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STOCHASTIC BEHAVIOR OF THE WORLD ECONOMY UNDER ALTERNATIVE POLICY REGIMES

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ABSTRACT

This paper uses a multicountry econometric model with rational expectations to analyze the effects of alternative monetary policy regimes on the stability of various macroeconomic variables in the face of stochastic shocks to the economy. The policy regimes use a short-term interest-rate instrument to respond to deviations of various target variables from their targeted values. The principal conclusions are that there are significant tradeoffs between stabilizing output and stabilizing prices, and that more aggressive targeting can lead to large increases in interest-rate variability with only small reductions in the variability of the target variable.

Stochastic Behavior of the World Economy under Alternative Policy Regimes

Joseph E. Gagnon and Ralph W. Tryon[1]

This paper analyzes alternative regimes for monetary policy. The regimes considered are reaction functions that link the short-term nominal interest rate to targets for the monetary base, real output, and prices. We analyze these regimes by using stochastic simulations of a three-country macroeconometric model. An important feature of the model is that agents' expectations are forward looking, so that the future effects of different policy regimes are incorporated in current behavior.

This research follows the lead of Frenkel, Goldstein, and Masson (1989) and Taylor (1989b). As in these authors' studies, this paper focuses on the stabilizing properties of alternative regimes in the face of shocks that are likely to hit the world economy in the future. As in Taylor, the distribution of the shocks is estimated by using the complete model structure and historical data.

A major innovation of this study, however, is its modeling of policy instruments in the historical sample. Taylor assumed that private agents had perfect foresight of exogenous future government spending and money supplies throughout the period 1972-86. Frenkel, Goldstein, and Masson did not need to make such a strong assumption because they used instrumental variables rather than the model's own structure to capture future expectations. Nevertheless, Frenkel, Goldstein, and Masson implicitly

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assumed that the process determining policy instruments was stable over the historical period. We believe that it is more reasonable to assume that policy regimes have undergone shifts during the past fifteen years. We also believe that it is more reasonable to assume that private agents did not have perfect foresight about the future values of policy instruments in the historical period.

Given an estimated distribution of the shocks in the historical period, we simulate the model over a future baseline period by using alternative regimes for monetary policy. The alternative regimes can be compared on the basis of their ability to stabilize key macroeconomic variables in the face of random shocks. An innovative feature of our simulations is that the baseline path in the absence of shocks is the model's ex ante prediction of the next ten years. In other words, we do not include "addfactors" in any equation to force the model to track a judgmental path. We followed this approach for two reasons. First, we believe that the addition of fixed addfactors would invalidate the use of random shocks based on a historical distribution that did not allow for addfactors. Second, as the model's ex ante prediction, the baseline path provides valuable information about the long-run properties of the model.

Because of the computational intensity of our simulations, we have analyzed only a small subset of interesting monetary policy regimes. Nevertheless, we have found the results to be illuminating, despite their limitations, and they challenge us to seek ways to make a more exhaustive analysis feasible.

Simulation Framework

The model we use, MX3, is a quarterly macroeconometric model of the Group of Three (G3) economies: United States, Japan, and Germany.[2] The model is closed by a rest-of-world (ROW) sector by using national income accounts data from the rest of the Group of Seven (G7) industrial countries. Each country bloc in MX3 has twelve behavioral equations, nineteen identities, four government policy rules, and two exogenous variables.

Innovations and Structure of the MX3 Model

MX3 differs from traditional large-scale quantitative macroeconometric models in three important dimensions. The first, and most obvious, difference is that expectations are rational and forward looking rather than backward looking. When simulating MX3, expectations of future variables are taken to be rational in the sense that expectations are set equal to the model's own prediction of the future.[3]

The second innovation of MX3 lies in its treatment of lags in the structural relations. In MX3, the behavioral equations contain only one lagged dependent variable and no other lagged variables. (The appearance of a lagged dependent variable in the decision rule is a general result of optimizing behavior with costly adjustment.) Higher-order dynamics in the behavior of any individual time series are assumed to reflect the trans-

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2. For a more detailed description of the theory and estimation of the model, and a complete equation listing, see Gagnon (1992). The appendix to this paper displays the structure of a typical country bloc in MX3.

3. Because it is not feasible to compute true expectations in a large stochastic nonlinear model, the expectations variables are solved under the assumption that future disturbances are identically zero; that is, the model solution enforces certainty equivalence. This procedure introduces an approximation error. Simply put, the model solves nonlinear functions of expectations when the theory calls for expectations of nonlinear functions.

mission and equilibration of shocks throughout the entire system of equations. In other words, a system of several first-order equations typically gives rise to time-series behavior of individual variables that is higher than first order. This research takes the view that the apparent significance of lagged variables in much empirical work can be traced to misspecification of the estimation equation and, in particular, to the lack of a good measure of expected future variables.

The third, and perhaps most significant, difference between MX3 and traditional models concerns the long-run properties of the model. MX3 is designed to exhibit the qualities of an optimal growth model in the long run. The ultimate sources of growth in this economy are exogenous increases in labor force and technology. MX3's parameters are carefully restricted to ensure that changes in government policy and permanent shocks to supply are consistent with steady-state growth paths.

MX3 is designed to be a structural model for analyzing fiscal and monetary policy. By allowing expectations to react endogenously to changes in policy rules, MX3 takes a large step toward addressing Lucas' (1976) critique of model-based policy analysis. The essence of the Lucas critique is that the "structural" equations of most macroeconometric models really are not capturing stable decision rules of economic agents. Instead, these equations are better characterized as reduced forms that combine the interactions of policymakers and private agents. Lucas demonstrated that one would not expect such a reduced-form relationship to hold constant in the face of a change in the policymakers' behavior.

Lucas' prescription for macroeconometric modeling is to consider the decision problem for each class of economic agents. Lucas argued that, for a wide range of decisionmaking environments, agents base their actions on expectations of future variables as well as on the realizations of current and past variables.[4] Only when modellers have correctly identified the optimal decision rules and information sets of each class of agents can they hope to gauge the effects of different policy rules accurately.

Unfortunately, a fully satisfactory analysis of macroeconomic dynamics based on optimizing behavior has yet to be developed, and it is likely to be years away for models of the scale of MX3. The strategy behind MX3 was to build a tractable model now by appealing heuristically to the structural equations that might result from a suitably specified set of agents, tastes, and technologies.

The long-run structure of MX3 is that of an optimal growth model with Cobb-Douglas technology, perfectly competitive firms, and long-lived utility-maximizing households. In MX3, households and firms rationally forecast future income and real interest rates when making their consumption and investment plans. Growth in the model is driven exogenously by growth in the labor force and in technology. With Cobb-Douglas technology and perfect competition, the share of total output that accrues to capital is given by the exponent on capital in the production function. The capital-output ratio equates the returns to capital with the cost of capital, which in turn is dependent on the real rate of interest. The real interest rate serves to equilibrate consumption and investment at the level of output given by the production function.

4. Rational expectations embody a simplifying assumption that ignores any process by which agents learn about the nature of the economy or the shocks that have ocurred recently. Under rational expectations, agents know the true stochastic structure of the economy, including the rules of the policy regime in effect.

Although it would be possible to build a model of the economy with only the simple relationships described above, such a model would not be able to explain the short- to medium-run dynamics evident in the data. The transmission of shocks throughout the economy is almost certainly influenced by adjustment costs, gestation lags, and delays in the assimilation of new information. These characteristics of the economic environment may prevent markets from behaving competitively in any given period, and yet market forces may move the economy to a competitive outcome over a longer horizon.

