-term nominal interest rate is typically adjusted in response to the current output gap and the current deviation of consumer price inflation from an exogenously specified target, along the lines proposed by Henderson and McKibbin (1993) and Taylor (1993). Alternatively, the short-term interest rate may be adjusted to target a particular path for the price level, as in nominal GDP targetting.

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. For country blocks with independent monetary policies, the determination of these variables is described in the following paragraphs. For country blocks whose currency is pegged to the German mark, interest rates and expected inflation move in parallel with the corresponding German variables, apart from an endogenously determined sovereign risk premium. This sovereign risk premium is linearly related to the net external debt-GDP ratio, and helps avoid explosive paths for the net external debt stock.

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 short-term interest rate shock. Regression analysis has been used to obtain country-specific values for these parameters. 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, while long-term expected inflation is a moving average of current and past short-term inflation rates, exhibiting relatively slow partial 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 country blocks with independent monetary policies, the equations that determine the bilateral U.S. dollar exchange rate are shown in figure 1. Under both limited-information and model-consistent expectations, the bilateral exchange rate is determined by real interest parity (the bilateral differential in real interest rates) and a sovereign risk premium that depends on the ratio of net external debt to GDP (both measured in U.S. dollars). 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 external debt stock.

Under either method of expectations formation, an unanticipated temporary increase in U.S. interest rates generates an initial rise in the value of the U.S. dollar, followed by depreciation back toward its equilibrium value, 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, adjusted for long-term expected inflation. In this case, a one 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 one percentage point, then investors are only willing to hold assets denominated in German marks if the U.S. dollar is expected to depreciate one percent against the mark over the subsequent quarter. Thus, the temporary interest rate differential generates

an immediate one percent jump in the value of the dollar, followed by depreciation back to its long-run value in the subsequent period.

Figure 1

Exchange Rate Determination

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

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

Notes: $\boldsymbol{RER}_t$ is the natural logarithm of the bilateral consumer price-adjusted real exchange rate, where the exchange rate is defined in units of local currency per U.S. dollar. $\boldsymbol{RL}_t$ is the current long-term interest rate, and $\boldsymbol{RS}_t$ is the current short-term interest rate. $\boldsymbol{NXDEBT}_t$ is the net external debt position, and $\boldsymbol{GDPVD}_t$ is nominal GDP (both measured 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, $\boldsymbol{RER}_{t+1}$, are computed using model-consistent expectations. The ***US*** superscript indicates the corresponding variable in the U.S. country block. Each equation also includes an intercept and a residual term (not shown).

4. The Dynamic Properties of FRB/Global

This section describes the dynamic properties of FRB/Global using three simulation experiments: an exogenous reduction in U.S. government spending, an exogenous depreciation of the U.S. dollar, and an exogenous increase in the OPEC oil export price. Each simulation is performed under the assumption of limited-information expectations.

The effects of each shock are evaluated under two alternative U.S. monetary policy rules. Under the "active" monetary policy rule, the federal funds rate is adjusted in response to the output gap and the deviation of consumer price inflation from the target rate (cf. Henderson and McKibbin 1993; Taylor 1993). Thus, for each percentage point that output exceeds potential, the short-term nominal interest rate is raised 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 is raised 150 basis points. Under the "passive" monetary policy rule, the nominal federal funds rate is held constant throughout the simulation.

In every 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 absolute or percentage point deviations from the baseline path; the construction of this baseline is described in appendix C.

A. U.S. Government Spending Shock

In this experiment, real U.S. government purchases of goods and services are permanently reduced by one percent of the baseline path of U.S. GDP, starting in 1997q1, while U.S. tax rates are held constant through 2010q4. Since this shock originates within the U.S. country block, and foreign trade comprises a fairly limited share of the U.S. economy, this experiment serves as a useful benchmark for comparing the simulation results from FRB/Global and FRB/US.

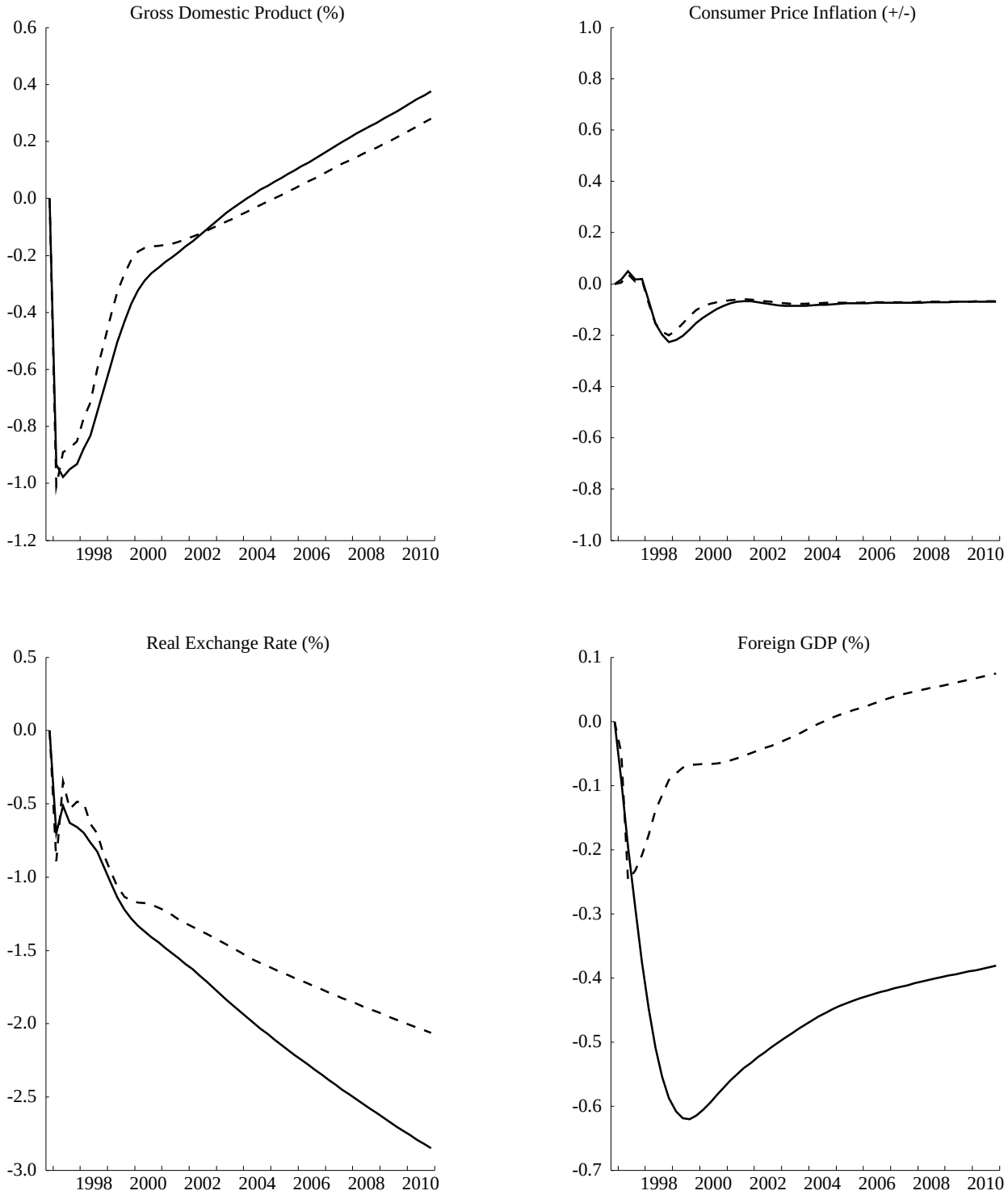
As seen in the upper panels of Chart 2, the two models generate nearly identical paths for U.S. real GDP and consumer price inflation. The lower two panels show the paths of the trade-weighted real exchange rate and foreign trade-weighted GDP, the two foreign variables that enter into the determination of U.S. net exports. As mentioned previously, each of these variables is determined by a single equation in FRB/US. Thus, it is interesting to note that the 1200 foreign equations in FRB/Global generate a very similar path for the real exchange rate, especially over the first several years of the simulation. The differences in foreign GDP are slightly larger, but the impact on U.S. exports is small, and the effect on U.S. GDP is negligible. This example illustrates a more 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 as well as the effects of external shocks on both the U.S. and foreign economies.

It is useful to examine the impact of this shock over the period 1997q1 to 1999q4, and to compare the effects on the United States, Canada, Germany, and Japan (the four G-7 country blocks maintaining independent monetary policies). As seen in the upper-left panel of Chart 3, Canadian real GDP (the dotted line) closely tracks the contraction and recovery in U.S. output, since Canadian exports to the U.S. account for a relatively large share of Canadian aggregate demand. The U.S. contraction has a much smaller effect on Japan (the dashed line) and Germany (the dash-dotted line). The lower-left panel of Chart 3 shows how the "active" monetary policy rule prescribes a cut in short-term interest rates in each country. The Canadian short rate falls by a full percentage point, whereas the Japanese and German short rates only fall by about 20-40 basis points. As seen in the lower-right panel of Chart 3, long-term real interest rates in all three foreign countries fall less than in the United States. Thus, as indicated by the long-term real interest parity equation shown in Figure 1, each foreign currency exhibits real appreciation relative to the U.S. dollar, accounting for the trade-weighted U.S. real exchange rate depreciation displayed in the lower-left panel of Chart 2.

Table 2 provides a summary of how the U.S. fiscal shock affects the trade balance and current account in each of the twelve blocks of FRB/Global. The U.S. trade balance improves by about $15 billion per year, due to a combination of the real exchange rate depreciation and

Chart 2
U.S. Government Spending Shock: Model Comparison

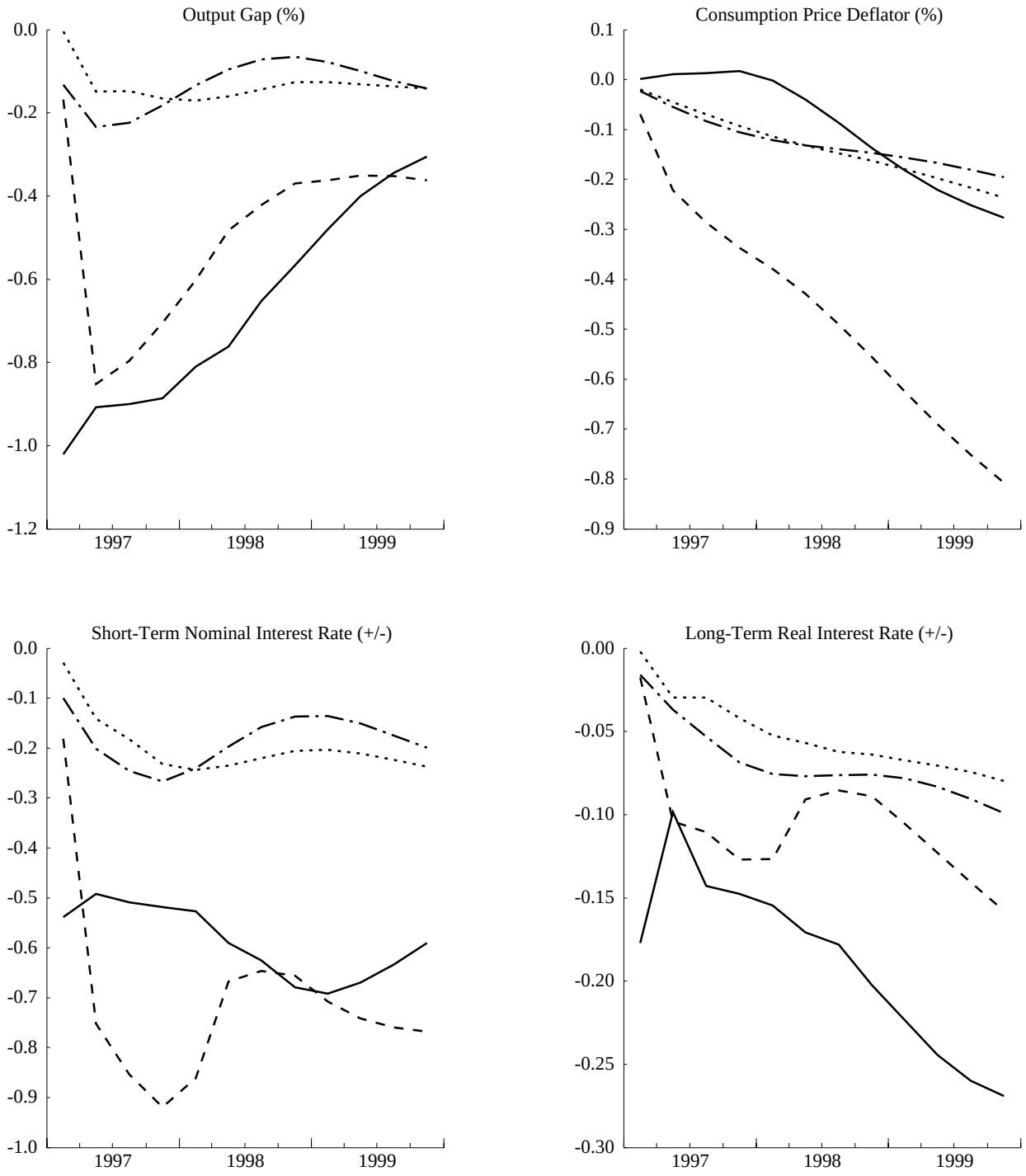
Absolute (+/-) and Relative (%) Deviations from Baseline, in Percentage Points



