Fall

1986

Federal Reserve Bank
of San Francisco

Economic

Review

Number

4

Interpreting the Reagan Deficits

Thomas J. Sargent*

This paper describes two ways of rationalizing the large net-of-interest deficits experienced by the U.S. during the Reagan Administration. Both of these rationalizations imply that U.S. government expenditures are destined to fall relative to their pre-Reagan path.

Figures on government deficits are difficult to interpret because the economically relevant budget constraint is an intertemporal one. As such, it restricts the present value of a sequence of government deficits but not the size of deficits for particular years or even for long strings of years. For any observed string of government deficits, there always exists a string of prospective future surpluses that renders the budget in balance in the present value sense.

By alluding to prospects for future government surpluses, anyone can therefore assert that a record of observed deficits is consistent with maintaining sound government credit and a stable government currency. Several years of big deficits by themselves therefore fail to indicate that the entire sequence of government budgets is out of balance. This fact opens recent deficit figures for the United States to alternative interpretations, some hopeful, others foretelling doom.

* Visiting Scholar, Federal Reserve Bank of San Francisco, and Professor of Economics, University of Minnesota. I received helpful comments on an earlier draft from Randy Pozdena, Michael Keeley and Carl Walsh.

This paper tries to rationalize the large net-of-interest deficits in the federal budget of the United States that have marked the Reagan Administration. I take for granted that the recent deficits are temporary and that they foretell future government surpluses. I spend no time discussing the view that the deficits are simply a mistake, a failure of policy, or the result of shortsightedness or ignorance of the intertemporal government budget constraint. Instead I focus on alternative interpretations of recent events that are consistent with George Stigler's vision that all agents in a social system are rational and purposeful. I seek to explain the fiscal and monetary actions observed during the Reagan administration as reflecting the optimal decisions of government policymakers.

There will be one equation in the background of my discussion, one whose validity is granted by all competing theories of macroeconomics. This equation is the intertemporal government budget constraint. It states that, at any moment, the value of interest-bearing government debt is equal to the sum of two terms: the present value of future government surpluses net of interest, and the present value of future government revenues from printing currency (seignorage revenues).

Presumably, the government deficit net of interest and the revenues from currency creation are controlled by separate and independent agencies of the U.S. government. However, in a recurrent and strategic sense, independence is not feasible. Because revenues from printing currency are one component of the government budget constraint, the notion that there can be truly independent monetary and fiscal authorities is a myth.

Arithmetic makes the strategies of the monetary and fiscal authorities interdependent.[1] Classic recommendations for the conduct of monetary policy, such as Friedman's (1959) k-percent growth rule for currency or the gold standard, are well understood as coordination rules for monetary and fiscal policy. For these coordination rules to be feasible, the intertemporal government budget restraint must be respected. Throughout this paper, I will assume that a version of Friedman's k-percent coordination rule (one with a small value of k) is followed.

I seek to interpret the following observations about monetary and fiscal policy during the Reagan years: a string of large annual net-of-interest government deficits accompanied by a monetary policy stance that has been tight, especially before February 1985, and even more so before August 1982. I take as indicators of tight monetary policy high real rates of interest on U.S. government debt and pretax yields that exceed the growth rate of the economy. (Real rates of this magnitude imply that the interest-bearing government debt is growing relative to the size of the economy unless the net-of-interest government budget is in sufficient surplus.) I take for granted that the string of net-of-interest government deficits and tight monetary policies (low rates of seignorage production) cannot both continue forever, simply because they would violate the intertemporal government budget constraint.[2]

I shall describe two rationalizations of recent observations on government policy, each of which is consistent with the government budget constraint, under the hypothesis of "rational expectations" and the presumption that the government as a whole is committed to a monetary regime with low inflation rates over the long haul. The last stipulation is equivalent to an assumption that the present value of seignorage in the government budget restraint is taken for granted to be small.

I. Barro Tax Smoothing

The first rationalization is constructed by applying the optimal tax smoothing model of Robert Barro (1979). I assume that the monetary authorities are committed to supplying little or no seignorage, and that this is beyond dispute. It follows therefore that the present value of seignorage is small. Because of the government budget constraint, the net-of-interest government budget must be in surplus in present value by an amount equal to the current value of interest-bearing government debt. How can this implication be reconciled with the string of large net-of-interest deficits observed during the Reagan administration? Barro's model supplies a possible answer.