Only recently have economists begun to enrich the dynamics of growth models by solving the decision problems of agents with costs of adjustment or gestation lags. At present, this work has yielded only rudimentary models that require the assumption of continuously competitive market clearing in order to obtain a solution. The structure of MX3 reflects the view that economic theory in its present state yields clearer insights about the long-run behavior of the economy than about short-run dynamics. The approach taken in MX3 is to enforce a competitive steady state in the long run, but to allow (heuristically) for imperfect competition and costly adjustment in the short run. In several instances, the model's dynamics are inspired by optimal decision rules in the face of convex adjustment costs. These decision rules determine the control variable as a function of its previous value and the discounted expected future sum of the forcing variables. The structural equations of the model, however, are not derived from the maximization of specific objective functions.

Each country bloc in MX3 is composed of four different types of economic agents. Producers in each country produce a homogeneous good that is differentiated from the goods produced in the other countries. Productive capacity is modeled by a Cobb-Douglas function in terms of the capital stock and the labor force. Total production can deviate temporarily from capacity production, but these deviations will be associated with equilibrating price movements. Fixed investment responds to deviations between the rate of return on physical capital and the rate of return on other assets.

Traders do not utilize capital and labor; they are modeled as pure arbitragers. Domestic traders purchase goods from domestic producers to sell to foreigners. This trade is characterized by significant costs of transportation and adjustment that prevent the continuous equalization of prices across countries. The preferences of households, producers, and governments for foreign goods relative to domestic goods jointly determine the demand curve faced by foreign traders selling to the domestic market.

Households maximize utility from discounted future consumption subject to their budget constraint. Households own the firms that produce and trade goods, and the net income earned by these firms passes directly to the households. The notional labor supply of each household is constant, but actual labor supplied may fluctuate as output fluctuates around capacity. (The model, in other words, enforces equal capacity utilization of capital and labor.)

Governments determine the level of the monetary base and real government spending. The government budget constraint determines the level of bonds outstanding. Tax rates are modeled with an ad hoc adjustment mechanism to ensure that the ratio of bonds to taxable income returns to an exogenous target level. The target level of government debt and the speed of adjustment to that target may be considered as additional policy instruments of government.

Financial markets determine the levels of interest rates and exchange rates. These financial markets represent the combined behavior of the four sectors in the model. Production technology and the labor force are modeled as exogenous to the rest of the economy.

Ideally, all of the private sector's behavioral equations and the government's policy equations in MX3 should be estimated simultaneously by a technique such as full-information maximum likelihood (FIML).[5] Unfortunately, the computational requirements for FIML in all but the smallest rational-expectations models are prohibitive for standard estimation techniques. Therefore, MX3 was estimated by instrumental-variables techniques. One advantage of estimating each equation separately and using instruments for current and future endogenous variables is that the exact rules of the government's policy regimes need not be specified before estimating the private sector's behavioral equations. (These policy rules must be specified, however, in order to simulate the model.)

One significant change was made to MX3 before this study. The risk-premium coefficients in the fixed-investment equations were calibrated on the assumption that the capital stock in each country was close to its equilibrium level in 1988, given the outputs and real interest rates that prevailed. In no case did this adjustment set the risk-premium coefficient more than two standard deviations from its estimated value. This calibration was necessary because the long-run capital stock is very sensitive to the value of the risk premium, and the risk premium was not

5. The advantages of FIML are especially important in the context of rational-expectations models because future expectations in the equations being estimated can be solved directly by the model's own structure. Moreover, the implied cross-equation restrictions of rational expectations can be tested, both jointly across all equations and individually in particular equations.

estimated very precisely. With 1988 chosen as a benchmark year, the model was able to project a reasonably smooth baseline path for each country over the period 1989-98.

Baseline Path

The stochastic simulations reported here were simulated over the period 1989:1-98:4. The "baseline path" refers to the behavior of all the model variables over this period in the absence of any shocks. To create the baseline path the exogenous variables in the model were projected to grow at a constant rate from their year-end 1988 levels. Government policy instruments were also projected to grow at constant rates from their year-end 1988 levels. The model was then simulated dynamically from 1989:1 through 1998:4 with all shocks equal to zero.

The labor-force growth rates were taken from projections for the next five years in OECD (1989). Because the baseline goes ten years into the future, the labor-force growth rates were shaded up or down slightly in consultation with country desk officers for Japan and Germany and U.S. labor-market specialists at the Federal Reserve. Labor-force growth was arbitrarily set at a slightly higher rate in ROW to reflect the experience of non-OECD countries. The assumed labor-force growth rates are presented in table 1.

The level of production technology was estimated as a Hodrick-Prescott trend in the Solow residual for each country. The projected future growth rate of technology was constrained to be equal across countries and constant over time. The growth rate of technology in the 1989-98 baseline is slightly higher than the average rate over the estimation period but substantially lower than the rate over the last four years.

Table 1. Properties of the Baseline Path, 1989-98

Percent

Variable	Germany	Japan	ROW[a]	United States
Labor force (growth rate)	0.5	1.0	1.5	1.4
Technology (growth rate)	1.25	1.25	1.25	1.25
Long-run potential output (growth rate)	2.35	2.97	3.35	3.17
Real government spending (growth rate)	2.35	2.97	3.35	3.17
Target ratio of public sector debt	26.8	24.9	55.2	31.3
Monetary base (growth rate)	4.35	4.97	7.35	7.17
1998 inflation rate	3.9	2.5	2.6	4.2
1998 interest rate	4.2	4.1	5.8	5.4
1998 *GDP* (growth rate)	2.2	3.4	4.1	3.3

a. Rest of the world.

Given the long-run growth rates of technology and the labor force, it is possible to compute the implied long-run growth rates of potential output in each country:

$$(1) \quad \frac{\Delta CAP}{CAP} = \frac{\Delta LF}{LF} + \frac{\Delta Q}{Q(1-\alpha)},$$

where CAP [$= Q \cdot K^{\alpha} \cdot LF^{1-\alpha}$] refers to production capacity, LF is the labor force, Q is the level of technology, and K is the capital stock. Equation 1 is valid whenever the long-run capital-output ratio is constant. The long-run capital-output ratio is constant in MX3 provided that the real interest rate, the depreciation rate, and the risk premium for holding capital are constant in the long run. Table 1 presents the implied long-run real growth rates for the countries of MX3.

Fiscal policy in MX3 is captured by the level of real government consumption and the target ratio of public sector debt to national income. The baseline path assumes that real government spending grows at the long-run rate of real output growth, starting at the observed level of government spending at year-end 1988. The target ratio of public sector debt to national income is fixed at the observed ratio at year-end 1988. An ad hoc tax-adjustment process gradually changes the tax rate to keep debt near its target level.

Monetary policy in the baseline path fixes a constant growth rate for the monetary base. The monetary base is assumed to grow at the long-run growth rate of nominal *GDP*, defined as the sum of the long-run growth rate of production capacity and the long-run inflation rate. The long-run inflation rate is assumed to be 4 percent in the United States and ROW and 2 percent in Germany and Japan.[6]

After some fluctuations and transitions in the first few years of the baseline, all the prices and real quantities of the model converge to smooth growth paths. Even though the paths are smooth, there is some evidence that the model has not reached a steady state by the end of the baseline period. The interest rates and inflation rates are close to their long-run values in the United States and Japan by 1998. In Germany and ROW, however, the inflation rates and interest rates are still moving gradually toward their long-run levels by the end of the baseline path. The rate of growth of real output is close to its long-run value in Germany and the United States in 1998, but Japan and ROW still have further adjustments to make. Table 1 presents the values of these variables in the last year of the baseline path.