Solid: FRB/US
Dashed: FRB/Global

Chart 3
U.S. Government Spending Shock

Absolute (+/-) and Relative (%) Deviations from Baseline, in Percentage Points



Solid: United_States
Dashed: Canada
Dotted: Germany
Dot-Dashed: Japan

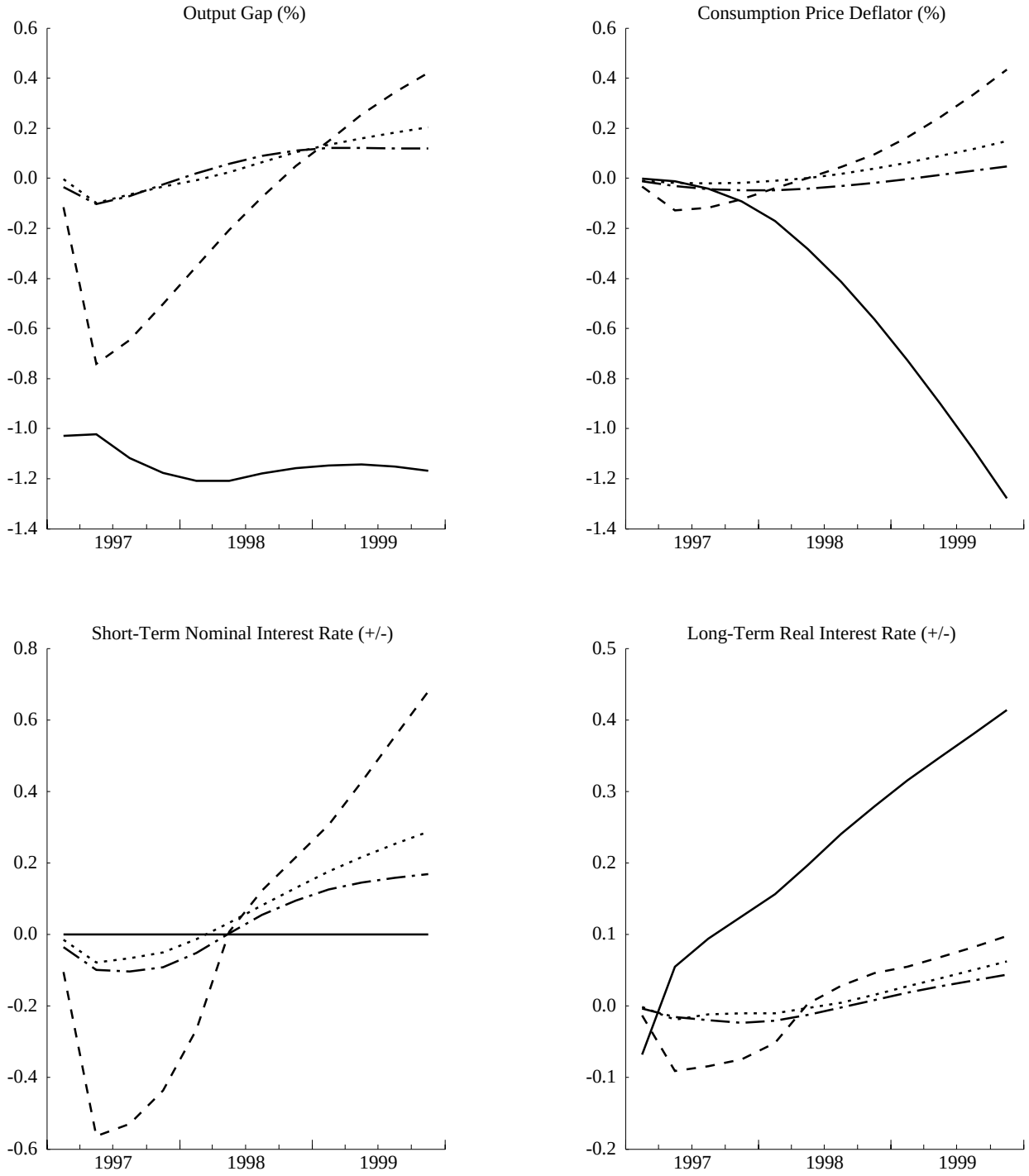
Table 2

U.S. Government Spending Shock - Active U.S. Monetary Policy

	Trade Balance ($US)			Current Account ($US)		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
United States	15.1	16.9	11.8	24.3	27.8	23.7
Germany	0.1	0.2	0.1	-0.8	-0.8	-1.3
Japan	-0.6	-1.4	-1.6	-5.3	-7.4	-9.0
Canada	-1.5	-1.3	-1.2	-1.0	-0.9	-0.9
France	0.1	-0.3	-0.7	-0.4	-1.0	-1.7
Italy	0.1	-0.3	-0.4	0.0	-0.7	-0.9
United Kingdom	-0.8	-0.6	-0.4	-1.6	-1.8	-1.8
Smaller OECD	-1.0	-1.7	-1.1	-0.8	-1.6	-1.1
Mexico	-0.3	-0.5	-0.6	-0.2	-0.4	-0.6
NIEs	-1.6	-1.2	-0.4	-1.1	-1.2	-0.8
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

Chart 4
U.S. Government Spending Shock: Constant U.S. Federal Funds Rate

Absolute (+/-) and Relative (%) Deviations from Baseline, in Percentage Points



Solid: United_States
Dashed: Canada
Dotted: Germany
Dot-Dashed: Japan

lower domestic absorption. The current account improves even more, as lower interest rates and profit rates dampen the rates of return 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 ROW trade balance is determined by the constraint that the global trade deficit remain at its baseline value. Nevertheless, a fall 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.

Finally, Chart 4 depicts the macroeconomic effects of the U.S. government spending shock when the U.S. maintains a constant federal funds rate. In this case, U.S. real GDP remains stagnant at about one percent below baseline during the first three years of the simulation, while consumer price inflation falls due to the downward-sloping short-run Phillips curve. Thus, expected long-term inflation falls, and the long-term real interest rate gradually increases. Meanwhile, foreign real interest rates are falling in response to the "active" monetary policy rules in Canada, Germany, and Japan, leading 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, generating an explosive downward spiral for U.S. output and prices.

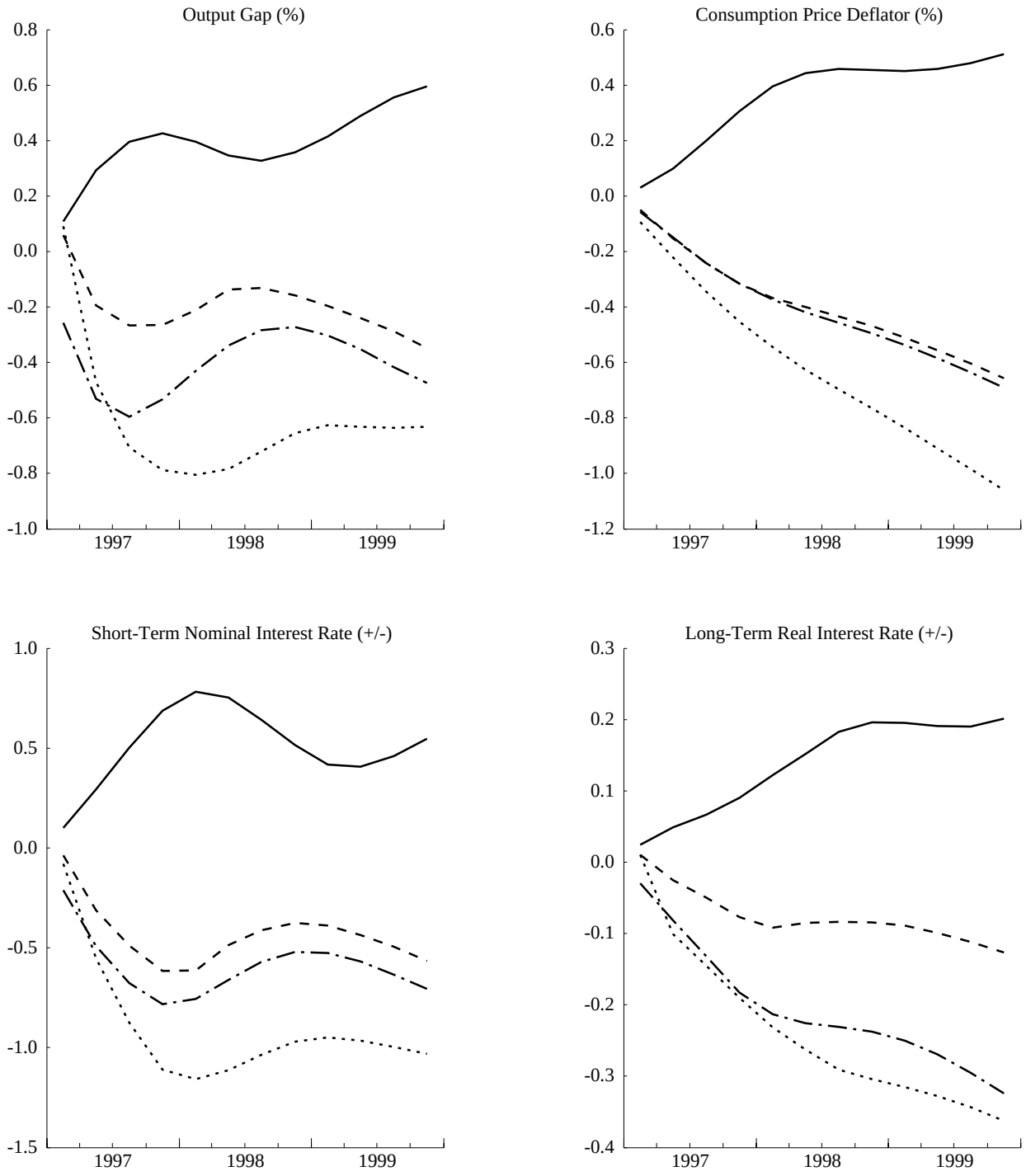
B. U.S. Dollar Depreciation

In this experiment, the U.S. dollar depreciates by 5 percent against the Canadian dollar, and by a trade-weighted average of 10 percent against the other G-10 currencies (represented in FRB/Global by the other foreign G-7 country blocks and the SOECD block). After the depreciation occurs in 1997q1, the G-10 exchange rates remain fixed at the new level throughout the simulation period. Since the depreciation is not triggered by a change in expectations about future interest rates, this experiment may be viewed as representing an exogenous downward shift in preferences for holding dollar-denominated assets.