Barro's model of tax smoothing can be thought of as a reinterpretation of Milton Friedman's (1956) model of permanent income as developed by Robert E. Hall (1978).[3] The permanent income model of consumption confronts a consumer with an exogenous process for labor income and a constant real rate of return on savings. The consumer has preferences over a long horizon that can be represented as a discounted sum of a current period utility function that depends on current consumption alone. That is, preferences are additively time-separable, and the utility function is concave in current consumption.

Hall shows that for a discount factor equalling the reciprocal of the gross interest rate on assets, the marginal utility of consumption follows a random walk. To the extent that the marginal utility of consumption is approximately linear in consumption, consumption itself may approximately follow a random walk. As Hall has stressed, for any income process, no matter how unsmooth, the model predicts that consumption is approximately a random walk. This means that at every point in time, future consumption is expected to be approximately constant.

Hall's model precisely represents the consumption-smoothing idea present in Friedman's original work on the consumption function. A possibly very

unsmooth labor income process is used to support a consumption process whose future is expected at each point in time to be perfectly smooth. Borrowing and lending are used to convert an unsmooth income path into a smooth consumption path. At any time, the mean of the consumption path is set so that the present value of consumption equals the present value of labor income plus initial nonhuman assets.

Barro can be regarded as having changed the names of the variables in Hall's model and applied them to government. In place of the household budget constraint, Barro uses the government budget constraint. What was the exogenous labor income process in the Friedman model becomes an exogenous process for government purchases. What was consumption in the household budget constraint becomes total tax collections in Barro's model. What were household assets become the stock of interest-bearing government debt. The interest rate confronting the household in Hall's model becomes the interest rate at which the government can borrow and lend in Barro's model.

The intertemporal version of the re-interpreted budget constraint is precisely the intertemporal government budget constraint described above, with seignorage assumed to have a present value of zero. In place of the preference function used by Hall, Barro uses an additively time-separable loss function measuring distortions from taxing. The current period loss function is convex in total tax collections.

Barro poses the problem of a government that faces an exogenous and given stochastic process for government purchases and that chooses a tax strategy to minimize the expected discounted value of losses from tax distortions. In mathematical terms, this model is equivalent to Hall's consumption model, with the change of variables described above. It follows that the model gives the result that optimally, total tax collections should follow a random walk. That is, in the face of an unsmooth government expenditure stream, tax collections should be smoothed. In this way, distortions are allocated over time in a way to minimize the present value of the distortion.

We note that this result depends critically on the feature of the loss function that the distortion at time t is assumed to depend only on total tax collections

at t, and not on future tax collections, as would occur in a model in which private agents are speculating about future government tax collections. In Barro's model, expected future tax collections are set equal to current tax collections, with current tax collections set to satisfy the intertemporal government budget constraint.

The Barro model can be used to rationalize the observed deficits of the Reagan Administration as part of an optimal tax smoothing response to an "innovation" about the present value of government expenditures that arrived coincidentally with Reagan's election.

Assume that the election of Reagan signalled a downward revision in the size of the U.S. government, as measured by the expected present value of federal expenditures. Assume further that the path of reductions, compared to the path that could have been expected prior to Reagan, was skewed toward the future or "back-loaded". That is, the election of Reagan meant reductions in the government expenditures could be expected to take place gradually over time, with larger reductions in the future than in the present.

Given such a change in the path of expected government expenditures at the start of the Reagan administration, Barro's tax smoothing model predicts that the (optimal) response of the government would be an immediate permanent reduction of tax collections, relative to the pre-Reagan path. The consequence of these immediate reductions would be a string of deficits while expenditures remained high, to be followed by a string of net-of-interest government surpluses after the reductions in expected government expenditures had been realized.

According to this scenario, there is nothing pathological about the large deficits we have observed. Instead, they are to be interpreted as the result of optimal tax smoothing by the federal government. Note that Barro's argument implies that the Reagan Administration should have tried for a 25 percent reduction in tax rates at one shot, rather than the 5-10-10 phasing in over three years embodied in the Kemp-Roth tax legislation.

Barro's model implies that the large deficits observed pose no inflationary threat because they pose no danger of being monetized subsequently. The fact that the interest-bearing U.S. government

debt has grown under Reagan is merely a signal that the budget will swing into surplus sometime in the future, and that government expenditures are destined to fall relative to their pre-Reagan path.