Historical Residuals

The final step before conducting stochastic simulations was to create the historical residuals in the stochastic equations. Residuals were created over forty-nine quarters, from 1976:4 through 1988:4. Because of the presence of rational expectations in many of the stochastic equations, the residuals of these equations are conditional on the assumptions about the rules of the policy regime and about the exogenous variables in the model. In creating the residuals, it was assumed that agents had perfect foresight about the future paths of the labor force and technology. It was

6. Unfortunately, this procedure does not correct for the fact that the long-run income elasticity of money demand is not unity. Thus, the long-run inflation rates in the baseline path are not equal to their originally assumed values.

also assumed that agents had perfect foresight about the residuals in the model identities and the trade share equations, which do not involve future expectations.[7] Beginning in 1989:1 and extending into all later periods, all residuals are assumed to be zero.

Rather than assume perfect foresight about policy instruments, government spending and the monetary base were modeled as first-order (nonstationary) autoregressions. In other words, agents expected that the monetary base and government spending would grow at constant rates into the future, but they were surprised by innovations to the monetary base and government spending in the solution period. The target ratio of government debt was assumed to be constant.

We assume that there was an unanticipated shift in both the monetary and fiscal policy regimes during the historical period. The monetary regime shift consisted of a slowdown in the growth rate of the monetary base beginning in 1980:1 in all countries. The fiscal regime shift consisted of an increase in the growth rate of U.S. government spending and a decrease in the growth rate of government spending in the remaining countries beginning in 1981:1. In addition, the target ratio of government bonds to national income jumped up in the United States and ROW in 1981:1.

The assumed growth rates of the monetary base and government spending before the regime shifts were estimated as the average observed growth rates between 1976:1 and the dates of the regime shifts. The assumed growth rates after the regime shifts were estimated as the average observed growth rates

7. Residuals in the identities arise from statistical errors and omissions, from the lack of complete data for ROW, and from the use of a short-term interest rate and an aggregate depreciation rate in the stock-flow identities. The trade-share residuals are quite small; because of their relative unimportance, the trade shares have not been subjected to shocks in the stochastic simulations.

between the regime shifts and 1988:4. The target ratios of public sector debt to national income were assumed to be the observed values in 1988:4, except for the United States and ROW before 1981:1, when they were assumed to be the observed values in 1981:1. The rules of these government policy regimes are documented in table 2.

Table 2 also presents evidence on the goodness of fit of these assumed policy rules. For the observed policy instruments--government expenditure, monetary base, and tax rate--residuals were calculated over the historical period. In each case the dependent variable is expressed as a ratio to facilitate comparison across residuals. The target ratio of government debt is unobservable, so no residuals were calculated for that equation. According to table 2, the assumed policy rules appear to fit reasonably well. Although the table does not show it, the properties of the policy-rule residuals are very similar in each regime.

There are thirty-one private sector behavioral equations for which random shocks are to be drawn for the stochastic simulations. The equations are private consumption (*C*), fixed investment (*IF*), inventory investment (*II*), export volume (*XGSNI*), export price (*PXGSNI*), money demand (*MB*), and the contract price (*X*) in each of the four countries, plus the open-interest-rate-parity equations for the three exchange rates (*ER*). (Countries are identified by the prefixes *G*, *J*, *R*, and *U* for Germany, Japan, rest-of-world, and the United States.) The mean, standard deviation (around zero), and first-order autocorrelation of these residuals are given in table 3. Table 4 presents the contemporaneous correlation matrix of the residuals. As can be seen from table 3, the residual means are very close

Table 2. Policy Regimes in the Historical Period, 1976-88

Percent

Instrument	Germany	Japan	ROW[a]	United States
Monetary base (growth rate)				
1976-79	7.88	9.52	13.30	8.16
1980-88	6.44	7.60	9.08	7.52
Government expenditures (growth rate)				
1976-80	2.32	4.12	2.24	1.24
1981-88	1.52	2.28	1.96	3.12
Target debt ratio				
1976-80	26.80	24.90	41.50	20.50
1981-88	26.80	24.90	55.20	31.30
Policy Residuals				
Monetary base				
Mean	-0.000	-0.000	0.000	0.000
Standard deviation	0.007	0.019	0.014	0.004
Autocorrelation	0.154	-0.288	-0.206	0.401
Government expenditure				
Mean	0.000	-0.000	0.000	0.000
Standard deviation	0.013	0.027	0.003	0.014
Autocorrelation	-0.544	-0.484	-0.230	-0.048
Tax rate				
Mean	-0.001	0.000	-0.002	-0.001
Standard deviation	0.004	0.005	0.013	0.006
Autocorrelation	-0.086	0.677	-0.293	-0.079

a. Rest of the world.

Table 3. Properties of the Private Sector Residuals

Equations	Mean	Standard Deviation	Autocorrelation
GX	0.002	0.012	0.663
GER	0.021	0.078	0.468
GC	-0.005	0.006	-0.362
GIF	0.004	0.011	0.346
GII	-0.002	0.016	0.743
GXGSNI	0.002	0.023	0.067
GPXGSNI	-0.001	0.004	0.027
GMB	0.001	0.012	0.602
JX	-0.005	0.013	0.714
JER	0.103	0.133	0.552
JC	-0.003	0.004	0.495
JIF	-0.008	0.021	0.834
JII	-0.005	0.018	0.784
JXGSNI	0.003	0.030	-0.141
JPXGSNI	-0.002	0.026	0.296
JMB	0.001	0.016	-0.234
RX	0.000	0.011	0.858
RER	0.012	0.026	0.426
RC	0.004	0.006	0.842
RIF	-0.008	0.012	0.915
RII	0.001	0.010	0.728
RXGSNI	0.001	0.017	0.041
RPXGSNI	-0.000	0.010	0.393
RMB	-0.001	0.012	-0.109
UX	-0.001	0.004	-0.085
UC	0.003	0.005	0.471
UIF	0.003	0.006	0.431
UII	0.004	0.013	0.610
UXGSNI	0.013	0.041	0.545
UPXGSNI	-0.000	0.009	0.118
UMB	0.003	0.006	0.187