Chart 5 depicts the results of this experiment when the United States follows the "active" monetary policy rule, and Chart 6 displays the results under a constant U.S. federal funds rate. Under either monetary policy regime, the exchange rate depreciation improves U.S. external competitiveness and stimulates net exports, thereby raising real GDP by about 0.6 percent within about a year. The exchange rate depreciation also passes gradually into U.S. import

Chart 5
U.S. Currency Depreciation

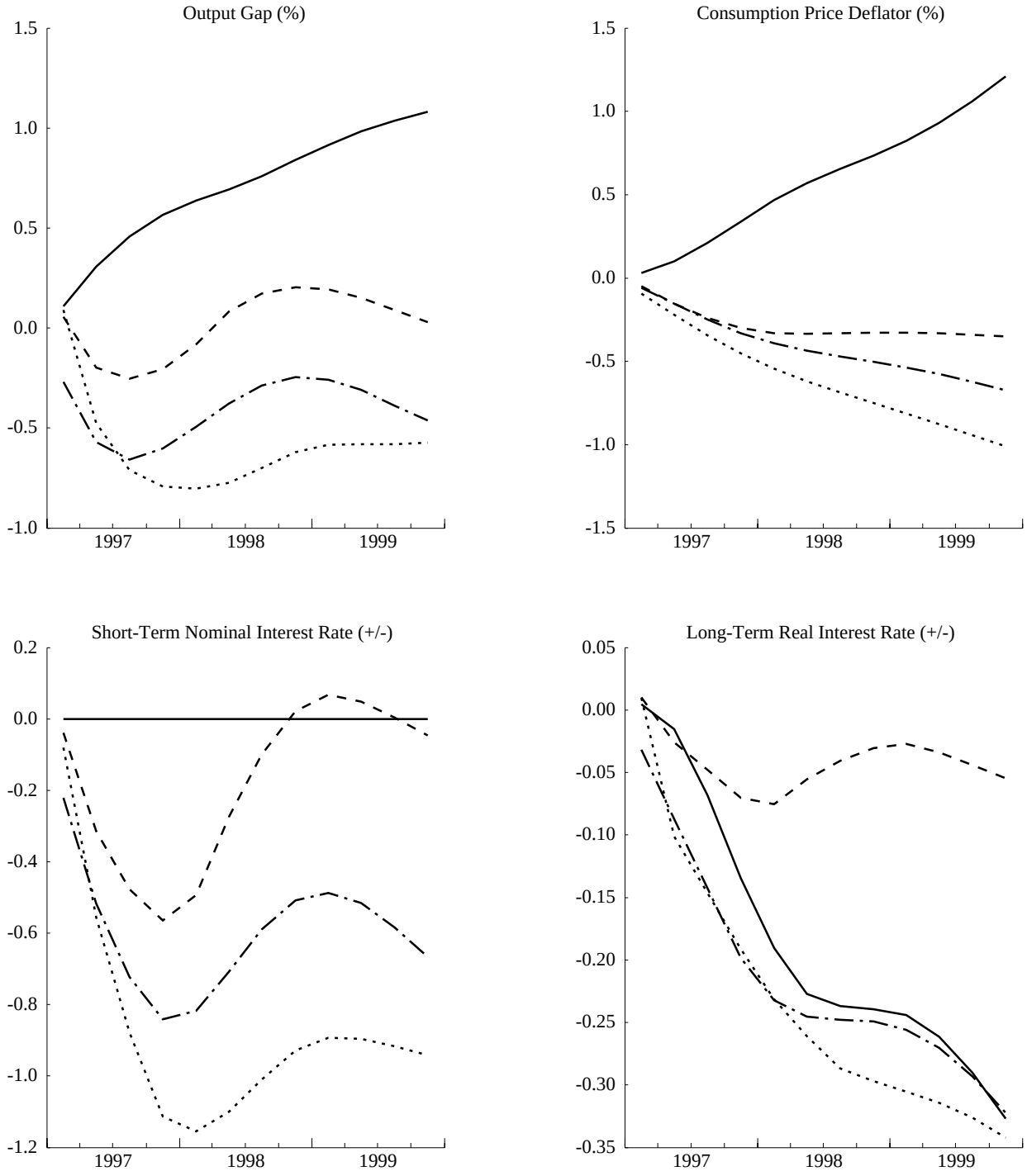
Absolute (+/-) and Relative (%) Deviations from Baseline, in Percentage Points



Solid: United_States
Dashed: Canada
Dotted: Germany
Dot-Dashed: Japan

Chart 6
U.S. Currency Depreciation: Constant U.S. Federal Funds Rate

Absolute (+/-) and Relative (%) Deviations from Baseline, in Percentage Points



Solid: United_States
Dashed: Canada
Dotted: Germany
Dot-Dashed: Japan

prices and ultimately into higher consumer price inflation. Thus, the "active" monetary policy rule prescribes an increase of almost 150 basis points in the federal funds rate by mid-1998, and gradually pushes up the long-term real interest rate.

Table 3 summarizes the simulation results for global trade and current accounts 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 1999. The U.S. current account improves by a smaller amount, as higher interest rates and profit rates generate higher net factor payments. Finally, Table 3 shows that Japan and the NIEs bear the brunt of the increase in U.S. net exports. The ROW is not severely affected, since its price level adjusts fairly quickly to maintain a constant trade-weighted real exchange rate.

C. OPEC Oil Export Price Shock

In this experiment, the OPEC oil export price increases permanently in 1997q1 and remains fixed thereafter at $5 per barrel above its baseline path. This shock corresponds to a 25 percent rise in fuel import prices faced by the U.S. as well as the other country/regional blocks of FRB/Global. Chart 7 and Table 4 display the impact of the OPEC oil price shock when the U.S. follows the "active" monetary policy rule. As seen in the upper-right panel of Chart 7, the U.S. consumer price level rises about 0.3 percent by the end of 1997. To push inflation back toward its target rate, the "active" monetary policy rule prescribes a 20 basis point increase in the federal funds rate, which causes a mild contraction in which U.S. real GDP falls about 0.3 percent. As inflationary pressures subside, the federal funds rate returns to baseline, and the output gap is largely closed by 1999. By contrast, Chart 8 exhibits the impact of the shock when the U.S. maintains a constant federal funds rate. In this case, output remains close to baseline, but consumer prices rise about 0.5 percent, nearly twice as much as under the "active" monetary policy rule.

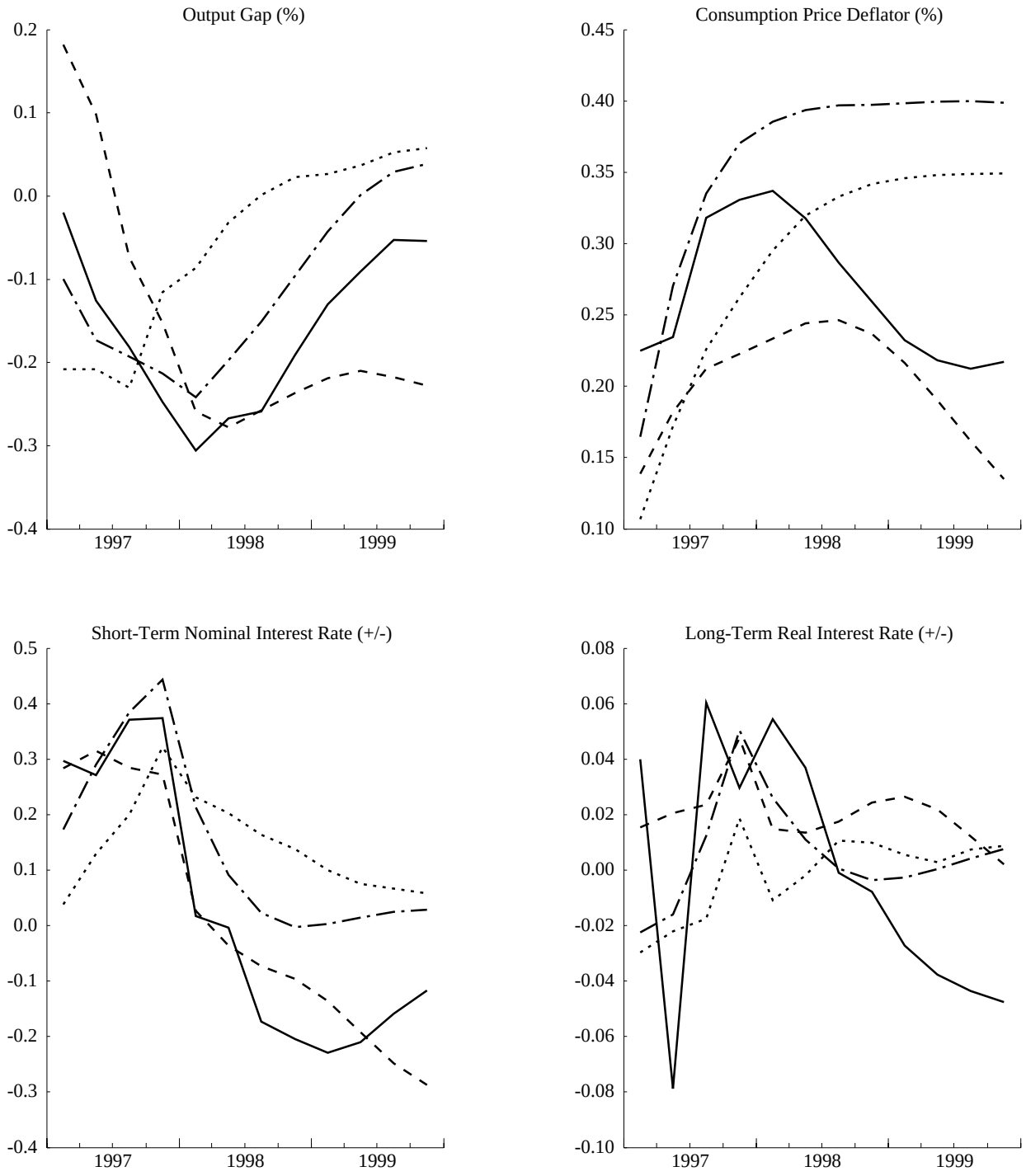
Table 3

U.S. Currency Depreciation - Active U.S. Monetary Policy

	Trade Balance ($US)			Current Account ($US)		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
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	0.5	1.2	0.6	0.3	0.8	0.5
France	3.7	2.3	-1.6	1.6	-1.2	-5.9
Italy	2.4	0.4	-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	-0.9	-2.4	5.8	2.1	0.8
Mexico	0.4	1.4	1.8	-0.5	0.0	0.5
NIEs	-12.1	-14.2	-13.5	-5.3	-6.4	-6.7
OPEC	-7.1	-2.1	-0.2	-9.7	-5.2	-3.5
ROW	13.5	-6.7	-6.4	15.1	9.6	14.5

Chart 7
OPEC Oil Export Price Shock

Absolute (+/-) and Relative (%) Deviations from Baseline, in Percentage Points



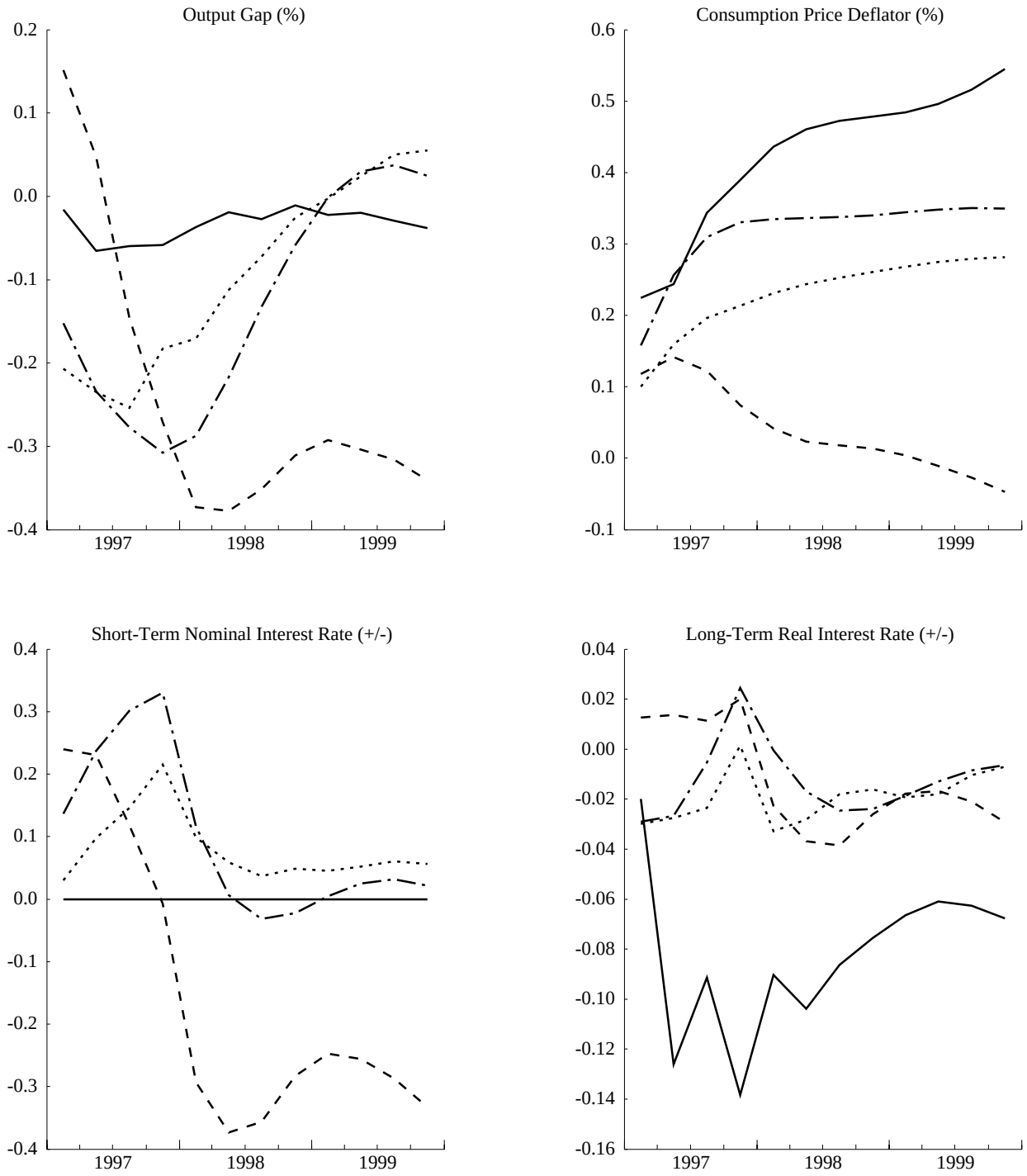
Solid: United_States
Dashed: Canada
Dotted: Germany
Dot-Dashed: Japan

Table 4

OPEC Oil Export Price Shock - Active U.S. Monetary Policy

	Trade Balance ($US)			Current Account ($US)		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
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	0.3	0.2	0.9	0.5	0.5
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	0.5	-0.2	-0.2	0.0	-1.0	-1.1
Smaller OECD	-1.2	0.2	1.7	-1.1	0.1	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

Chart 8
OPEC Oil Export Price Shock: Constant U.S. Federal Funds Rate
Absolute (+/-) and Relative (%) Deviations from Baseline, in Percentage Points



Solid: United_States
Dashed: Canada
Dotted: Germany
Dot-Dashed: Japan

5. Illustrative Applications of FRB/Global

This section discusses several applications of FRB/Global related to the spillover effects of fiscal and monetary policy under alternative European monetary policy regimes.