The scenario described depends critically on a controversial aspect of Barro's specification of the function measuring the current loss from distortion in the government's objective function. In particular, Barro specifies that the current distortion at time t depends only on current tax collections, and is not a function of the public's expectation of future taxes set by the government. This feature is critical in giving rise to the random walk characterization of taxes, which is at the heart of our interpretation of the Reagan deficits. It is also crucial in rendering Barro's solution of the optimal tax problem time-consistent.[4]

However, in models in which there is capital, either physical or human, the current distortion from taxation at time t typically depends in part on people's expectations about future taxes. In making investment decisions, people look and respond to the government's strategy for taxing in the future. Expectations about future taxes therefore distort private decisions.[5] Such distortions would alter Barro's loss function in a way that would make it suboptimal if tax collections followed a random walk. It would also render the solution of the optimal tax problem time-inconsistent. Various administrations differing over time would therefore be unable to carry out any solution.

As it turns out, when optimal tax problems are solved for systems with physical or human capital, the optimal tax strategy usually is far from a random walk prescription. Usually high taxes are called for in the present, to be followed by lower taxes in the future. Since high taxes now are imposed on existing capital and existing capital is perfectly inelastic in supply, the taxes take on a lump sum character. As a result, such current taxes should be imposed heavily to minimize the present value of distortions. Anticipated future taxes, in contrast, do distort

investment decisions and therefore future values of capital. As a result, they should be used sparingly. The assymmetry in attitude toward current and future taxes on capital is at the heart of the time inconsistency of the solution, as well as of the suboptimality of tax smoothing.

In summary, by restricting the nature of the function that is assumed to measure the losses from the distortions that taxes impose, Barro was able to create a model calling for "tax-smoothing". By tax-smoothing, he meant that, even if government expenditures were expected to vary in the future, it would be optimal for consumers to expect taxes to remain unchanged. Applied to the current situation in the U.S. (supposing that the election of Ronald Reagan signalled that government expenditures would fall relative to their pre-Reagan path), the model rationalizes a string of deficits like the one we have experienced. Not only does the model "explain" those deficits, but it also implies that they are not signs of a "problem". Rather, the current deficits are simply a "signal" of future reductions in the path of government expenditures.

This application of Barro's model is attractive because it explains many aspects of the current situation and supports a sanguine interpretation of recent U.S. deficits. However, such an application is not beyond criticism for reasons alluded to above. In particular, the restrictions on the loss function measuring distortions in Barro's model are very strong ones. Indeed, the restrictions suppress any "supply side" effects flowing from expectations about future taxes to current decisions.

I now turn to an alternative interpretation, one due to Neil Wallace. Wallace's interpretation hinges on the observation that economic policymaking in the United States is decentralized over a variety of agencies, and that government expenditures cannot be reduced without a struggle among those agencies. Wallace's explanation makes the deficit an instrument in that struggle.

II. Wallace's Game of Chicken

Wallace's interpretation assumes that the "game" played by government policy authorities has a different structure from that assumed by Barro. In particular, Wallace has interpreted monetary and fiscal policy during the Reagan Administration as unfolding like a game of chicken among distinct branches of government with different preferences about the size of the U.S. federal government.[6] In this game of chicken, reducing the present value of government expenditures is not a given, but instead is the objective of one of the participants in the game. This objective, in turn, is actually opposed by another player. The players' weapons consist of their separate authorities to set paths for government expenditures, tax collections, and currency creation. Using Wallace's analogy, the Reagan Administration plays the game for the purpose of reducing the present value of government expenditures — an objective whose attainment Barro's explanation took for granted.

The game of chicken is played among decentralized branches of government that control separate elements of the government budget constraint. There is a tax authority, whose role I shall assign to the Reagan Administration, and whose responsibility is to select a stochastic process for tax collections. There is a government expenditure authority, here assigned to Congress, that determines the stream of government expenditures. Finally, there is a central bank (the Federal Reserve System) that determines a time stream of currency and thereby controls the present value of seignorage that appears in the government budget constraint.

While these three players, the tax authority, the expenditure authority, and the monetary authority, must coordinate their strategies because of the arithmetic of the intertemporal government budget constraint, they are not forced to do so on a day-to-day basis by any formal legal or constitutional mechanism. The coordination of monetary and fiscal policy in the United States is not governed by a set of well-understood, recurrently applied, or explicit rules. Instead, policy actions seem to emerge from a process that is decentralized across institutions (Congress, President, and Federal Reserve) and spread over time through a succession of administrations and personalities. This decentralization

opens the way to the playing of what Neil Wallace has characterized as a game of chicken.