Table 4. Residual Correlation Matrix

Equations	*GX*	*GER*	*GC*	*GIF*	*GII*	*GXGSNI*	*GPXGSNI*	*GMB*
GX	1.00							
GER	0.64	1.00						
GC	-0.28	-0.09	1.00					
GIF	0.54	0.58	0.24	1.00				
GII	0.61	0.46	-0.30	0.49	1.00			
GXGSNI	0.12	0.14	0.10	0.26	0.03	1.00		
GPXGSNI	-0.15	0.15	-0.05	0.14	0.32	0.01	1.00	
GMB	0.24	0.01	-0.13	0.02	-0.13	0.20	-0.37	1.00
JX	0.61	0.54	0.03	0.44	0.28	0.04	-0.24	0.20
JER	0.39	0.69	-0.12	0.46	0.46	-0.07	0.34	-0.14
JC	-0.29	0.03	0.14	-0.11	-0.28	-0.24	0.12	-0.30
JIF	0.82	0.72	-0.11	0.63	0.48	0.26	-0.18	0.38
JII	0.69	0.64	-0.04	0.55	0.44	0.09	-0.06	0.09
JXGSNI	-0.16	0.06	0.03	0.05	0.20	0.03	0.28	-0.19
JPXGSNI	-0.36	0.10	0.01	-0.06	0.03	-0.12	0.60	-0.38
JMB	0.06	-0.06	-0.02	0.19	0.18	0.12	0.02	0.08
RX	0.51	0.48	-0.01	0.28	0.35	-0.10	-0.02	0.03
RER	0.31	0.65	-0.07	0.32	0.12	0.10	-0.07	0.22
RC	0.80	0.62	0.04	0.65	0.54	0.24	-0.14	0.43
RIF	0.70	0.50	-0.05	0.42	0.49	0.15	-0.15	0.31
RII	0.50	0.27	-0.07	0.34	0.48	0.08	-0.01	0.10
RXGSNI	0.23	0.13	0.02	0.22	0.07	0.36	-0.00	0.14
RPXGSNI	-0.22	0.04	-0.12	-0.20	0.12	-0.21	0.44	-0.42
RMB	-0.08	-0.04	-0.09	0.02	-0.06	-0.16	0.19	0.03
UX	0.59	0.67	-0.02	0.37	0.31	0.17	-0.02	0.05
UC	0.36	0.48	-0.02	0.40	0.24	0.06	-0.09	0.08
UIF	-0.04	0.25	0.08	0.08	-0.03	-0.07	-0.01	-0.23
UII	0.10	0.27	-0.02	0.13	0.18	0.47	0.12	-0.04
UXGSNI	0.13	-0.03	-0.27	0.04	0.17	0.40	0.12	0.32
UPXGSNI	-0.31	-0.23	0.24	-0.09	0.00	-0.34	0.20	-0.32
UMB	0.12	0.14	0.01	0.27	0.18	-0.17	0.09	0.09

Table 4. *(continued)*

Equations	*JX*	*JER*	*JC*	*JIF*	*JII*	*JXGSNI*	*JPXGSNI*	*JMB*
JX	1.00							
JER	0.34	1.00						
JC	0.13	0.35	1.00					
JIF	0.69	0.36	-0.26	1.00				
JII	0.86	0.52	0.17	0.75	1.00			
JXGSNI	0.15	0.07	-0.14	-0.07	-0.26	1.00		
JPXGSNI	-0.29	0.45	0.29	-0.36	-0.21	0.37	1.00	
JMB	0.14	-0.09	-0.36	-0.00	-0.24	0.17	-0.14	1.00
RX	0.67	0.44	0.22	0.38	0.63	-0.13	-0.04	-0.07
RER	0.58	0.54	0.20	0.50	0.49	0.10	0.13	-0.10
RC	0.71	0.38	-0.26	0.87	0.73	-0.03	-0.34	0.05
RIF	0.67	0.21	-0.31	0.70	0.65	0.03	-0.36	0.08
RII	0.51	0.18	-0.20	0.35	0.47	-0.02	-0.32	0.30
RXGSNI	0.05	-0.06	-0.27	0.26	0.05	0.05	-0.20	0.09
RPXGSNI	-0.28	0.40	0.29	-0.40	-0.20	0.28	0.74	-0.21
RMB	0.05	0.08	0.03	-0.07	-0.08	0.15	0.17	0.13
UX	0.26	0.29	-0.06	0.57	0.37	-0.12	-0.19	0.05
UC	0.54	0.47	0.22	0.43	0.58	-0.20	-0.07	-0.16
UIF	0.07	0.22	0.25	0.02	0.14	0.04	0.09	-0.18
UII	0.14	0.05	-0.06	0.30	0.21	0.10	-0.05	0.00
UXGSNI	0.23	-0.29	-0.50	0.18	-0.22	0.19	-0.06	0.20
UPXGSNI	-0.19	0.10	0.35	-0.29	-0.18	-0.01	0.31	0.04
UMB	0.16	0.26	-0.04	0.08	0.15	0.19	0.27	0.09

Table 4. *(continued)*

Equations	*RX*	*RER*	*RC*	*RIF*	*RII*	*RXGSNI*	*RPXGSNI*	*RMB*
RX	1.00							
RER	0.35	1.00						
RC	0.58	0.44	1.00					
RIF	0.71	0.36	0.86	1.00				
RII	0.59	0.17	0.60	0.75	1.00			
RXGSNI	-0.22	0.07	0.20	0.15	-0.07	1.00		
RPXGSNI	0.11	-0.01	-0.29	-0.25	-0.26	-0.05	1.00	
RMB	-0.06	-0.10	-0.13	-0.15	-0.18	0.10	0.13	1.00
UX	0.20	0.23	0.41	0.28	0.09	0.21	-0.26	-0.05
UC	0.55	0.51	0.47	0.45	0.35	0.04	-0.09	-0.03
UIF	0.20	0.27	0.01	0.06	-0.06	0.34	0.22	-0.01
UII	-0.04	0.30	0.17	0.11	0.09	0.32	-0.17	-0.08
UXGSNI	-0.36	-0.08	0.08	-0.03	-0.13	0.27	-0.14	0.04
UPXGSNI	-0.03	-0.14	-0.26	-0.36	-0.32	-0.21	0.31	0.03
UMB	0.28	0.19	0.17	0.20	0.03	-0.03	0.19	0.34

Equations	*UX*	*UC*	*UIF*	*UII*	*UXGSNI*	*UPXGSNI*	*UMB*
UX	1.00						
UC	0.24	1.00					
UIF	0.03	0.63	1.00				
UII	0.19	0.11	0.20	1.00			
UXGSNI	0.13	-0.37	-0.26	0.43	1.00		
UPXGSNI	-0.10	-0.10	0.11	-0.19	-0.15	1.00	
UMB	-0.13	0.18	0.07	-0.25	-0.03	0.09	1.00

to zero, except for some of the exchange-rate residuals.[8] The largest standard deviations occur in the exchange-rate and U.S. export equations. Only four of the thirty-one residual series exhibit autocorrelation greater than 0.8. Another nine residuals, however, have autocorrelation coefficients between 0.5 and 0.8.

The autocorrelation in the estimated residuals suggests that there could be efficiency gains from estimation by FIML. The use of FIML in estimating rational-expectations models allows the model structure to determine the future expectations, as is the case when the model is simulated and when the model residuals are computed. The single-equation methods that were used to estimate MX3 do not capture all the model's information and restrictions in determining future expectations. The loss of information about expectations may be quite important: although only nineteen of the thirty-one stochastic equations contain future expectations, eleven of the thirteen residual series that were highly autocorrelated are in equations with future expectations.

To test for the implications of our assumptions about the policy regimes in the historical period, we recomputed the residuals under the assumption that agents had perfect foresight of future values of the policy instruments. This assumption is identical to that of Taylor (1989b). By looking at the actual values of the residuals, we did not identify any noticeable differences across the two sets of residuals, even in the quarters immediately surrounding the assumed regime shifts.

8. All of the model equations are expressed in logarithms or ratios to capacity output, so that a residual value of 0.01 represents a 1 percent shock to an equation.

Table 5 lists some summary statistics of the residuals computed under perfect foresight. For most equations, the standard deviation and autocorrelation are less than or equal to the corresponding values in table 3. (The statistics are identical for equations without future expectations.) We also computed the log likelihood of the model by using the historical residuals. The log likelihood under the assumption of perfect foresight of policy instruments is 4,075.28. The log likelihood assuming stochastic policy rules and unanticipated regime shifts is 3,966.75.