A. Comparison of EMS and EMU

The first scenario is designed to highlight the effects of different monetary policy regimes on the simulation of a fiscal shock originating in Germany. The shock is a permanent increase in German government spending equal to 1 percent of GDP beginning in the first quarter of Year 1. Although hypothetical, this shock is qualitatively similar to the German fiscal expansion that followed reunification in 1990.

Two monetary policy regimes are considered: the current monetary policy arrangements (labelled the European Monetary System, or EMS), and arrangements representing those envisioned under European Monetary Union (EMU). Under the EMS regime, German monetary policy follows the "active" monetary policy rule described in the previous section (namely, German short rates respond to deviations of *German* output and inflation from target), while the French, Italian, and SOECD currencies are pegged to the German mark.[13] The United States, Canada, Japan, and the United Kingdom follow independent monetary policies under the "active" monetary policy rule. Under the EMU regime, monetary policy for the member countries would be implemented by the European Central Bank (ECB). To characterize this arrangement, it is assumed that the ECB 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 with the EMS regime, in which short-term interest rates in all member countries are determined by the output and inflation gap in Germany (apart from a sovereign risk premium).

The actual composition and relative influence of the members of EMU remains an open issue. For this experiment, all members of the European Union except the United Kingdom are assumed to join EMU, and the weights in the European central bank's reaction function

[13] Since the SOECD block includes Australia and New Zealand, the simulations are only intended to provide an approximate representation of both EMS and EMU.

are calculated from the relative dollar values of GDP of the member states. Based on the dollar value of GDP, Germany's weight is slightly over 1/4, France and Italy each have a weight of about 1/5, and the SOECD weight is about 1/3.

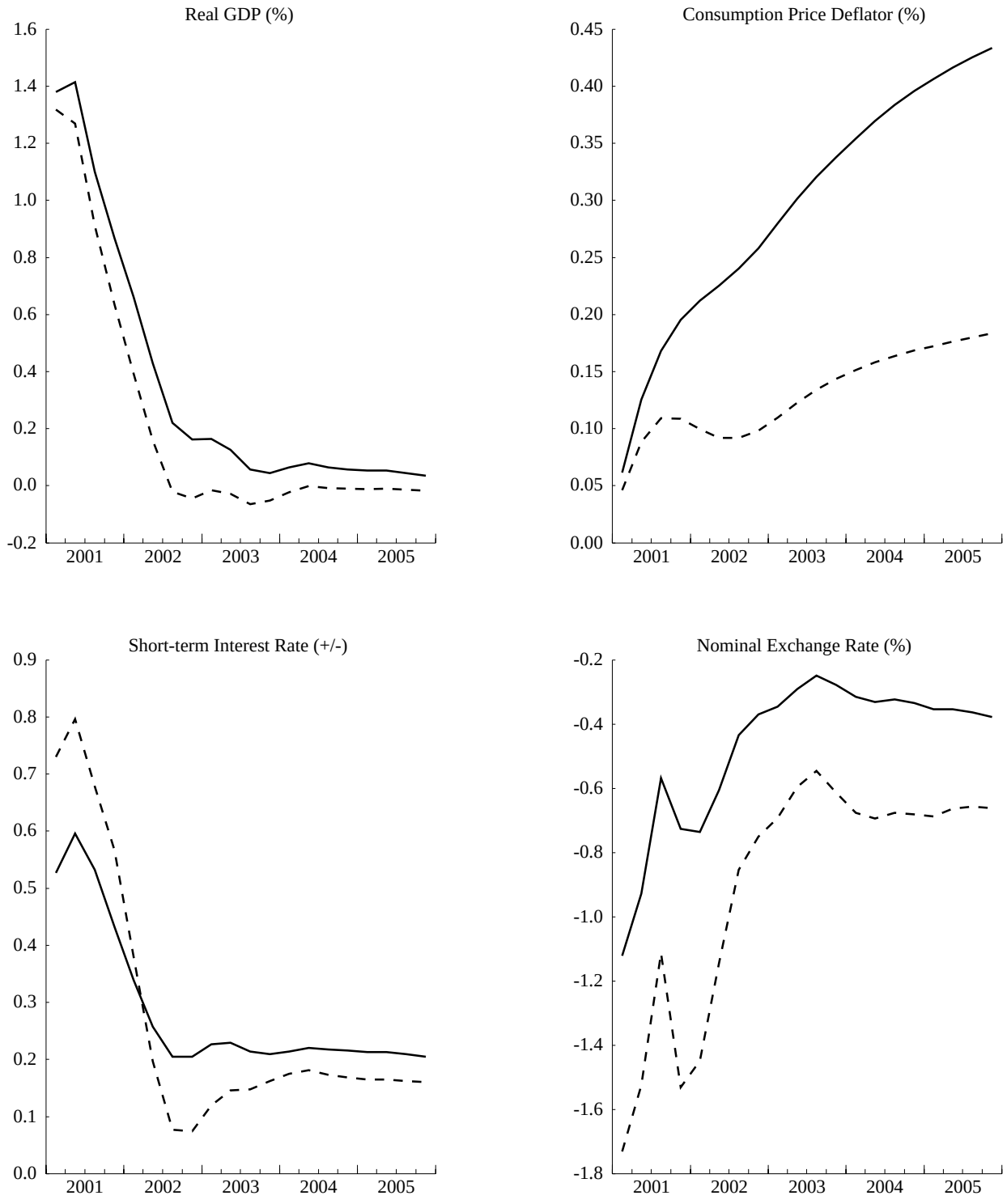
Charts 9 and 10 depict the effect of a German fiscal expansion on Germany and France, respectively. The dashed line segments in each panel display the effects of the fiscal expansion under EMS. The German fiscal expansion has a direct positive effect on German GDP and prices, as shown in the upper panels of chart 9. The German central bank responds to the shock by raising short-term interest rates about 75 basis points. As shown by the dashed line in the lower-left panel of chart 10, France must raise interest rates by a similar magnitude in order to maintain the exchange rate peg. The interest rate hike in France has a substantial contractionary effect on French real GDP and prices (shown in the upper panels of chart 10), which is only partially offset by higher net exports to Germany.

The solid lines in charts 9 and 10 depict the effects of the same fiscal shock under the EMU regime. As seen in the lower left panel of each chart, the interest rate response is about 25 basis points smaller under EMU than under EMS. The smaller interest rate response reflects the fact that the ECB adjusts interest rates based on the effects of a shock on the output gaps and inflation rates of all member countries. Of course, since the effects of a German-specific fiscal expansion on the GDP and inflation rates of all member countries are much smaller than the effect on Germany, interest rates rise by less than they do under EMS, in which interest rates target only the German output/inflation gaps.

The upper two panels of chart 9 illustrate that German output and prices rise more in response to the fiscal expansion under EMU than under EMS. These results highlight the point that EMU will tend to generate somewhat higher variability of German output and inflation, because German short-term interest rates will reflect economic conditions in all member countries rather than in Germany alone as under the current regime.

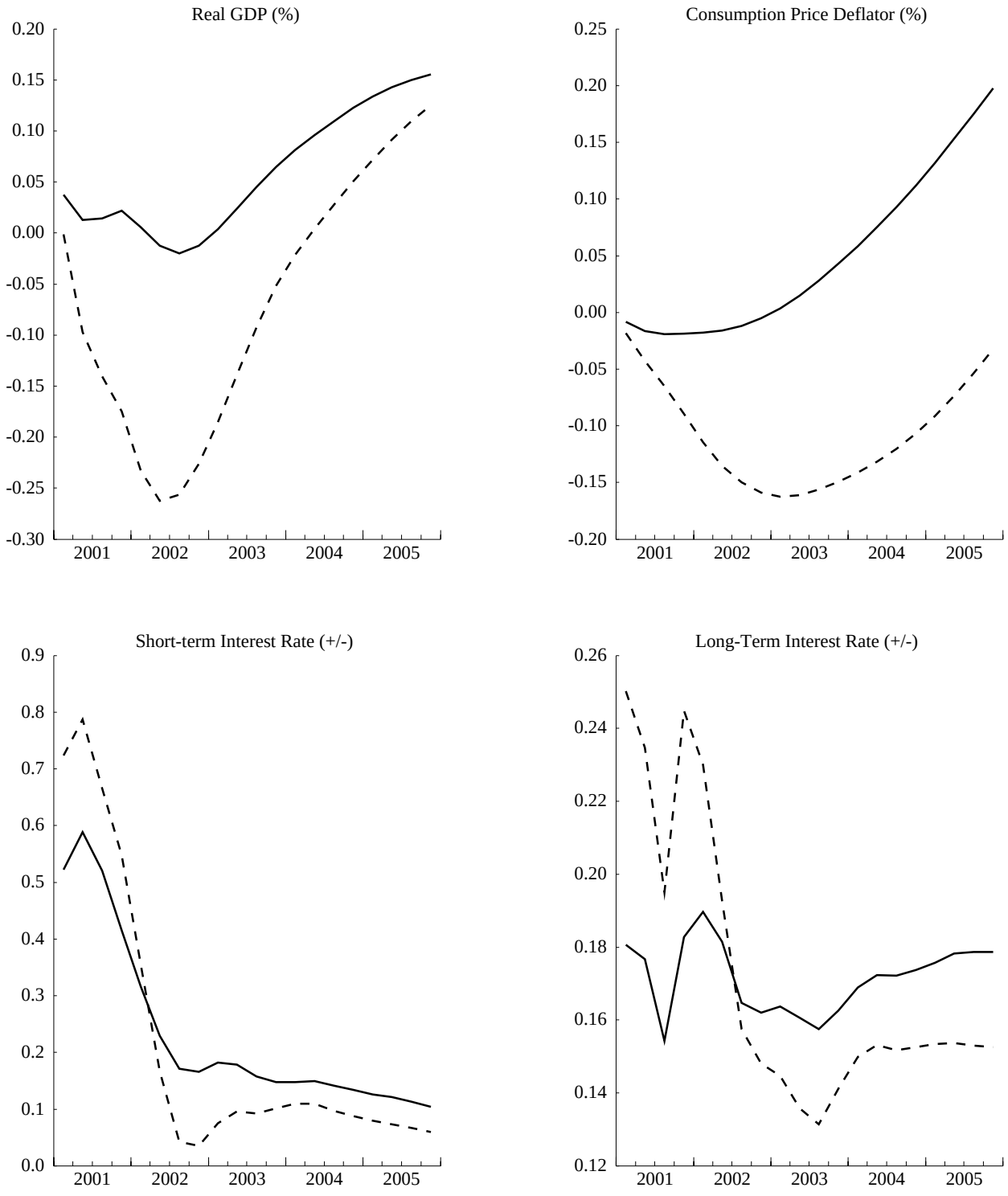
Chart 10 indicates that the German fiscal expansion has much smaller contractionary effects on France under EMU. In particular, the variability of French output and inflation decline markedly compared with the EMS regime. These results illustrate the general point that a country that currently pegs to the German mark will tend to experience lower output

Chart 9
German Fiscal Expansion - Effects on Germany
Absolute (+/-) and Relative (%) Deviations from Baseline, in Percentage Points



Solid: EMU-Style Monetary Policy
Dashed: EMS-Style Monetary Policy

Chart 10
German Fiscal Expansion - Effects on France
Absolute (+/-) and Relative (%) Deviations from Baseline, in Percentage Points