In the game of chicken being played under the Reagan Administration, the tax and monetary authorities jointly desire a reduction in the present value of government expenditures (something they do not control) as well as a stable price level. The expenditure authority is assumed to desire a larger government in the sense of a larger expected present value of government expenditures than does the tax authority.

To achieve its objective, suppose that the tax authority plays the game as follows. It achieves a once-and-for-all reduction in tax collections that reduces the present value of tax collections relative to its initial value. The tax authority (the President) then encourages the central bank to adhere to a k-percent rule for the monetary base for the indefinite future. Such a monetary policy implies that the central bank withholds seignorage revenues from the government. Given these "plays" by the President and the Federal Reserve, the only plays open to the government expenditure authority are ones that capitulate to the President's objective and that reduce the present value of government expenditures by an amount commensurate with the reduction in the present value of tax collections. As long as the President and the Federal Reserve adhere to their strategies, the stream of government expenditures must be reduced because of the arithmetic of the government budget restraint.

Congress may, however, reason as follows. It can simply refuse to reduce the present value of government expenditures despite the tax reduction engineered by the tax authority. Then, as long as the monetary authority refuses to monetize interest-bearing government debt, the arithmetic of the government budget constraint requires that the tax authority eventually reverse itself and raise taxes by an amount that makes the present value of taxes equal to the present value of expenditures plus whatever debt has accumulated. If the monetary authority and Congress both refuse to chicken out, then the arithmetic of the budget constraint asserts that the only feasible thing for the tax authority to do is to raise taxes.

Of course, it is feasible that neither the tax

9

authority nor the expenditure authority will chicken out. In that case, the central bank would be forced to chicken out by departing from its k-percent rule and generating substantial seignorage. By monetizing the debt, the central bank would permit government expenditures to exceed tax collections in present value terms, albeit at the cost of generating inflation.

While the authorities are playing this game of chicken, we would observe large net-of-interest government deficits, low rates of monetization of government debt (low growth rates for the monetary base), and maybe also high real interest rates on government debt. The result of high real interest rates on government debt and the net-of-interest government deficit is a growing real value of the stock of interest-bearing government debt. The rising stock of this debt would be a signal that the game is not yet over, in the sense that there has been insufficient capitulation. In the U.S. today, the real stock of interest-bearing federal debt continues to grow in relation to GNP.

The game of chicken interpretation has a number of merits as an explanation of these events. While it is tempting to criticize resorting to a game of chicken as an inferior way to run a government, such criticism ignores the extensive decentralization across time and institutions that exists under U.S. government. Given the limited power assigned to the Presidency for economic policy in general and government expenditures in particular, resorting to the game of chicken may be the best method available for achieving the preference, reflected in Reagan's policies, for reducing the size of the U.S. government.

Several important macroeconomic policy events during the Reagan years bear interpretations in terms of one party or another in our game of chickening out. The Federal Reserve partly chickend out on two occasions, one in August 1982, and another at the start of 1985. Each time, the Fed was responding to outside pressures that were partly consequences of, and which in turn fed back upon, the original game of chicken.

In August 1982, the Fed substantially eased monetary policy, increasing the growth of narrow monetary aggregates and driving real interest rates downward. These actions were in large part responses to the international debt crisis that coincided with the high real interest rates associated with the game of chicken that dominated U.S. macropolicy. The Fed eased its monetary policy specifically in response to the Mexican crisis and the threat it posed for U.S. financial stability. Such concerns limit the Fed's ability to continue to play a tight monetary policy in the face of continued net-of-interest U.S. government budget deficits.

The second partial capitulation by the Fed was associated with a move starting in early 1985 to lower real interest rates in the U.S. as a device to drive down the value of the dollar. The Fed was responding to the increasing strength of protectionist pressures in the U.S. that were themselves responses to the U.S. trade deficit which was, in turn, one consequence of the string of government deficits associated with the game of chicken.

III. Conclusion

While they differ in a number of respects, our two alternative rationalizations of the Reagan deficits share the premise that, compared to the pre-Reagan path, U.S. federal expenditures are destined to fall. In Barro's model, the fall in the path of expenditures occurs exogenously, and precipitates the Reagan deficits via optimal tax smoothing. In Wallace's view, the fall in the path of federal expenditures relative to the pre-Reagan path is an outcome of (or "reward to") the game of "chicken", with an endless string of prospective budget deficits being the stick by which the President and Federal Reserve persuade a reluctant Congress to reduce federal expenditures. According to both explanations, large net-of-interest deficits are signals of prospective surpluses to be achieved via reductions in expenditure.