These likelihood values are based only on the thirty-one private sector residuals. We were surprised to find that the assumption of perfect foresight leads to a better fit of the behavioral equations. We can think of two reasons for this anomalous result. First, our assumed policy rules and regime shifts are not capturing the true policy rules and regime shifts in the historical period. But table 2 shows that the assumed policy rules do not perform badly. Second, the private sector stochastic equations were estimated with instrumental variables that did not allow for regime shifts. If the second explanation is relevant, the estimated coefficients may be biased from their true values in a way that causes apparently better fit of the model when no regime shifts are assumed in the historical period. Once again, the best solution would be to estimate the model and the policy rules simultaneously by FIML, allowing for unanticipated regime shifts.

Table 5. Properties of the Private Sector Residuals under Assumption of Perfect Foresight of Policy Instruments

Equations	Mean	Standard Deviation	Autocorrelation
GX	0.003	0.009	0.379
GER	0.027	0.069	0.460
GC	-0.004	0.006	-0.199
GIF	0.006	0.009	-0.156
GII	0.001	0.013	0.648
GXGSNI	0.002	0.023	0.067
GPXGSNI	-0.001	0.004	0.027
GMB	0.001	0.012	0.602
JX	-0.001	0.007	0.462
JER	0.108	0.130	0.631
JC	-0.002	0.004	0.711
JIF	-0.002	0.010	0.566
JII	0.001	0.011	0.746
JXGSNI	0.003	0.030	-0.141
JPXGSNI	-0.002	0.026	0.296
JMB	0.001	0.016	-0.234
RX	0.006	0.009	0.779
RER	0.013	0.027	0.410
RC	0.005	0.007	0.848
RIF	-0.005	0.008	0.895
RII	0.005	0.010	0.675
RXGSNI	0.001	0.017	0.041
RPXGSNI	-0.000	0.010	0.393
RMB	-0.001	0.012	-0.109
UX	-0.001	0.004	-0.090
UC	0.004	0.005	0.276
UIF	0.003	0.006	0.411
UII	0.006	0.014	0.625
UXGSNI	0.013	0.041	0.545
UPXGSNI	-0.000	0.009	0.118
UMB	0.003	0.006	0.187

Stochastic Simulations

The stochastic simulations focus on alternative monetary policy regimes. The rules of the fiscal policy regime are always unchanged from their baseline specification.

Implementation

Six monetary policy regimes are considered. In each case the short-term interest rate is the policy instrument. Regimes 1 through 6 express the alternative policy rules (variables marked by an asterisk indicate baseline values; the interest rates and inflation rates are expressed in decimal form at annual rates, so that a 6 percent rate is .06):

(Regime 1) $$RS - RS^{*} = 5.0 \left[\log(MB) - \log(MB^{*})\right]$$

(Regime 2) $$RS - RS^{*} = 1.5 \left[\log(PGNP \cdot GDP) - \log(PGNP^{*} \cdot GDP^{*})\right]$$

(Regime 3) $$RS - RS^{*} = 3.0 \left[\log(PGNP \cdot GDP) - \log(PGNP^{*} \cdot GDP^{*})\right]$$

(Regime 4) $$RS - RS^{*} = 1.5 \left[DPGNP - DPGNP^{*} + \log(GDP) - \log(GDP^{*})\right]$$

(Regime 5) $$RS - RS^{*} = 1.5 \left[\log(PGNP) - \log(PGNP^{*})\right]$$

(Regime 6) $$RS - RS^{*} = 2.5 \left[\log(ER) - \log(ER^{*})\right].$$

In regime 1 the monetary authority targets the monetary base. In regime 2 the monetary authority targets nominal *GDP*. Regime 3 also targets nominal *GDP*, but uses a much larger reaction coefficient on deviations of nominal *GDP* from target. In regime 4 the monetary authority attempts to minimize deviations of both the inflation rate and the level of output from their respective targets. Regime 5 targets the price level. Finally, regime 6 targets the exchange rate in Germany, Japan, and ROW. (To complete the model under regime 6 it is assumed that the United States follows regime 1.)

The stochastic simulations are conducted over the forty quarters from 1989:1 through 1998:4. To begin a stochastic simulation, thirty-one residuals are drawn from a random number generator according to a normal distribution with mean zero and the estimated variance-covariance matrix. The model is solved in 1989:1 by using these residuals and the fixed lags and exogenous variables. The future expectations are computed by the Fair-Taylor algorithm. Future residuals are assumed to be zero. The stochastic solution for 1989:1 is then used for the necessary lags in solving in 1989:2. When solving in 1989:2 a new draw of residuals is taken from their estimated distribution, but future residuals are again assumed to be zero. This process is repeated for forty quarters, thus completing one stochastic replication over the baseline period. Ten stochastic replications are conducted for each policy regime over the baseline period, for a total of 400 draws of the residuals.[9]

To economize on computation time, the Fair-Taylor algorithm is allowed only one type-III iteration over a forecast horizon of twenty quarters. The type-II convergence criterion is 0.02 percent. In most cases type-II convergence is achieved, but sometimes the solution stops at the iteration limit of 100. Some trial solutions indicated that these restrictions allow reasonably accurate results. Occasionally the model diverged during solution; when the model cannot be solved during any period of a given replication, the entire replication is restarted using a

9. These replications were conducted with TROLL 13.1 software using the new stochastic simulator package. Each replication requires about 75 minutes of processing (CPU) time on an Amdahl 5850.

different seed for the random number generator. Regime 6 always led to solution divergence, and no results are available for this regime.

A Metric for Comparison

To compare the simulation results for different regimes, one needs a measure (or measures) of how well the regimes perform. The primary measure used here is the root-mean-squared deviation (RMSD) of key economic variables around their baseline values. In other words, the objective is stated in terms of the second moments, rather than the first moments, of the data. This choice of objective reflects our conviction that the average levels of real economic variables are invariant to any well-specified monetary policy in the long run. Although nominal variables do depend on monetary policy, this study ignores the factors involved in choosing a long-run inflation rate and focuses solely on deviations from the long-run rate.

The transition from one policy regime to another is likely to involve significant costs as agents learn gradually about the new regime. It would be of interest to consider the problem of making such a regime shift less costly, but we do not pursue that topic here. The assumption behind all the stochastic simulations in this paper is that the regime shift is understood perfectly by the private sector and is fully credible. Thus, comparisons of economic performance across policy regimes reflect differences in the long-run stochastic behavior of the economy and not the short-run transition costs.

The use of second moments as measures of economic performance may be rationalized on two grounds. First, fluctuations of variables around their expected values give rise to adjustment costs as agents adapt their behavior to the new conditions. Second, agents may be risk averse, so that their utility is increased when monetary policy succeeds in reducing the variance of an important variable. Of course it is possible that, by reducing the variance of one variable, policy may increase the variance of some other variable. In conducting the analysis it is necessary to consider all of the most important variables. Implicitly or explicitly, policymakers may have to weigh stabilization of one variable against the destabilization of another.

Simulation Results

Table 6 summarizes the results of the stochastic simulations. This table shows the RMSD of each variable from its baseline path. The RMSDs were calculated over 400 observations, representing ten stochastic replications of forty quarters each. The variables are measured in logarithms, except for the interest rate and the current account ratio, which are in decimals. The growth rates shown are log changes for all variables except the interest rate and current account ratio, which are in first differences.