Solid: EMU-Style Monetary Policy
Dashed: EMS-Style Monetary Policy

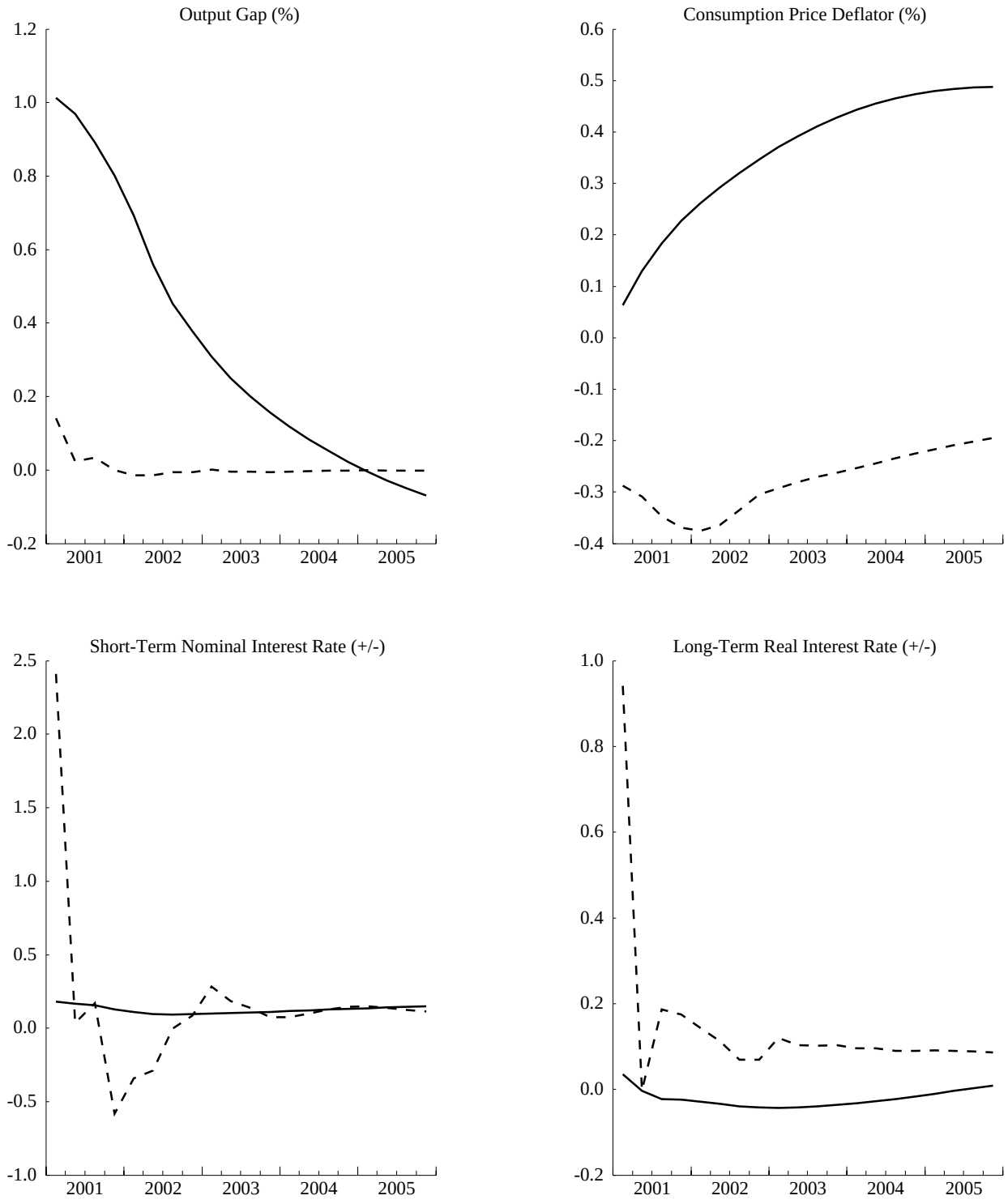
and inflation volatility by joining EMU. Under the current regime, German-specific shocks can induce significant macroeconomic fluctuations in the economies of other EMS members: each member's short-term interest rates move largely in parallel with German interest rates, which are adjusted in response to the German output and inflation gap. In contrast, the ECB may be expected to adjust the short-term euro interest rate to smooth a weighted average of the output and inflation gaps of all EMU member countries.

B. Independent Monetary Policy vs. Participation in EMU

While countries that currently participate in the EMS (other than Germany) may experience reduced inflation/output volatility under EMU, it seems reasonable to expect that a non-EMS country would sacrifice some control over domestic macroeconomic outcomes by giving up its monetary policy independence and joining EMU. Thus, it is useful to analyze a fiscal shock similar to that considered above -- now a permanent 1 percent of GDP increase in the fiscal spending of the United Kingdom (rather than Germany) -- in terms of its effects on the United Kingdom under each of two monetary policy scenarios. 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. Since the weights in this simulation are based on GDP weights, the United Kingdom receives a relatively small weight of 0.12. Under the alternative independent monetary policy scenario, 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.

The solid line in each panel of chart 11 denotes the impulse response under EMU, while the dashed line shows the response under an independent monetary policy for the United Kingdom. The upper left panel indicates that an independent monetary policy could successfully target U.K. output at baseline (as designed), while under EMU output experiences a sharp rise in response to the fiscal expansion. As seen in the lower left panel, the response under an independent monetary policy reflects a considerably more aggressive interest rate response of the U.K. central bank to the rise in GDP than would be taken by the ECB if the United Kingdom were one of several members.

Chart 11
U.K. Fiscal Expansion - Effects on United Kingdom
Absolute (+/-) and Relative (%) Deviations from Baseline, in Percentage Points



Solid: EMU (Including U.K.) Monetary Policy
Dashed: Independent U.K. Monetary Policy

This simulation illustrates how a country such as the United Kingdom stands to lose some control over domestic macroeconomic outcomes by joining EMU, insofar as it would be likely to experience some increase in output/inflation variability by foregoing an independent monetary policy. While FRB/Global simulations are helpful in assessing these costs, these simulations do not take into account some potential benefits of joining EMU, such as microeconomic benefits associated with lower transactions costs, or "credibility effects" that could reduce the risk premium on a country's external liabilities.

C. Rational vs. Adaptive Expectations

The final scenario highlights the extent to which alternative assumptions about expectations formation can affect the simulation results. The implications of different assumptions about expectations are most apparent in the case of shocks whose effects are concentrated sometime after the start date of the simulation. In the limited-information expectations version of the model, expectations depend exclusively on past information, so that future shocks are unforeseen. By contrast, in the rational expectations version, agents are assumed to have perfect foresight about the shock, meaning that they know the entire future path of the variable whose value is being exogenously changed in the simulation. In the fiscal shock analyzed here, the experiment can be thought of as the announcement of a future policy change. The assumption concerning expectations in the model determines the extent to which the pre-announced policy has contemporaneous effects on the economy.

Consider the short and medium-term response of each variant of the model to a German fiscal spending shock that occurs two years after the start date of the simulation. Thus, the fiscal shock described above begins in Year 3 rather than Year 1; after twelve quarters, government spending returns to baseline. The EMU monetary policy regime is assumed to be in effect for Germany, France, Italy and the SOECD, while the United Kingdom conducts an independent monetary policy.

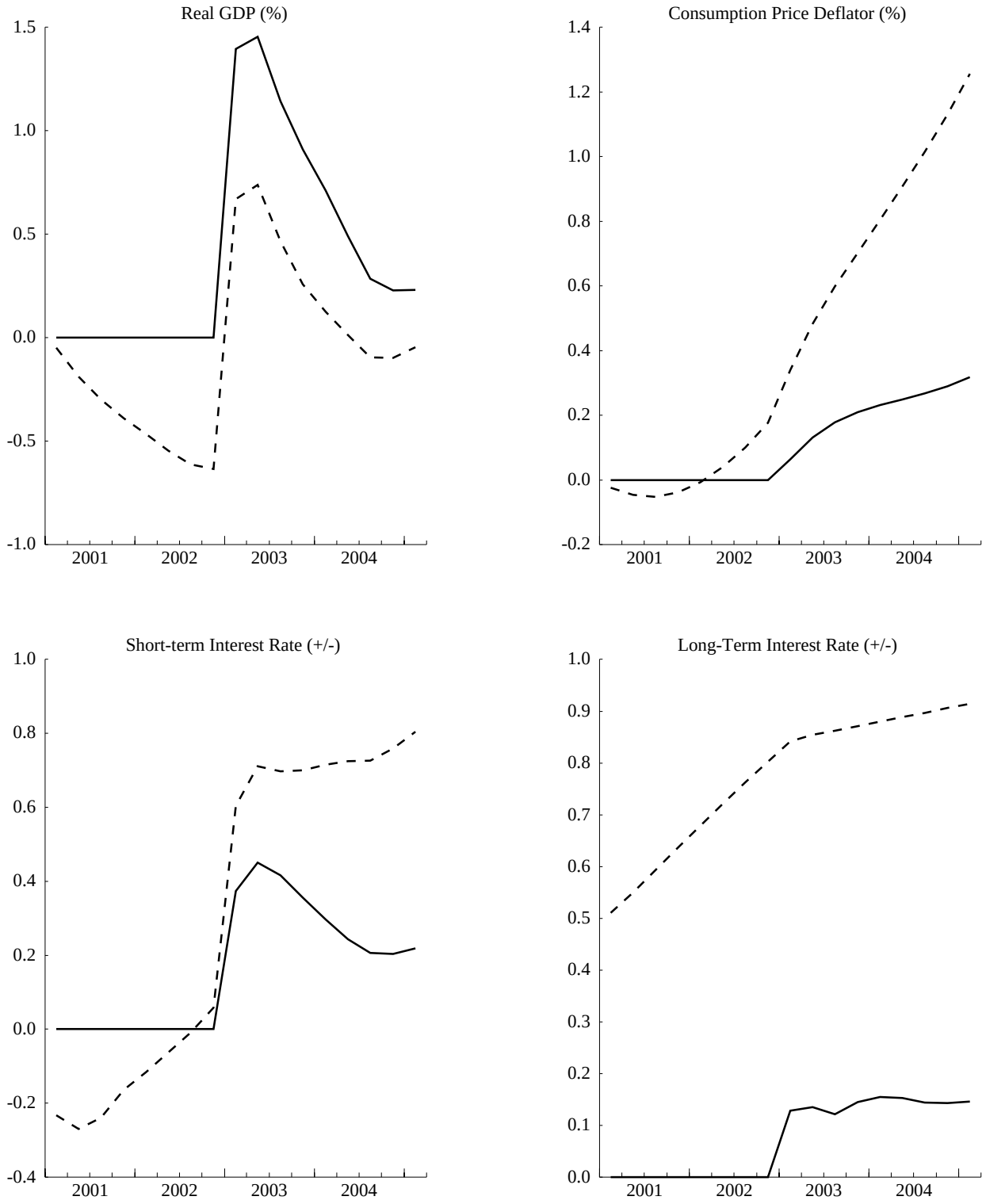
Chart 12 depicts the results for Germany. Looking first at the results for the limited-information expectations version -- shown by the solid line in each panel -- it is evident that there is no response to the shock before it actually occurs. As seen in the lower right panel,

this is true even of long-term interest rates, reflecting that agents do not expect future short-term rates to rise until after they are "surprised" by the shock when it is implemented in the first quarter of Year 3. After that, model dynamics appear very similar to the effects of the German fiscal expansion considered above (in chart 9).

The dashed lines depict the results for the rational expectations version of the model. In this case, as soon as the shock is announced in the first quarter of Year 1, agents realize that the European central bank will have to raise short-term interest rates (the lower left panel) beginning in Year 3 to restrain the effects of the projected fiscal expansion on output and prices. The projected rise in future short rates has an immediate impact on long-term interest rates, as shown in the lower right panel. This rise in long-term interest rates in turn causes real activity to contract modestly in Year 1 and Year 2, so that a future fiscal expansion has a contractionary effect in the short-run.

Thus, our model includes two different, and somewhat extreme, perspectives on the expectations formation process. In evaluating policy scenarios, it is helpful to consider the possible sensitivity our results to these different assumptions about expectations. In cases in which results diverge noticeably--as in the case illustrated above--the choice of how to weight each model depends on one’s view of the extent to which the shock is likely to be anticipated by economic agents.

Chart 12
Future German Fiscal Expansion - Model-Consistent vs. Limited-Information Expectations
Absolute (+/-) and Relative (%) Deviations from Baseline, in Percentage Points



Solid: Limited-Information Expectations
Dashed: Model-Consistent Expectations

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Appendix A: The Foreign G-7 Country Blocks

Government Expenditures. Total government expenditures are disaggregated into five components: consumption, investment, subsidies, transfers to households, and interest payments. As previously noted, real government consumption and investment expenditures on goods and services are exogenously determined; the corresponding nominal values are obtained using government consumption and investment price deflators. The nominal value of government subsidies moves proportionally to 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.[14]

Tax Revenue. Total government revenues are disaggregated into four components: direct taxes, social security payroll taxes, fuel taxes, and other indirect taxes.[15] Direct tax revenue is comprised mainly of personal and corporate income taxes, and is computed by multiplying the direct tax rate by nominal net national product (i.e., nominal GDP, plus net factor income from abroad, less depreciation allowances). As noted above, 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 to labor income, which is the product of the hourly wage rate and total employment.[16] 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 (e.g., the Value-Added Tax) are assumed to vary proportionally to the value of private consumption and investment expenditures.

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[14] 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.

[15] Strictly speaking, payroll taxes are a sub-category of direct taxes, so that "direct taxes" in this discussion should be understood as referring to the non-payroll component of direct tax revenue.