Each rationalization relies on the looseness of the intertemporal government budget constraint to which I referred at the beginning of the paper. A long string of large deficits is consistent with budget balance provided that sufficient surpluses occur later. We have rationalized the large Reagan deficits by appealing to the idea that they are temporary and

bound to be replaced by surpluses long before they damage the economy.

Some readers may find the entire endeavor of rationalizing the large Reagan deficits to be misplaced. Perhaps it is farfetched to rationalize deficits in the ways that we have, and better to regard them simply as reflecting shortsighted mistakes that the U.S. is bound to pay for in the future via more inflation, increased financial fragility, or higher taxes. Nevertheless, to reach the conclusion that the deficits of the last five years were mistakes, one must first understand the arguments that could rationalize them.

APPENDIX

We describe linear-quadratic versions of the models of Hall (1978) and Barro (1979). The exposition is designed to highlight parallels between the two models. For further details and implications of the models, see Sargent (1987).

Hall's Model

A representative consumer chooses a contingency plan for $(c_t)_{t=0}^{\infty}$ to maximize

(H1) $\quad E_0 \sum_{t=0}^{\infty} \beta^t u(c_t), 0 < \beta < 1$

where c_t is consumption at t, E_t is the mathematical expectation operator conditioned on information known to the consumer at t, and u is a one-period utility function given by

(H2) $\quad u(c_t) = u_0 + u_1 c_t - \dfrac{u_2}{2} c_t^2$

where $u_0, u_1, u_2 > 0$. The objective (H1) is maximized with respect to $(c_t, A_{t+1})_{t=0}^{\infty}$ subject to the sequence of budget constraints

(H3) $\quad A_{t+1} = R[A_t + y_t - c_t], t = 0, 1, \ldots$
$\qquad A_0$ given

where $R \geq 1$ is the gross rate of return on savings between periods t and t + 1, A_t is assets (indebtedness, if negative), and y_t is noncapital or labor income at t. We assume that y_t is a given stochastic process, outside the agent's control. We assume that $\beta R = 1$. We assume that (y_t) is a stochastic process that satisfies $\lim_{j \to \infty} E_t \beta^j y_{t+j} = 0$ for all t. We impose upon assets the condition

(H4) $\quad E_0 A_t \geq M > - \infty$ for all t

which rules out a strategy of larger and larger borrowing to support bliss consumption. Subject to H4, the solution of the difference equation H3 is the following intertemporal version of the budget constraint:

(H5) $\quad \sum_{j=0}^{\infty} (\dfrac{1}{R})^j E_t c_{t+j} = A_t + \sum_{j=0}^{\infty} (\dfrac{1}{R})^j E_t y_{t+j}$

Equation H5 states that the expected present value of consumption equals the expected present value of labor income plus the value of initial assets A_t.

Hall shows that a first order necessary condition associated with the problem of maximizing H1 subject to H5 is $E_t u'(c_{t+1}) = (\beta R)^{-1} u'(c_t)$. Since we have set $\beta R = 1$, this becomes $E_t u'(c_{t+1}) = u'(c_t)$. With utility given by H2, this in turn implies $E_t c_{t+1} = c_t$, so that consumption is a random walk.

Barro's Model

A government chooses a tax collection sequence $(\tau_t)_{t=0}^{\infty}$ to maximize

(B1) $\quad -E \sum_{t=0}^{\infty} \beta^t L(\tau_t), 0 < \beta < 1$

where τ_t are total tax revenues, and L is the loss function

(B2) $\quad L(\tau_t) = v_1 \tau_t + \dfrac{v_2}{2} \tau_t^2$

The maximization is carried out subject to the sequence of government budget constraints

11

(B3) $B_{t+1} = R[B_t + g_t - \tau_t]$, $t = 0, 1, \ldots$

$\quad$ B_0 given

where B_t is the initial level of government interest bearing debt, $R \geq 1$ is the gross real rate of return on government debt, and g_t is government expenditures at t. Government expenditures are taken to be an exogenous stochastic process that satisfies $\lim_{j \to \infty} \beta^j E_t g_{t+j} = 0$ for all t.

We impose the boundary condition

(B4) $B_t \leq M < +\infty$ for all t

which rules out a strategy of "never tax, always borrow more." Subject to B4, the solution of the difference equation B3 is the intertemporal government budget constraint

(B5) $E_t \sum_{j=0}^{\infty} R^{-j} \tau_{t+j} = B_t + E_t \sum_{j=0}^{\infty} R^{-j} g_{t+j}$

Equation B5 states that the expected present value of tax collections equals the sum of the current value of debt plus the expected present value of government expenditures. The government is assumed to maximize B1 subject to B5 by choosing a strategy for setting $(\tau_t)_{t=0}^{\infty}$, taking B_0 and the stochastic process for g_t as given. Assume as in Hall's model that $\beta R = 1$.