Because the RMSDs in table 6 were calculated over a finite number of observations, they are subject to sampling error; therefore they may not equal the true RMSDs implied by the model structure and estimated residual covariance. Ideally, we would like to present a 95 percent confidence interval for each RMSD in table 6. Getting such a confidence interval by bootstrapping over the realizations of the deviations of each variable from baseline seemed impractical, both because of the large number of variables and stochastic draws and because of the high degree of autocorrelation

Table 6. Summary of Stochastic Simulations of Policy Regimes

Root-mean-squared deviation from baseline

Variables	Regime 1: *MB*	Regime 2: *GDPV*	Regime 3: *GDPV1*	Regime 4: *DPGNP & GDP*	Regime 5: *PGNP*
			United States		
GDP (log)[a]	0.080	0.081	0.083	0.020	0.119
	(0.032-0.145)	(0.031-0.150)	(0.031-0.155)	(0.015-0.029)	(0.048-0.276)
GDP (dlog)	0.020	0.018	0.018	0.017	0.029
PGNP (log)	0.088	0.087	0.087	0.215	0.021
PGNP (dlog)[a]	0.012	0.012	0.012	0.018	0.006
	(0.010-0.015)	(0.009-0.014)	(0.009-0.015)	(0.014-0.025)	(0.004-0.008)
GDPV (log)	0.033	0.024	0.017	0.216	0.106
GDPV (dlog)	0.021	0.018	0.016	0.024	0.025
CAB (ratio)	0.004	0.004	0.004	0.005	0.005
CAB (del)	0.002	0.001	0.002	0.002	0.002
RS (level)	0.031	0.036	0.051	0.094	0.047
RS (del)	0.015	0.027	0.048	0.052	0.014
MB (log)	0.006	0.024	0.035	0.161	0.129
MB (dlog)	0.003	0.011	0.017	0.024	0.020
			Germany		
GDP (log)[a]	0.034	0.029	0.033	0.020	0.043
	(0.021-0.050)	(0.015-0.040)	(0.014-0.061)	(0.014-0.026)	(0.021-0.073)
GDP (dlog)	0.026	0.021	0.018	0.018	0.025
PGNP (log)	0.066	0.035	0.038	0.183	0.020
PGNP (dlog)[a]	0.015	0.013	0.013	0.018	0.011
	(0.012-0.019)	(0.011-0.015)	(0.011-0.014)	(0.013-0.026)	(0.009-0.014)
GDPV (log)	0.080	0.031	0.023	0.180	0.044
GDPV (dlog)	0.036	0.028	0.024	0.027	0.029
ER (log)	0.207	0.198	0.208	0.258	0.206
ER (dlog)	0.118	0.110	0.109	0.105	0.127
CAB (ratio)	0.020	0.018	0.020	0.021	0.019
CAB (del)	0.024	0.023	0.025	0.027	0.026
RS (level)	0.049	0.047	0.070	0.112	0.042
RS (del)	0.052	0.042	0.071	0.114	0.024
MB (log)	0.010	0.076	0.098	0.087	0.104
MB (dlog)	0.010	0.030	0.037	0.042	0.037

Table 6. *(continued)*

Root-mean-squared deviation from baseline

Variables	Regime 1: *MB*	Regime 2: *GDPV*	Regime 3: *GDPV1*	Regime 4: *DPGNP & GDP*	Regime 5: *PGNP*
			Japan		
GDP (log)[a]	0.030	0.023	0.022	0.021	0.029
	(0.021-0.035)	(0.018-0.028)	(0.016-0.029)	(0.017-0.032)	(0.023-0.037)
GDP (dlog)	0.031	0.026	0.022	0.022	0.029
PGNP (log)	0.031	0.024	0.024	0.092	0.020
PGNP (dlog)[a]	0.015	0.014	0.013	0.016	0.013
	(0.012-0.017)	(0.012-0.016)	(0.010-0.016)	(0.013-0.020)	(0.011-0.016)
GDPV (log)	0.053	0.035	0.028	0.099	0.039
GDPV (dlog)	0.043	0.036	0.031	0.033	0.038
ER (log)	0.267	0.265	0.276	0.323	0.265
ER (dlog)	0.170	0.175	0.180	0.173	0.168
CAB (ratio)	0.024	0.025	0.025	0.024	0.025
CAB (del)	0.036	0.037	0.038	0.036	0.037
RS (level)	0.025	0.053	0.085	0.121	0.037
RS (del)	0.027	0.054	0.094	0.148	0.025
MB (log)	0.005	0.084	0.137	0.135	0.082
MB (dlog)	0.005	0.036	0.062	0.093	0.030
			ROW		
GDP (log)[a]	0.023	0.022	0.022	0.016	0.028
	(0.017-0.027)	(0.014-0.032)	(0.013-0.033)	(0.011-0.021)	(0.019-0.039)
GDP (dlog)	0.020	0.017	0.015	0.015	0.017
PGNP (log)	0.047	0.029	0.028	0.160	0.019
PGNP (dlog)[a]	0.012	0.011	0.011	0.015	0.011
	(0.010-0.015)	(0.010-0.012)	(0.009-0.013)	(0.011-0.022)	(0.009-0.012)
GDPV (log)	0.052	0.028	0.023	0.160	0.026
GDPV (dlog)	0.028	0.024	0.021	0.024	0.021
ER (log)	0.136	0.126	0.127	0.320	0.121
ER (dlog)	0.050	0.049	0.052	0.054	0.068
CAB (ratio)	0.011	0.012	0.014	0.013	0.010
CAB (del)	0.009	0.010	0.013	0.009	0.013
RS (level)	0.026	0.042	0.068	0.098	0.060
RS (del)	0.023	0.036	0.063	0.100	0.034
MB (log)	0.005	0.053	0.086	0.097	0.103
MB (dlog)	0.005	0.023	0.037	0.046	0.031

a. Numbers in parentheses are the smallest and largest RMSDs from ten separate replications of forty quarters each.

present in the deviations within each stochastic replication.[10] Instead, we calculated the RMSD for the log of *GDP* and the growth rate of *PGNP* for each replication separately, rather than for all ten replications jointly. Below the overall RMSDs for these variables in table 6 we list the smallest and the largest RMSD from the ten separate replications of forty quarters each. These intervals are almost certainly larger than a 95 percent confidence interval for the overall RMSD because they include outliers and because the overall RMSD is calculated over a sample ten times larger than the RMSDs from the separate replications.

Regime 1: Monetary Base Targeting

The first regime we consider is monetary base targeting, using the reaction function given above in the equation for regime 1. This regime is roughly equivalent to a fixed monetary base, since the actual changes in the monetary base under this regime are quite small. As shown in table 6, the RMSD of the monetary base is less than 0.01, or about 1 percent, for each country. The RMSD of the growth rate of the monetary base is of about the same magnitude.

It is striking that under this regime the variability of the (log) level of both output and prices in the United States is much higher than the variability of the growth rate. This is not the case in the other countries (except perhaps for the price level in Germany). Thus, shocks appear to be more persistent in the United States than abroad. (Recall that the shocks to the price equation are serially correlated in the United States. Also, the estimated contract lengths are longer, and the sensitivity to excess

10. The autocorrelation of the deviations from baseline is due solely to the dynamic specification of the model. The random shocks were serially independent.

demand is lower, in the United States.) Both the level and the growth rate of nominal output (*GDP•PGNP*, labeled *GDPV* in the tables), in contrast, are less variable in the United States than in any of the other countries.

The bilateral dollar exchange rates are by far the most volatile series reported. The deutschemark and yen exchange rates have RMSDs of 0.207 and 0.267 respectively, whereas the RMSD in the ROW exchange rate is 0.136. The exchange rate deviations from baseline are also highly serially correlated. The relatively high variability of the price level (and the monetary base) in Germany can probably be attributed to the exchange-rate shocks.