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

Net Factor Income. Net factor income is disaggregated into four components: direct investment payments, direct investment receipts, portfolio investment payments, and portfolio investment receipts. Each of these components 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, where 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 non-fuel 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.[17] Potential GDP is defined as potential non-fuel output less net fuel imports, reflecting the concept of GDP as a measure of value-added (i.e., gross output less raw materials).

Aggregate Wages. Under limited-information expectations, the aggregate wage inflation rate is specified as a function of 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 (1980). 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.

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[17] 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 utilizes a constant fraction of total domestic fuel consumption.

In particular, for a given value of the average expected aggregate wage, a one percentage point increase in unemployment throughout the coming year reduces the current contract wage rate by 0.02 percent. Finally, the aggregate wage rate is defined as the average of the four wage contracts currently in effect.

Domestic Prices. The domestic non-fuel output price deflator 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 one percentage point increase in the output gap generates a 0.36 percent rise in the domestic non-fuel output price deflator. The gap between the markup rate and its equilibrium value shrinks by about 33 percent per quarter. Given fuel import and export prices and the non-fuel output price deflator, nominal GDP is computed as nominal domestic non-fuel output less net fuel imports, and nominal domestic spending is computed as nominal GDP plus net non-fuel 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 to the domestic absorption deflator, so that the relative prices of the components of domestic absorption are held constant. Finally, the domestic fuel price depends on the price of imported fuel and the fuel tax rate.

[18] The relative weights are identical to those in the production function; i.e., 0.92 on labor and 0.08 on fuel.

Appendix B: Other Foreign Blocks of FRB/Global

Three blocks of equations represent Mexico, the NIEs, and the SOECD. These three blocks have a similar structure to 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 sovereign risk premia. 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 nominal inertia. The OPEC currencies are assumed to be fixed to the U.S. dollar, and the OPEC non-fuel output price level adjusts in a flexible way to maintain a constant 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 one percent increase in world fuel consumption generates a one 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; e.g., ROW net non-fuel merchandise exports are determined by the sum of net non-fuel 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 non-fuel 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 are obtained from a variety of sources, as summarized in Table C1. Highlights of the baseline are shown in Tables C2 and C3. The FRB/Global baseline is extrapolated to 2025q4 under the assumption of a gradual transition onto a balanced growth path. Thus, in each country block, the output gap is 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 20 years.

Table C1

Sources of FRB/Global Baseline Data

Source	FRB/Global Variables
United States:	
FRB/US Baseline	domestic variables
USIT Model Baseline	external sector variables
Foreign Industrial Countries:	
BIS database	national accounts, fiscal and trade data
IMF Balance of Payments Statistics	foreign direct & portfolio investment
IMF Direction of Trade Statistics	bilateral export and import shares
IMF Government Finance Statistics	fiscal data, government debt stocks
OECD / IEA Oil & Gas Statistics	oil production, consumption, and trade
OECD / IEA Energy Prices & Taxes	oil prices and tax rates
Penn World Tables	real capital stocks, depreciation rates
Developing Countries:	
IMF International Finance Statistics	Mexico and NIEs data
DRI database	additional data for NIEs
IMF World Economic Outlook	OPEC and ROW data

Table C2

Highlights of FRB/Global Baseline

(1995 average, percentage points)

	Share of World GDP	Exports/GDP	Net External Assets/GDP	Government Debt/GDP
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**	**NA**
NIEs	**3**	**56**	**16**	**NA**
OPEC	**2**	**31**	**125**	**NA**
ROW	**20**	**20**	**-20**	**NA**

Table C3

FRB/Global Baseline Import Shares

	Share of Total Merchandise Imports in $US (1995 average, percentage points)		
	United States	**Germany**	**Japan**
Exporter:			
United States	---	5	19
Germany	5	---	4
Japan	15	5	---
Canada	18	0.5	3
France	2	11	2
Italy	2	8	2
United Kingdom	3	6	2
SOECD	6	39	15
Mexico	8	0.1	0.4
NIEs	10	4	12
OPEC	4	2	13
ROW	27	20	27

Appendix D: List of FRB/Global Variables

Note: In the FRB/Global model, each variable has a one-letter prefix to indicate the specific country/regional block (e.g., cgdp indicates Canadian real GDP).

abs . . . . . Domestic Expenditures - Real
absv . . . . . Domestic Expenditures - Nominal
cadisc.x . . . . . Current Account Discrepancy ($US)
cc . . . . . Private Consumption Expenditure - Real
ccav . . . . . Capital Consumption Allowance
cld . . . . . Direct Investment Claims on Foreigners ($US)
clo . . . . . Other Claims on Foreigners ($US)
clp . . . . . Portfolio Claims on Foreigners ($US)
clpa . . . . . Portfolio Claims on Foreigners ($US, BOPS Basis)
clr . . . . . Foreign Exchange Reserves ($US)
coilb . . . . . Domestic Oil Consumption (MBD)
curbal . . . . . Current Account
cv . . . . . Private Consumption Expenditure - Nominal
dcld . . . . . Change in Direct Investment Claims ($US)
dclo . . . . . Change in Other Claims on Foreigners ($US)
dclp . . . . . Change in Portfolio Claims ($US)
dclpa . . . . . Change in Portfolio Claims ($US, BOPS Basis)
dclr . . . . . Change in Foreign Exchange Reserves ($US)
debtg.x . . . . . Government Debt / Nominal Potential GDP Target
dinv . . . . . Inventory Investment - Real
dinvolb . . . . . Oil Inventories (MBD)
dinvv . . . . . Inventory Investment - Nominal
dlid . . . . . Change in Direct Investment Liabilities ($US)
dlio . . . . . Change in Other Liabilities to Foreigners ($US)
dlip . . . . . Change in Portfolio Liabilities ($US)
dlipa . . . . . Change in Portfolio Liabilities ($US, BOPS Basis)
dp41 . . . . . Four-Quarter Inflation Rate Lead
dpc . . . . . Inflation Rate - Consumption Price Deflator
dpc1 . . . . . One-Quarter Inflation Rate Lead
dpc1.a . . . . . One-Quarter Inflation Rate Lead - Adaptive Expectations
dpc1.r . . . . . One-Quarter Inflation Rate Lead - Rational Expectations
dpexp . . . . . Long-Term Expected Inflation (annual rate)
dpexp.a . . . . . Long-Term Expected Inflation - Adaptive Expectations
dpexp.r . . . . . Long-Term Expected Inflation - Rational Expectations
er . . . . . Exchange Rate (l.c./$US)
er.x . . . . . Fixed Exchange Rate (l.c./$US)
ertar.x . . . . . Exchange Rate Target
ferm . . . . . Foreign Exchange Rate (Bilateral Import Weights)
ferx . . . . . Foreign Exchange Rate (Bilateral Export Weights)
fmgnfl . . . . . Foreign Non-Fuel Merchandise Imports (Bilateral Export Weights)
fmso . . . . . Foreign Non-Factor Service Payments (Bilateral Export Weights)
fmsydr . . . . . Foreign Rate of Return on Direct Investment Liabilities
fmsypr . . . . . Foreign Rate of Return on Portfolio Liabilities
fpq . . . . . Foreign Output Price Deflator (Bilateral Export Weights)
fpxgnfl . . . . . Foreign Export Price Deflator (Bilateral Import Weights)

fqgap . . . . . Foreign Output Gap (Bilateral Export Weights)
frl . . . . . Foreign Long-Term Interest Rate (Bilateral Import Weights)
frs . . . . . Foreign Short-Term Interest Rate (Bilateral Import Weights)
gc.x . . . . . Government Consumption Expenditures - Real
gcv . . . . . Government Consumption Expenditures - Nominal
gdebt . . . . . Government Debt
gdef . . . . . Government Deficit
gdp . . . . . Gross Domestic Product - Real
gdpgap . . . . . GDP Gap (Share of Potential GDP)
gdppot . . . . . Potential GDP - Real
gdppotv . . . . . Potential GDP - Nominal
gdpv . . . . . Gross Domestic Product - Current Prices
gexp . . . . . Government Expenditures - Total
gexpor.x . . . . . Other Government Expenditures / Nominal Potential GDP
gexpoth . . . . . Other Government Expenditures
gif.x . . . . . Government Investment Expenditures - Real
gifv . . . . . Government Investment Expenditures - Nominal
gintr . . . . . Rate of Return on Government Debt
gnpv . . . . . Gross National Product - Nominal
grec . . . . . Total Government Receipts
grecor.x . . . . . Other Government Receipts / Nominal GNP
grecoth . . . . . Government Receipts - Other
gsub . . . . . Government Subsidies
gsubr.x . . . . . Government Subsidies / Nominal GDP
gth . . . . . Government Transfers to Households
gthr.x . . . . . Government Transfers to Households / Nominal Potential GDP
if . . . . . Real Private Fixed Investment - Total
ifnr . . . . . Real Private Fixed Investment - Nonresidential
ifnrv . . . . . Business Fixed Investment - Nominal
ifr . . . . . Residential Investment - Real
ifrv . . . . . Residential Investment - Nominal
ifv . . . . . Private Fixed Investment - Nominal
kinv . . . . . Inventory Capital Stock - Real
kinvv . . . . . Inventory Capital Stock - Nominal
knr . . . . . Business Fixed Capital Stock
knrrtr.x . . . . . Retirement Rate for Business Fixed Capital Stock
kr . . . . . Residential Capital Stock
krrtr.x . . . . . Retirement Rate for Residential Capital Stock
le . . . . . Employment
lf . . . . . Labor Force
lid . . . . . Direct Investment Liabilities to Foreigners ($US)
lio . . . . . Other Liabilities to Foreigners ($US)
lip . . . . . Portfolio Liabilities to Foreigners ($US)
lipa . . . . . Portfolio Liabilities to Foreigners ($US, BOPS Basis)
lu . . . . . Unemployed
mg . . . . . Merchandise Imports - Real
mgfl . . . . . Fuel Imports - Real
mgflv . . . . . Fuel Imports - Nominal

mgnfl . . . . . Non-Fuel Merchandise Imports - Real
mgnflv . . . . . Non-Fuel Merchandise Imports - Real
mgsni . . . . . Goods and Services Imports - Real (NIA)
mgsniv . . . . . Goods and Services Imports - Nominal (NIA)
mgv . . . . . Merchandise Imports - Nominal
mm . . . . . Nominal Money Stock (M1)
moilb . . . . . Fuel Imports (mbd)
mso . . . . . Non-Factor Service Payments - Real
msov . . . . . Non-Factor Service Payments - Nominal
msydr . . . . . Rate of Return on Direct Investment Liabilities
msydv . . . . . Direct Investment Payments
msydvd . . . . . Direct Investment Payments ($US)
msypr . . . . . Rate of Return on Portfolio Liabilities
msypv . . . . . Portfolio Investment Payments
msyv . . . . . Factor Payments
msyvd . . . . . Factor Payments ($US)
netxni . . . . . Net Exports - Real (NIA Basis)
netxniv . . . . . Net Exports - Nominal (NIA Basis)
nfiv . . . . . Net Factor Income
nnpv . . . . . Net National Product - Nominal
nxdebt . . . . . Net External Debt ($US)
oilmkup . . . . . Domestic Oil Price Markup
ompmkup . . . . . Imported Oil Price Markup
pabs . . . . . Domestic Absorption Price Deflator
pc . . . . . Consumption Price Deflator (NIA Basis)
pgc . . . . . Government Consumption Price Deflator
pgdp . . . . . GDP Price Deflator
pgif . . . . . Government Investment Price Deflator
pifnr . . . . . Business Fixed Investment Price Deflator
pifr . . . . . Residential Investment Price Deflator
pinv . . . . . Inventory Investment Price Deflator
pmg . . . . . Goods Import Price Deflator
pmgcnv.x . . . . . Fuel Import Price Deflator Conversion Factor
pmgfl . . . . . Fuel Import Price Deflator
pmgfluv . . . . . Fuel Import Unit Value
pmgnfl . . . . . Non-Fuel Merchandise Import Price Deflator
pmgsni . . . . . Import Price Deflator (NIA Basis)
pmso . . . . . Non-Factor Service Import Price Deflator
poilb . . . . . Domestic Oil Price
pop.x . . . . . Population (millions)
pq . . . . . Price of Total Output
ptar.x . . . . . Price Level Target
pxg . . . . . Goods Export Price Deflator
pxgcnv.x . . . . . Fuel Export Price Deflator Conversion Factor
pxgfl . . . . . Fuel Export Price Deflator
pxgflg . . . . . Natural Gas Export Price Deflator
pxgflp . . . . . Crude Petroleum Export Price Deflator
pxgfluv . . . . . Fuel Export Unit Value