$\quad$ Mathematically, Barro's model is equivalent to Hall's. Simply replace c_t in Hall's model with τ_t in Barro's, y_t in Hall's model with g_t in Barro's, A_t in Hall's with B_t in Barro's, (u_0, u_1, u_2) in Hall's model with $(0, -v_1, v_2)$ in Barro's. It immediately follows from Hall's results that the optimal tax collection strategy in Barro's model satisfies $E_t \tau_{t+1} = \tau_t$, so that tax collections are a random walk.

FOOTNOTES

1. Sargent and Wallace (1981) describe some of the implications of the interdependence between monetary and fiscal policy.

2. This is Sargent and Wallace's unpleasant monetarist arithmetic.

3. See the Appendix for a more formal presentation and comparison of Hall's and Barro's models.

4. See Kydland and Prescott (1977) for a discussion of the time-inconsistency problem in macroeconomics. See Lucas and Stokey [1983] for a study of dynamic inconsistency in the context of an optimal tax smoothing model that shares many features with Barro's model.

5. See Sargent's (1987) chapter on dynamic optimal taxation for an extended example exploring the time-inconsistency phenomenon created by the responsiveness of investment to anticipations of future taxes.

6. Wallace advanced his ideas orally in March 1981 during discussions that later led to our co-authoring "Unpleasant Monetarist Arithmetic" (1981).

REFERENCES

Barro, Robert J. 1979, "On the Determination of the Public Debt," *Journal of Political Economy*, Vol. 87 (1979), pp. 940-951.

Friedman, Milton. *A Theory of the Consumption Function.* Princeton: Princeton University Press, 1956.

Friedman, Milton. *A Program For Monetary Stability.* New York: Fordham University Press, 1959.

Hall, Robert E. "Stochastic Implications of the Life Cycle - Permanent Income Hypothesis: Theory and Evidence," *Journal of Political Economy*, Vol. 86, No. 6 (1978).

Kydland, Finn E. and Edward C. Prescott. "Rules Rather than Discretion: The Inconsistency of Optimal Plans," *Journal of Political Economy*, Vol. 85, No. 3 (1977), pp. 473-491.

Lucas, Robert E., Jr., and Nancy Stokey. "Optimal Monetary and Fiscal Policy in an Economy Without Capital," *Journal of Monetary Economics*, Vol. 12, No. 1 (1983), pp. 55-94.

Sargent, Thomas J. *Macroeconomic Theory.* 2nd Ed. Academic Press, 1987.

Sargent, Thomas J., and Neil Wallace. "Some Unpleasant Monetarist Arithmetic," *Quarterly Review*, Federal Reserve Bank of Minneapolis, Fall 1981.

International Financial Crises, Past and Present

Hang-Sheng Cheng*

Prior to the international financial crisis in 1931, the principal barrier hindering adjustment by the international financial system to macro-economic shocks was the fixed exchange rate system under the gold exchange standard. The lack of international liquidity support also contributed to the fragility of the international financial system. In contrast, flexible exchange rates since 1973 and the international liquidity support that has developed since 1982 have helped avert an international financial crisis in the present, even though underlying problems remain unresolved.

In recent years, as less-developed countries encountered increasing difficulties in servicing their debts to international banks, serious questions have arisen on the stability of the international financial system. In 1983 and 1984, at the peak of such concerns, fears of widespread debt defaults conjured up the specter of the disaster of 1931, when a rapidly spreading international banking panic brought down the international financial system, created havoc in the world economy, and lengthened the duration and exacerbated the severity of the Great Depression. In the last two years, the international-debt situation has improved considerably and fears of an imminent cataclysm have subsided. The underlying international debt problem, however, is not resolved.

* Vice President, International Studies, Federal Reserve Bank of San Francisco. Helpful comments were received from Milton Friedman, Frederick Furlong, Robert Gemmill, Richard Herring, Charles Kindleberger, Jürg Niehans, Henry Wallich, and Carl Walsh on earlier drafts of this paper.

In the present calmer environment, it is useful to compare the 1931 experience with the developments since 1982 for insight into underlying conditions and policy responses. The comparison sheds light on the workings of the international financial system, the conditions under which it might break down and plunge into crisis, as well as the policies that might be helpful for averting or arresting crises.