The differences in variability across countries tell something about the magnitudes of the shocks hitting the different economies (for example, exchange-rate and production-function shocks); they also reflect different degrees of equation error in the estimated equations. Differences in the parameters in the estimated money-demand functions (and other equations) also contribute--there is no particular reason for the same feedback rule to have the same effects in different countries.

Regimes 2 and 3: Nominal *GDP* Targeting

In regime 2 monetary policy is set on a nominal *GDP* target with a feedback coefficient of 1.5. As expected, the variability of the log level of nominal *GDP* is lower than when the target is the monetary base. In the United States, the RMSD of *GDPV* falls from 0.033 to 0.024, a reduction of about 30 percent. The variability of the growth rate of *GDPV* also falls, but only from 0.021 to 0.018. In Japan the reductions are of roughly comparable magnitudes, but in Germany and ROW the nominal *GDP* regime has a stronger effect. In all countries the variability of the monetary base is significantly increased, since it is no longer a target, and in all countries except Germany the variability of nominal interest rates is also increased.

In the United States the regime has almost no effect on the variability of the <u>components</u> of nominal *GDP*, prices and real output. There is only a slight decrease in the RMSD of the growth rate of real output, from 0.02 to 0.018, whereas the RMSD of the inflation rate is unchanged. The other countries show a more pronounced reduction in price variability, although this reduction is more apparent in the price level than in the inflation rate. It is evident that stabilizing the level of a variable does not necessarily lead to a corresponding reduction in the variability of the growth rate.

The third column of table 6 shows the results for a nominal *GDP* target using a feedback coefficient of 3.0 instead of 1.5. The variability of nominal *GDP* is further reduced in all cases, and the variability of interest rates and the monetary base is further increased. There is, however, essentially no further reduction in the variability of real output and prices, either in levels or in growth rates, and in the United States and Germany the variability of real output actually increases. Further, note that the variability of the money growth rate is quite high outside the United States, with a RMSD of 0.037 in Germany and ROW and 0.062 in Japan. These figures imply quite large changes in the quarterly growth rates of the monetary base. These results suggest that the returns to stabilization efforts may diminish sharply as the degree of control over the target is tightened.

Regime 4: Inflation and Output Targeting

This regime targets monetary policy on the sum of the inflation rate and the (log) level of real *GDP*. The motivation for this variant of a nominal income target is that agents may be less concerned about the price level than about the inflation rate--that is, they ignore past inflation--while they are concerned about the level of output.

The results summarized in table 6 show that regime 4 is quite effective in reducing the variability of real output but leads to greater price variability than any of the other regimes considered so far. In the United States, for example, the RMSD of *GDP* is reduced to 0.020, and the RMSD of the *GDP* growth rate is reduced to 0.017, whereas the RMSDs of the price level (*PGNP*) and the inflation rate rise to 0.215 and 0.018 respectively. The same pattern of results appears for the other three countries, but the size and significance of the changes are much lower for Japan and ROW. The variability of interest rates and the monetary base is very high in all countries.

These results conform to the intuitive basis for the regime, with variability in the price level being much greater than variability in inflation. The regime is not "balanced" very well, however, in that the reduction in the variability of output comes at the expense of an increase in the variability of inflation (relative to the other regimes). An obvious alternative would be to raise the weight on inflation in the constructed target in order to reduce the variability of both output and inflation. We tried a limited number of replications of regime 4 after doubling the coefficient on the inflation rate, and the RMSD for inflation decreased.

Regime 5: Price Level Targeting

Regime 5 is a simple price level target, for which the same feedback coefficient (1.5) is used as for the nominal income target (regime 2). The regime is quite effective in reducing the variability of the price level (from 0.088 to 0.021 in the United States and from 0.066 to 0.020 in Germany) and also leads to some reduction in the variability of inflation. This improvement comes at the expense of much greater variability in output: in the United States, the RMSD of the growth rate of output is 0.029, and the RMSD of the level of output is 0.119.

Regime 6: Exchange Rate Targeting

Regime 6 failed to solve for any trial. Failure (that is, divergence, or in some cases violation of non-negativity constraints) typically occurred early in a given trial, often while we were solving for the first period, and in all cases by the fifth period. Numerous attempts to get modified versions of the regime to solve also failed, although we did ascertain that the source of the difficulty was the Japanese sector of the model. The model solved satisfactorily, however, when the United States and Japan targeted their monetary bases and Germany and ROW targeted their exchange rates with the dollar. The model always diverged when any country targeted the Japanese exchange rate. We conjecture that either the initial conditions for the Japanese data or the parameters of the Japanese sector are such that the algorithm cannot find a stable solution with a fixed Japanese exchange rate, even though such a solution may exist.

Conclusions

Given the limitations of this study, we hesitate to draw firm conclusions about the stabilization properties of alternative monetary policy regimes. Nevertheless we were encouraged by our finding that increasing the feedback coefficient between the target and the policy instrument tends to stabilize the target variable, albeit at the cost of destabilizing other variables. We also note that stabilizing the level of a variable is not always equivalent to stabilizing its growth rate, even though the literature on macroeconomic policy analysis often ignores this distinction.

There are several dimensions in which this research can be extended. First, the policy regimes could be made more complex, and they could incorporate the signal extraction problem faced by central banks in trying to interpret the earliest available economic indicators as noisy measures of contemporaneous activity. Second, more care should be taken in distinguishing between permanent and temporary shocks to the economy. In this paper, all shocks are assumed to be temporary, and agents are assumed to have perfect foresight of future growth in technology and labor. In reality, technology and labor are themselves stochastic processes, and shocks to these processes may have a permanent effect on the level of potential output, thus calling into question the advisability of a predetermined target for the level of output. Finally, there is evidence that the model's parameter estimates could be improved significantly by FIML estimation with well-specified monetary and fiscal policy rules in the historical period.

Appendix: An MX3 Country Bloc

This appendix presents the structure of a typical country bloc in the MX3 macroeconometric model.

Private Sector Behavior

Consumption: $$\left\{1 + b/\left[1 + \frac{\Delta}{4} + (1 - TAU_t)\frac{RS_t}{4} - \frac{DPA_{t+1}}{4}\right]\right\} C_t = b \cdot C_{t-1}$$

$$+ \left[C_{t+1} - (1 - b)\beta\left(\frac{GDEBT_t + MB_t}{PA_{t+1}}\right)\right] / \left[1 + \frac{\Delta}{4} + (1 - TAU_t)\frac{RS_t}{4} - \frac{DPA_{t+1}}{4}\right]$$

$$+ (1 - b)\beta \cdot YN_t + (1 - b)\beta\left(\frac{GDEBT_{t-1} + MB_{t-1}}{PA_t}\right) + \epsilon_{1t}.$$

Inventory investment: $II_t = e_0 + e_1\left(GDP_{t+1} - GDP_t\right) - e_3\left(RS_t - DPA_{t+1}\right) + \epsilon_{2t}.$

Fixed investment: $$(1 + c \cdot d)IF_t = c \cdot IF_{t-1} + d \cdot IF_{t+1}$$

$$+ (1 - c)(1 - d)\left[\alpha(1 - TAU_t)GDP_t/CC_t - (1 - \delta)K_{t-1}\right] + \epsilon_{3t}.$$

Contract price: $$X_t = p_0 \cdot PGNP_t + p_1 \cdot PGNP_{t+1} + p_2 \cdot PGNP_{t+2}$$

$$+ (1 - p_0 - p_1 - p_2)PGNP_{t+3} + p_3\left[p_0 \cdot \log(CU_t) + p_1 \cdot \log(CU_{t+1})\right.$$

$$\left.+ p_2 \cdot \log(CU_{t+2}) + (1 - p_0 - p_1 - p_2) \log(CU_{t+3})\right] + \epsilon_{4t}.$$