pxgnfl . . . . . Non-Fuel Merchandise Export Price Deflator
pxgsni . . . . . Export Price Deflator (NIA Basis)
pxso . . . . . Non-Factor Service Export Price Deflator
qgap . . . . . Domestic Non-Fuel Output Gap
qoilb.x . . . . . Domestic Oil Production (mbd)
qpot . . . . . Domestic Non-Fuel Output - Potential
qq . . . . . Domestic Non-Fuel Output - Real
qv . . . . . Domestic Non-Fuel Output - Nominal
rer . . . . . Bilateral CPI-Based Real Exchange Rate
rer.a . . . . . Real Exchange Rate - Adaptive Expectations
rer.r . . . . . Real Exchange Rate - Rational Expectations
rl . . . . . Long-Term Interest Rate
rl.a . . . . . Long-Term Interest Rate - Adaptive Expectations
rl.r . . . . . Long-Term Interest Rate - Rational Expectations
rlbar . . . . . Average Return on Outstanding Long-Term Bonds
rpxgnfl . . . . . Relative Non-Fuel Export Price (Relative Price Weights)
rpxso . . . . . Relative Non-Factor Service Price (Relative Price Weights)
rs . . . . . Short-Term Interest Rate
rs.x . . . . . Short-Term Interest Rate Target
rstar . . . . . Equilibrium Real Short-Term Interest Rate
sales . . . . . Domestic Sales - Real
ssctg . . . . . Social Security Contributions
ssctgr.x . . . . . Social Security Tax Factor
taxd . . . . . Direct Taxes (excluding Social Security Contributions)
taxdr . . . . . Direct Taxes / Nominal NNP
taxdr.x . . . . . Direct Tax Rate Target
taxds . . . . . Direct Taxes (including Social Security Contributions)
taxils . . . . . Indirect Taxes less Subsidies
taxind . . . . . Indirect Taxes
taxindo . . . . . Indirect Taxes - Non-Fuel
taxior.x . . . . . Indirect Tax Factor - Non-Fuel
taxoil . . . . . Indirect Taxes - Fuel
toilb . . . . . Oil Tariff Rate
un . . . . . Unemployment Rate
unnat.x . . . . . Natural Unemployment Rate (NAIRU)
w . . . . . Nominal Wage Rate
w.a . . . . . Nominal Wage Rate - Adaptive Expectations
w.r . . . . . Nominal Wage Rate - Rational Expectations
wdpc . . . . . Real Wage Rate
wx . . . . . Contract Wage Rate
xdw . . . . . Contract Wage Deviation from Aggregate Wage
xdw.a . . . . . Contract Wage Deviation - Adaptive Expectations
xdw.r . . . . . Contract Wage Deviation from Aggregate Wage
xg . . . . . Merchandise Exports - Real
xgfl . . . . . Fuel Exports - Real
xgflgv . . . . . Natural Gas Exports - Nominal
xgflpv . . . . . Crude Petroleum Exports - Nominal
xgflv . . . . . Fuel Exports - Nominal

xgnfl . . . . . Non-Fuel Merchandise Exports - Real
xgnflv . . . . . Non-Fuel Merchandise Exports - Nominal
xgsni . . . . . Goods and Services Exports - Real (NIA)
xgsniv . . . . . Goods and Services Exports - Nominal (NIA)
xgv . . . . . Merchandise Exports - Nominal
xoilb.x . . . . . Fuel Exports (mbd)
xso . . . . . Non-Factor Service Receipts - Real
xsov . . . . . Non-Factor Service Receipts - Nominal
xsydr . . . . . Rate of Return on Direct Investment Claims
xsydv . . . . . Direct Investment Receipts
xsydvd . . . . . Direct Investment Receipts ($US)
xsypr . . . . . Rate of Return on Portfolio Claims
xsypv . . . . . Portfolio Investment Receipts
xsyv . . . . . Factor Receipts
xsyvd . . . . . Factor Receipts ($US)
xtranr.x . . . . . Net Foreign Transfers / Nominal GDP
xtranv . . . . . Net Foreign Transfer Receipts
xtranvd . . . . . Net Foreign Transfer Receipts ($US)
ygint . . . . . Government Interest Payments
yk . . . . . Income to Capital - Nominal
yle . . . . . Income to Labor - Nominal
ypd . . . . . Disposable Income - Real
ypdv . . . . . Disposable Income - Nominal

Appendix E: The Prototypical Foreign G-7 Country Block

1. Aggregate Demand

A. Components of Domestic Absorption

CC: "Real Consumption Expenditure"

$$\Delta \log (cc) = \alpha_0 + \alpha_1*(r1 - dpexp) + \alpha_2*\Delta \log(ypd) + \alpha_3* lf/pop.x$$

$$+ \alpha_4* \log(cc/ypd)_{-1}$$

CV: "Nominal Consumption Expenditure"

$$cv == cc * pc/100$$

IF: "Real Private Fixed Investment - Total"

$$if == ifr + ifnr + gif.x$$

IFR: "Real Private Fixed Investment - Residential"

$$\log(ifr/gdp) = \beta_\eta + \sum_{\varkappa=\Theta}^{\varkappa=K} \beta_\varkappa \log(ifr/gdp)_{-\varkappa} + \sum_{\varkappa=\Theta}^{\varkappa=K} \beta_{K+\varkappa} \Delta\log(gdp)_{-\varkappa}$$

$$+ \sum_{\varkappa=\eta}^{\varkappa=\theta} \beta_{\Theta\Theta\varkappa} \log(krrtr.x_{-\varkappa} + 0.01*(rl_{-\varkappa} - dpexp_{-\varkappa})) + \beta_{\Theta\iota} * \log(kr/gdp)_{-\Theta}$$

IFNR: "Real Private Fixed Investment - Nonresidential"

$$\log(ifnr/gdp) = \gamma_\eta + \sum_{\varkappa=\Theta}^{\varkappa=\lambda} \gamma_\varkappa \log(ifnr/gdp)_{-\varkappa} + \sum_{\varkappa=\Theta}^{\varkappa=\iota} \gamma_{\lambda+\varkappa} \Delta\log(gdp)_{-\varkappa}$$

$$+ \gamma_{\Theta I} \log(knrrtr.x_{-\Theta} + 0.01*(rl_{-\Theta} - dpexp_{-\Theta})) + \gamma_{\Theta\iota} * \log(knr/gdp)_{-\Theta}$$

DINV: "Inventory Investment - Real"

$$dinv/qpot = \zeta_0 + \zeta_1* \Delta(sales/qpot) + \zeta_2*(kinv/sales)_{-1} + \zeta_3*(rs - dpc1)$$

IFRV: "Nominal Private Fixed Investment - Residential"

$$ifrv == ifr * pifr/100$$

IFNRV: "Nominal Private Fixed Investment - Nonresidential"

ifnrv == ifnr * pifnr/100

IFV: "Nominal Private Fixed Investment - Total"

ifv == ifrv + ifnrv + gifv

DINVV: "Inventory Investment - Nominal"

dinvv == 4 * (kinvv - $kinvv_{-1}$)

CCAV: "Capital Consumption Allowance"

ccav == (knrrtr.x * knr_{-1} * pifnr + krrtr.x * kr_{-1} * pifr)/100

B. Accounting Identities

GDP: "Gross Domestic Product"

gdp = cc + if + gc.x + xgsni - mgsni + dinv

GDPV: "Gross Domestic Product - Current Prices"

gdpv = cv + ifv + gcv + xgsniv - mgsniv + dinvv

GNPV: "Gross National Product - Nominal"

gnpv == gdpv + nfiv

NFIV: "Net Factor Income - Nominal"

nfiv == xsyv - msyv

ABSV: "Domestic Absorption - Nominal"

absv == pq*qq/100 - mgflv - xgsniv + xgflv + mgsniv

ABS: "Domestic Absorption - Real"

abs == cc + if + gc.x + dinv

SALES: "Domestic Sales - Real"

sales == cc + if + gc.x

NNPV: "Net National Product - Nominal"

nnpv == gnpv - ccav

YK: "Income to Capital - Nominal"

yk == nnpv - yle + gsub - taxind

YLE: "Income to Labor - Nominal"

yle == le * w

YPDV: "Disposable Income - Nominal"

ypdv == yk + yle + ygint + gth + gexpoth - taxd - ssctg - grecoth

YPD: "Disposable Income - Real"

ypd == 100 * ypdv / pc

2. Fiscal Accounts

A. Government Receipts

GREC: "Total Government Receipts"

grec == taxd + taxind + grecoth + ssctg

GRECOTH: "Government Receipts - Other"

grecoth == grecor.x * gnpv

SSCTG: "Social Security Contributions"

ssctg == ssctgr.x * yle

TAXD: "Direct Taxes"

taxd == taxdr * nnpv

TAXDR: "Tax Rate Reaction Function"

taxdr = pswitch.taxdr * taxdr.x + (1 - pswitch.taxdr) *

(η_1 + η_2* (gdebt/gdppotv - debtg.x) * absv(gdebt/gdppotv - debtg.x))

TAXOIL: "Indirect Taxes - Oil"

taxoil == 0.365 * toilb * coilb

TAXINDO: "Indirect Taxes - Others"

taxindo == taxior.x * (cv + ifv)

TAXIND: "Indirect Taxes - Total"

taxind == taxoil + taxindo

B. Government Expenditures

GEXP: "Government Expenditures - Total"

gexp == gcv + gifv + gth + ygint + gsub + gexpoth

GEXPOTH: "Government Expenditure - Other"

gexpoth == gexpor.x * gdppotv

GIFV: "Government Investment"

gifv == gif.x * pgif/100

GCV: "Government Expenditures - Goods"

gcv == gc.x * pgc/100

GTH: "Transfer to Households"

gth == gthr.x * gdppotv

GSUB: "Subsidies"

gsub == gsubr.x * gdpv

GINTR: "Rate of Return on Government Debt"

gintr = Ψ_1 * rs + (1 - Ψ_1) * rlbar

YGINT: "Interest Paid on Debt"

ygint == 0.01 * gintr * $gdebt_1$

C. Government Balances

GDEF: "Current Deficit"

gdef == gexp - grec

GDEBT: "Government Debt"

gdebt == gdef/4 + $gdebt_{-1}$

3. External Sector

A. Non-Fuel Merchandise

MGNFL: "Nonfuel Goods Imports - Real"

$$\log(mgnfl) = \Lambda_0 + \Lambda_1 * \log(pmgnfl/pq) + \Lambda_2 * \log(abs) + \Lambda_3 * \log(mgnfl_{-1})$$

PMGNFL: "Nonfuel Goods Import Deflator"

$$\log(pmgnfl) = \varsigma_3 + \varsigma_4 * \log(fpxgnfl * er/ferm) + (1 - \varsigma_4) * \log(pmgnfl)_{-1}$$

MGNFLV: "Nonfuel Goods Imports - Nominal"

mgnflv == mgnfl * pmgnfl/100

XGNFL: "Nonfuel Goods Exports - Real"

$$\log(xgnfl/fmgnfl) = \lambda_1 * \log(rpxgnfl) + (1-\lambda_1) * \log(xgnfl/fmgnfl)_{-1}$$

PXGNFL: "Nonfuel Goods Export Deflator"

$$\log(pxgnfl) = \varsigma_0 + \varsigma_1 * \log(pq) + \varsigma_2 * \log(fpq * er/ferx) + (1 - \varsigma_1 - \varsigma_2) * \log(pxgnfl)_{-1}$$

XGNFLV: "Nonfuel Goods Exports - Nominal"

xgnflv == xgnfl * pxgnfl/100

B. Fuel Exports and Imports

COILB: "Oil Consumption - million barrels per day"

$$\log(coilb/qq) = \theta_0 + \theta_1 * \log(poilb/pq) + \theta_2 * \log(coilb/qq)_{-1}$$

DINVOLB: "Oil Inventories - million barrels per day"

$$dinvolb/coilb = \kappa_0 + \kappa_1 * (rs - dpc1) + \kappa_2 * \Delta (coilb/coilb_{-1})$$

MOILB: "Oil Imports - million barrels per day"

moilb == coilb - qoilb.x + xoilb.x + dinvolb

MGFLV: "Oil Imports - Nominal"

mgflv == 0.365 * pmgfluv* moilb

MGFL: "Oil Imports - Real"

mgfl == 100 * mgflv / pmgfl

XGFL: "Oil Exports - Real"

xgfl == 100 * xgflv / pxgfl

XGFLV: "Oil Exports - Nominal"

xgflv == 0.365 * pxgfluv* xoilb.x

PXGFLUV: "Oil Export Unit Value"

pxgfluv/pmgfluv = 1

PXGFL: "Oil Export Deflator"

pxgfl == pxgcnv.x * pxgfluv

POILB: "Domestic Oil Price"

poilb/(pmgfluv + toilb + oilmkup) = 1

TOILB: "Oil Tariff Rate"

$$toilb/pq = \sigma_{28}$$

OILMKUP: "Oil Markup Rate"

$$oilmkup/pq = \sigma_{29}$$

PMGFLUV: "Oil Import Unit Value"

$$pmgfluv/(opoilbd * er + ompmkup) = 1$$

OMPMKUP: "Oil Import Markup Rate"

$$ompmkup/pq = \sigma_{30}$$

PMGFL: "Oil Import Deflator"

$$pmgfl == pmgcnv.x * pmgfluv$$

D. Non-Factor Services

MSO: "Other Service Payments - Real"

$$\log(mso) = \mu_0 + \mu_1 * \log(pmso/pq) + \mu_2 * \log(abs) + \mu_3 * \log(mso)_{-1}$$