This comparative historical study cannot cover the gamut of issues on the conditions and policies for ensuring international financial stability. Instead, it will focus on two subjects: cooperation for ensuring ample liquidity during times of international *financial* stress, and the role of exchange rate flexibility in the international transmission of *economic* stresses.

The article concludes that the lack of an international mechanism for providing liquidity support prior to 1931 left the international financial system virtually defenseless against systematic, pervasive world economic stresses. In addition, the gold exchange standard then prevailing significantly contributed to the international transmission of mone-

tary deflation and other economic stresses, gave impetus to destabilizing speculative capital flows, and severely constrained the ability of monetary authorities to support the financial institutions in their own countries during times of stress.

In contrast, the flexible exchange rate system since 1973 has released the major industrial nations from the constraints of the gold standard and helped them adjust to the series of large and pervasive shocks to the world economy in the 1970s and early 1980s. Moreover, since 1982, an international mechanism has been developed to provide the essential international liquidity support for containing international financial crises.

I. The 1931 Crisis

The financial crisis that swept over Europe from May to September 1931 and subsequently engulfed the whole world was unprecedented in its severity, scope, and speed with which it spread.

Calm Before the Crisis

As late as spring 1931, the international financial system appeared remarkably stable, despite the spectacular stock market crash in October 1929 and the onset of the worldwide Depression. With declining world agricultural prices, economic depression had begun in some far-flung countries and regions, such as Australia and the Dutch East Indies in late 1927, and had then spread to Brazil and Finland in 1928, Argentina and Canada in the first half of 1929, and to the United States and most of the European countries by the second half of 1929.[1] Times were hard and businesses were failing, but confidence in the soundness of the international financial system was not weakened.

There appeared to be some grounds for continued confidence. The outlying countries that first sustained large declines in export proceeds were able to counteract the resultant balance-of-payments strains through a combination of currency depreciation and domestic deflation. Few resorted to exchange controls.[2] None — except the Soviet Union, Mexico, Ecuador, and some local governments of Argentina, Brazil, and of the United States — had defaulted on their foreign bond issues.[3] International capital flows remained largely unrestricted as an active interbank deposit network provided international liquidity to national banking systems bound together on a gold exchange standard. For market participants reared on a belief in the efficacy of the gold standard adjustment mechanism, the unfolding worldwide depression was merely following the same course as had ordinary slumps of past business cycles.[4]

The surface calm, however, belied the increasing fragility of the financial structure underneath. As had the economic depression, the financial structure started to crumble first in the peripheral countries. From 1925 to 1930, bank demand deposits fell 27 percent in Australia, 16 percent in South Africa, 14 percent in Japan, 32 percent in Bolivia, 40 percent in Chile, and 25 percent in Peru.[5] In contrast, demand deposits either increased or were unchanged in virtually all the industrial countries in 1930, even while they were engulfed by the Depression. A 1934 League of Nations' study attributed this anomaly to banks' efforts to keep strapped borrowers afloat by rolling over old loans and extending new credits; the banks expected business conditions to improve in the near future. In the process, bad loans piled up and seriously reduced the solvency of these banks.[6]

The stress on banking surfaced in 1930. But only in the United States, with its unique system of an extraordinarily large number of independent banks (about 25,500 in 1929), were there widespread bank failures. Nevertheless, even in the U.S., banking conditions appeared to be quite stable until October 1930, as the total deposits of failed banks up to then were not significantly larger than during the preceding decade. In the next three months, however, a rash of bank failures, starting from the Midwest, climaxed in the failure of the $200 million Bank of United States in December. The panic, however, was shortlived and faded completely when the new year arrived.[7] Moreover, it seemed only to be a domestic financial stress with no noticeable impact on banks abroad.

In the meantime, banking conditions in Europe

began to deteriorate quickly. Central banks managed to keep the worsening situation from public view by conducting secret rescue operations of insolvent banks through acquisitions by financially stronger banks backed by large central bank subsidies.[8] The undercover operations succeeded in containing imminent banking crises — but not for long.

Spread of the Crisis

The deceptive calm ended abruptly with a massive run on the Credit Anstalt, the largest bank in Austria, in May 1931.[9] The collapse of Credit Anstalt was preceded by more than eighteen months of worsening business conditions and mounting loan losses in Austria. By the end of 1930, the net worth of Credit Anstalt neared zero without the public's knowledge. Ironically, it was the bank's publication of an international rescue plan to write off its loan losses and to replenish its capital that set off a run that quickly spread to other Austrian banks.