Money demand: $$\log(MB_t/PA_t) = r_0 + r_1 \cdot \log(MB_{t-1}/PA_{t-1}) + r_2 \cdot \log(A_t)$$

$$+ r_3 \cdot RS_t + \epsilon_{5t}.$$

Exchange rate: $\left(ER^1_t - ER^1_{t+1}\right) / ER^1_t = \left(RS^1_t - RS_t\right) / 4 + ERRES_t.$

Exchange risk premium: $ERRES_t = \rho_0 + \rho_1 \cdot ERRES_{t-1} + \epsilon_{6t}.$

Export volume: $$\log(XGSNI_t) = h_0 + h_1 \cdot \log(XGSNI_{t-1}) + h_2 \cdot \log(AW_t/CAPW_t)$$

$$+ h_3 \cdot \log(PXGSNI_t/PMGSNI_t) + h_4(1-h_1) \log(CAPTOT_t) + \epsilon_{7t}.$$

Export price: $\log(PXGSNI_t) = g_0 + g_1 \cdot \log(PXGSNI_{t-1}) + g_2 \cdot \log(PGNPW_t)$

$+ (1 - g_1 - g_2) \log(PGNP_t) + g_3 \cdot \log(PXGSNI_{t-1}/PXGSNI_{t-2})$

$- g_4(1 - g_1)TIME + \epsilon_{8t}$.

Export share: $X01S_t = \Psi_1 + T_{10} \cdot X01S_{t-1} + T_{12} \cdot \log\left[ER^1_t \cdot PGNP^1_t / ER^2_t \cdot PGNP^2_t\right]$

$+ T_{13} \cdot \log\left[ER^1_t \cdot PGNP^1_t / ER^3_t \cdot PGNP^3_t\right]$.

Export share: $X02S_t = \Psi_2 + T_{20} \cdot X02S_{t-1} - T_{12} \cdot \log\left[ER^1_t \cdot PGNP^1_t / ER^2_t \cdot PGNP^2_t\right]$

$+ T_{23} \cdot \log\left[ER^2_t \cdot PGNP^2_t / ER^3_t \cdot PGNP^3_t\right]$.

Export share: $X03S_t = (1 - \Psi_1 - \Psi_2) - T_{10} \cdot X01S_{t-1} - T_{20} \cdot X02S_{t-1}$

$- T_{13} \cdot \log\left[ER^1_t \cdot PGNP^1_t / ER^3_t \cdot PGNP^3_t\right] - T_{23} \cdot \log\left[ER^2_t \cdot PGNP^2_t / ER^3_t \cdot PGNP^3_t\right]$.

Government Policy

Money growth rate: $MB_t = m \cdot MB_{t-1}$.

Tax rate: $TAU_t = w \cdot TAU_{t-1} + (1 - w)TBAR_t$.

Government spending: $G_t = n \cdot G_{t-1}$.

Target debt ratio: $BRATIO_t = z$.

Identities and Definitions

Absorption: $A_t = C_t + IF_t + II_t + G_t$.

Gross domestic product: $GDP_t = A_t + EX_t - IM_t$.

Gross national product: $GNP_t = GDP_t + RS_t \cdot NFA_{t-1}/PGNP_t$.

Disposable income: $YN_t = PGNP_t \cdot GNP_t/PA_t - \delta \cdot K_{t-1} - TAX_t/PA_t$.

GNP deflator: $PGNP_t = p_0 \cdot X_t + p_1 \cdot X_{t-1} + p_2 \cdot X_{t-2} + (1 - p_0 - p_1 - p_2)X_{t-3}$.

Absorption deflator: $PA_t \cdot A_t = PGNP_t \cdot GNP_t - PXGSNI_t \cdot XGSNI_t + PMGSNI_t \cdot MGSNI_t$
$- RS_t \cdot NFA_{t-1}$.

Import volume: $MGSNI_t = X10S_t^1 \cdot XGSNI_t^1 + X20S_t^2 \cdot XGSNI_t^2 + X30S_t^3 \cdot XGSNI_t^3$.

Import price: $PMGSNI_t = \left(ER_t^1 \cdot PXGSNI_t^1 \cdot X10S_t^1 \cdot XGSNI_t^1 + ER_t^2 \cdot PXGSNI_t^2 \cdot X20S_t^2 \cdot XGSNI_t^2\right.$
$\left. + ER_t^3 \cdot PXGSNI_t^3 \cdot X30S_t^3 \cdot XGSNI_t^3\right) / MGSNI_t$.

Tax revenues: $TAX_t = TAU_t \cdot TI_t$.

Taxable income: $TI_t = PGNP_t \cdot GNP_t - \delta \cdot K_{t-1} \cdot PA_t + RS_t \cdot GDEBT_{t-1}$.

Equilibrium tax rate: $TBAR_t = \left[G_t \cdot PA_t + RS_t \cdot GDEBT_{t-1}\right.$
$\left. - 4(MB_t - MB_{t-1})\right]/TI_t - BRATIO_t + GDEBT_{t-1}/TI_t$.

Capital accumulation: $K_t - IF_t = \delta \cdot K_{t-1}$.

Government debt: $GDEBT_t = \left(1 + RS_t/4\right)GDEBT_{t-1} + \left(PA_t \cdot G_t - TAX_t\right)/4$
$- \left(MB_t - MB_{t-1}\right)$.

Net foreign assets: $NFA_t = \left(1 + RS_t/4\right)NFA_{t-1} + PXGSNI_t \cdot XGSNI_t/4$
$- PMGSNI_t \cdot MGSNI_t/4$.

Capacity output: $CAP_t = Q_t \cdot K_{t-1}^{\alpha} \cdot LF_{t-1}^{1-\alpha}$.

Capacity utilization: $CU_t = GDP_t/CAP_t$.

Cost of capital: $CC_t = (1 - TAU_t)(RR_t + \delta) + \pi$.

Inflation rate (absorption): $DPA_t = 4(PA_t - PA_{t-1})/PA_{t-1}$.

Inflation rate (GNP): $DPGNP_t = 4(PGNP_t - PGNP_{t-1})/PGNP_{t-1}$.

Exogenous Variables

Labor force: LF.

Production technology: Q.

References

Gagnon, Joseph E. 1992. "A Forward-Looking Multicountry Model for Policy Analysis: MX3." *Economic and Financial Computing* 2, forthcoming.

Lucas, Robert E. 1976. "Econometric Policy Evaluation: A Critique." *Carnegie-Rochester Conference Series on Public Policy* 1, 19-46.

Frenkel, Jacob A., Morris Goldstein, and Paul R. Masson. 1989. "Simulating the Effects of Some Simple Coordinated versus Uncoordinated Policy Rules." In Ralph C. Bryant, David A. Currie, Jacob A. Frenkel, Paul R. Masson, and Richard Portes, eds., *Macroeconomic Policies in an Interdependent World*. Washington: International Monetary Fund, Brookings Institution, and Center for Economic Policy Research.

Taylor, John B. 1989a. "The Current Account and Macroeconomic Policy: An Econometric Analysis." In Alfred E. Burger, ed., *U.S. Trade Deficit: Causes, Consequences, and Cures*. Boston: Kluwer Academic.

______. 1989b. "Policy Analysis with a Multicountry Model." In Bryant and others (1989).

Organization for Economic Cooperation and Development (OECD). 1989. *Economic Outlook*. Paris. December.

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