PMSO: "Other Services Payment Deflator"

$$pmso/pmgnfl = 1$$

MSOV: "Other Service Payments - Nominal"

$$msov == mso * pmso/100$$

XSO: "Other Service Receipts - Real"

$$\log(xso/fmso) = \nu_1 * \log(rpxso) + (1 - \nu_1) * \log(xso/fmso)_{-1}$$

PXSO: "Other Services Receipts Deflator"

$$pxso/pxgnfl = 1$$

XSOV: "Other Service Receipts - Nominal"

$$xsov == xso * pxso/100$$

MSYDR: "Rate of Return on Direct Investment Liabilities"

$$msydr = \nu_2 * (gdpgap - 100)$$

MSYPR: "Rate of Return on Portfolio Liabilities"

$msypr = \nu_3 * rs + (1-\nu_3) * rlbar$

XSYDR: "Rate of Return on Direct Investment Claims"

$xsydr = \nu_4 * (fgdpgap - 100)$

XSYPR: "Rate of Return on Portfolio Claims"

$xsypr = fmsypr * ferx_{-1}/ferx$

MSYDV: "Direct Investment Income Payments"

$msydv == (0.01 * msydr * lid_{-1}) * er$

MSYPV: "Portfolio Investment Income Payments"

$msypv == (0.01 * msypr * lip_{-1}) * er$

MSYV: "Investment Income Payments"

$msyv == msydv + msypv$

XSYDV: "Direct Investment Income Receipts"

$xsydv == (0.01 * xsydr * cld_{-1}) * er$

XSYPV: "Portfolio Investment Income Receipts"

$xsypv == (0.01 * xsypr * clp_{-1}) * er$

XSYV: "Investment Income Receipts"

$xsyv == xsydv + xsypv$

E. Accounting Identities

CURBAL: "Current Account Balance"

$curbal == xgnflv + xgflv + xsov + xsyv + xtranv - (mgnflv + mgflv + msov + msyv)$

XTRANV: "Net Foreign Transfer Receipts"

$xtranv == xtranr.x * gdpv$

MGSNIV: "NIA Imports - Nominal"

mgsniv == mgnflv + mgflv + msov

MGSNI: "NIA Imports - Real"

mgsni == mgnfl + mgfl + mso

XGSNIV: "NIA Exports - Nominal"

xgsniv == xgnflv + xgflv + xsov

XGSNI: "NIA Exports - Real"

xgsni == xgnfl + xgfl + xso

NETXNIV: "NIA Net Exports - Nominal"

netxniv == xgsniv - mgsniv

NETXNI: "NIA Net Exports - Real"

netxni == xgsni - mgsni

CLD: "Direct Investment Claims on Foreigners"

$cld == cld_{-1} * ferx_{-1}/ferx + 0.25*dcld$

DCLD: "Change in Direct Investment Claims on Foreigners"

$dcld = \chi_5 * xgsniv/er$

LID: "Direct Investment Liabilities to Foreigners"

$lid == lid_{-1} * er_{-1}/er + 0.25*dlid$

DLID: "Change in Direct Investment Liabilities to Foreigners"

$dlid = \chi_6 * mgsniv/er$

CLP: "Portfolio Claims on Foreigners"

$clp == clp_{-1} * ferx_{-1}/ferx + 0.25*dclp$

DCLP: "Change in Portfolio Claims on Foreigners"

$dclp == \chi_7 * xgsniv/er + \chi_8 * (curbal/er + dlid - dcld)$

LIP: "Portfolio Liabilities to Foreigners"

$$lip == lip_{-1} * er_{-1}/er + 0.25*dlip$$

DLIP: "Change in Portfolio Liabilities to Foreigners (BOP Identities)"

dlip == dcld + dclp - dlid - curbal/er + cadisc.x

NXDEBT: "Net External Debt"

nxdebt == lid + lip - cld - clp

4. Aggregate Supply

A. Output and Employment

QQ: "Gross Output"

qq == gdp + mgfl - xgfl

QPOT: "Gross Potential Output"

$$\log(qpot) = \tau_1 * \log(lf * (1 - unnat.x/100)) + \tau_2 * \log(coilb) + \tau_3 * \log(kr)_{-1} + (1 - \tau_1 - \tau_2 - \tau_3) * \log(knr)_{-1}$$

GDPPOT: "Potential GDP"

gdppot == qpot + xgfl - mgfl

GDPGAP: "GDP Gap (Share of Potential)"

gdpgap == 100 * gdp / gdppot

GDPPOTV: "Potential GDP - Nominal"

gdppotv == pgdp*gdppot/100

QGAP: "Output Gap"

qgap == 100*(qq/qpot)

LE: "Labor Employment"

$$\log(qq) = \tau_4 * \log(le) + \tau_5 * \log(coilb) + \tau_6 * \log(kr_{-1} * qgap/100) + (1 - \tau_4 - \tau_5 - \tau_6) * \log(knr_{-1} * qgap/100)$$

LF: "Labor Force"

$$\log(lf/pop.x) = \upsilon_0 + \upsilon_1 * \log(w/pc) + \upsilon_2 * \log(lf/pop.x)_{-1}$$

UN: "Unemployment Rate"

$$un/100 == (lf - le)/lf$$

KR: "Capital Stock - Residential"

$$kr == kr_{-1} * (1 - krrtr.x/4) + ifr/4$$

KNR: "Capital Stock - Nonresidential"

$$knr == knr_{-1} * (1 - knrrtr.x/4) + ifnr/4$$

KINV: "Stock of Inventories"

$$kinv == dinv/4 + kinv_{-1}$$

KINVV: "Stock of Inventories - Nominal"

$$kinvv == kinv * pinv/100$$

B. Wage Determination

W.R: "Nominal Wage Rate: Rational Expectations"

$$\log(w.r) = \sum_{i=1}^{I} \gamma_i \log(wx_{-i})$$

W.A: "Nominal Wage Rate: Adaptive Expectations"

$$\log(w.a) = \log(w_{-0}) + .01(\phi_1 + \sum_{i=0}^{4} \phi_i (qgap_{-i} - 100) + \sum_{i=0}^{4} \phi_{5+i} 100 * (\Delta_4 \log(pc))_{-i}$$
$$+ \sum_{i=0}^{4} \phi_{10+i} 100 * (\Delta \log(w))_{-i} + \sum_{i=0}^{4} \phi_{15+i} (rs_{-i} - 100 * (\Delta_4 \log(pc))_{-i})$$
$$\sum_{i=0}^{4} \phi_{20+i} (\log(w * lem/gdpv)_i))$$

W: "Nominal Wage Rate"

$$w == eswitch.w * w.r + (1 - eswitch.w) * w.a$$

XDW.R: "Contract Wage Deviation from Aggregate Wage: Rational Expectations"

$$xdw.r \quad + \quad 0.25 * \sum_{\kappa=\eta}^{\kappa=I} \psi_{\Theta+\kappa}\, dpc_{+\kappa} + \sum_{\kappa=\eta}^{\kappa=I} \psi_{\iota+\kappa}\, wdpc_{+\kappa} + \psi_{\lambda}\left(\sum_{\kappa=\eta}^{\kappa=I} \psi_{M+\kappa}\, (un - unnat.x)_{+\kappa}\right)$$

WDPC: "Real Wage Identity"

wdpc == 100 * (log(w) - log(pc))

WX.R: "Contract Wage Identity: Rational Expectations"

xdw.r == 100 * (log(wx.r) - log(w))

C. Domestic Prices

PQ: "Price of Total Output"

$$\log(pq) = \Sigma_0 + \Sigma_1 * \log(w) + \Sigma_2 * \log(poilb) + (1 - \Sigma_1 - \Sigma_2) * \log(pq_{-1}) + \Sigma_3 * \log(qgap/100)$$

PGDP: "GDP Deflator"

pgdp == 100 * gdpv/gdp

PABS: "Domestic Absorption Deflator"

pabs == 100 * absv/abs

DPC: "Consumer Price Inflation Rate (annual rate)"

dpc == 400 * Δ log(pc)

PC: "Consumer Price Deflator"

pc/pabs = 1

PIFR: "Residential Investment Deflator"

pifr/pabs = 1

PIFNR: "Nonresidential Investment Deflator"

pifnr/pabs = 1

PINV: "Inventory Deflator"

pinv/pabs = 1

PGIF: "Government Investment Deflator"

pgif/pabs = 1

PGC: "Government Goods Expenditure Deflator"

pgc/pabs = 1

5. Financial Markets

A. Interest Rates

RS: "Interest Rate Reaction Function"

rs = pswitch.rs * rs.x + (1 - pswitch.rs) * (max(0.25, rs_E))

$rs_E = \xi_0 + \xi_1 * 100 * \log(gdp/gdppot) + \xi_2 * 100 * \log(pc/ptar.x)$

$+ \xi_3 * rs_{-1} + \xi_4 * 100 * \log(er/ertar.x) + \xi_5 * dpc$

RL.R: "Interest Rate Term Structure: Rational Expectations"

$rl.r = \Pi_0 + \Pi_1 * rs + (1 - \Pi_1) * rl_{+1}$

RL.A: "Interest Rate Term Structure: Adaptive Expectations"

$$rl.a = \pi_\eta + \sum_{\iota=\Theta}^{\iota=I} \pi_\iota rl.a_{-\iota} + \sum_{\iota=\Theta}^{\iota=I} \pi_{I+\iota} rs_{-\iota} + \sum_{\iota=\Theta}^{\iota=I} \pi_{\kappa+\iota} dpc_{-\iota} + \pi_{\Theta\eta} (qgap_{-\Theta} - 100)$$

RL: "Interest Rate Term Structure"

rl == eswitch.rl * rl.r + (1 - eswitch.rl) * rl.a

RLBAR: "Average Return on Outstanding Long-Term Government Debt"

$rlbar = \rho * rl + (1-\rho) * rlbar_{-1}$

B. Expected Inflation

DPC1: "Consumer Price Inflation Rate Lead (annual rate)"

dpc1 == eswitch.dpc * dpc1.r + (1-eswitch.dpc) * dpc1.a

DPC1.R: "Consumer Price Inflation Rate: Rational Expectations"

$dpc1.r = dpc_{+1}$

DPC1.A: "Consumer Price Inflation Rate: Adaptive Expectations"

$dpc1.a = 4 * dp41 - (dpc + dpc_{-1} + dpc_{-2})$

DP41: "Absorption Four Quarter Inflation Rate Lead"

$$dp41 = \sigma_{\eta} + \sum_{\eta}^{\kappa} \sigma_{\Theta+\iota} (qgap_{-\iota} - 100) + \sum_{\eta}^{\kappa} \sigma_{\lambda+\iota} 100 * (\Delta_{\iota} \log(pc))_{-\iota}$$

$$+ \sum_{\eta}^{\kappa} \sigma_{\Theta\kappa+\iota} 100 * (\Delta \log(w))_{-\iota} + \sum_{\eta}^{\kappa} \sigma_{\theta\theta+\iota} (rs_{-\iota} - 100 * (\Delta_{\iota} \log(pc))_{-\iota})$$

DPEXP.R: "Long-Term Expected Inflation: Rational Expectations"

$dpexp.r = \Sigma_4 * dpc1 + (1-\Sigma_4) * dpexp_{+1}$

DPEXP.A: "Long-Term Expected Inflation: Adaptive Expectations"

$dpexp.a = \Sigma_5 * zdpexpa.a * dpc + (1-\Sigma_5) * dpexp.a(-1)$

DPEXP: "Long-Term Expected Inflation"

dpexp == eswitch.dpexp * dpexp.r + (1 - eswitch.dpexp) * dpexp.a

C. Exchange Rate Determination

RER.R: "Uncovered Interest Parity Equation: Rational Expectations"

$$\begin{aligned}\log(rer.r) = {} & pswitch.er * \log(er.x * upc/pc) \\ & + (1 - pswitch.er) * (\log(rer_{+1})) \\ & + ((urs - udpc1) - (rs - dpc1))/400 \\ & + \chi_1 * (nxdebt - unxdebt)/(ugdppotv + gdppotv/er)\end{aligned}$$

RER.A: "Uncovered Interest Parity Equation: Adaptive Expectations"

$$\begin{aligned}\log(rer.a) = {} & pswitch.er * \log(er.x * upc/pc) \\ & + (1 - pswitch.er) * (\chi_2 - \chi_3 * (rl - dpexp - (url - udpexp)) \\ & + \chi_4 * (nxdebt - unxdebt)/(ugdppotv + gdppotv/er)\end{aligned}$$

RER: "Uncovered Interest Parity Equation"

rer == eswitch.er * rer.r + (1 - eswitch.er) * rer.a

ER: "Exchange Rate Identity"

rer == er * upc/pc