The central banks of major industrial countries — Britain, France, and the United States — did see in this situation a potential threat to the stability of the international financial system, but they underestimated its seriousness. It took them three weeks of acrimonious negotiations to come up with a paltry $14 million credit to the Austrian National Bank that was used up in five days. Negotiations for a second $14 million bogged down over the French government's insistence that Austria must agree to abandon a proposed customs union with Germany. After two weeks of frustration, the Bank of England unilaterally extended the credit, but it was too late to save Credit Anstalt. Bank runs and capital flights quickly spread to Hungary, Czechoslovakia, Romania, and Poland, which had special ties with banks in Austria.

In June, the panic hit Germany. The Reichsbank, the nation's central bank, lost nearly one-third of its gold and foreign exchange reserves in the first twelve days of June. When asked for help, the central banks responded with greater alacrity. In five days, a $100 million package was put together, with the central banks of Britain, France, and the United States and the Bank for International Settlements (BIS) sharing equally. Again, the magnitude of the

needed assistance was underestimated as the funds lasted less than a week.

The rest of this story almost exactly duplicates that of the Austrian episode. The Reichsbank asked for more credits; negotiations again went nowhere as the United States refused to take part if France would not share the burden, while France insisted on scrapping the customs union proposal and also demanded that full war reparation payments resume at the end of one year of moratorium; Britain, for its part, wanted to tie the granting of credit to a final resolution of the entire war debt and reparation issue that had vexed the major countries since the end of the war. In the end, nothing was resolved.

In mid-July, the closure of the nation's third largest bank, the Darmstaedter and National Bank (the Danat Bank), triggered a full-scale run on German banks. When the central bank's gold and foreign exchange reserves were nearly exhausted, Germany proclaimed a two-day bank holiday, and then imposed exchange controls that effectively sealed off the nation from the rest of the international financial system.

In mid-July, the panic spread to Britain. On the day of the Danat Bank failure in Germany, the Committee of Finance and Industry in Britain issued its report (the Macmillan Report) revealing that London's short-term claims on foreigners at the end of March had amounted to less than 40 percent of its corresponding liabilities. The fear aroused was further aggravated by large fund withdrawals by banks in Belgium, the Netherlands, Sweden, and Switzerland, which were caught in a liquidity squeeze by Germany's exchange controls. In the two weeks ending on July 29, the Bank of England lost $200 million in gold and dollars, or one-quarter of its international reserves.

Again, foreign central banks came to the rescue. Interestingly, as the banking crisis spread from Austria to Germany and then to Britain, the size of the major central banks' joint rescue package expanded rapidly: from $14 million for Austria to $100 million for Germany, and then to $250 million for Britain. The last-mentioned, announced on August 1, was shared equally by the Bank of France and the Federal Reserve Bank of New York. Again, the size proved inadequate. On Saturday, September 19, the Bank of England's remaining gold and

foreign exchange reserves exceeded its total obligations under forward exchange contracts and borrowings from foreign banks by only £5 million. The next Monday, England went off the gold standard, suspending indefinitely the Bank of England's obligation to convert sterling into gold.

The shock of sterling's downfall was felt all over the world. Unable to use their funds in London to sustain the gold convertibility of their currencies, some thirty-three countries in rapid succession left gold within a year. Only France, Germany, the United States, and South Africa remained on the gold standard. In the meantime, 27 countries imposed exchange controls, and virtually all countries raised import tariffs or imposed import quotas.[10] Annual international debt defaults rose from near zero in 1930 to $520 million in 1931 and $830 million in 1932.[11] International lending virtually ceased. Total world trade in 1933 fell to only 35 percent of its average level in 1928-29.[12] With remarkable speed, the international economy disintegrated along with the collapse of the international financial system.

Analysis

Although much has been written on the origin of the Great Depression, there has been surprisingly little systematic study on the *causes* of the financial collapse of 1931 and on the *policy actions* that were taken or not taken for dealing with the crisis. Such a study is beyond the scope of this paper, but some comments on each of these two aspects might nevertheless be useful.

Unquestionably, a major reason for the 1931 international financial crisis was the gradual but steady spread of the recession that began in outlying countries in late 1927. The prolonged and worldwide scope of the recession severely eroded banks' asset and capital positions, an erosion that could not have been avoided by any degree of banking prudence and asset diversification. Although the fragility of the international financial system should have been evident, there is little indication that either the banking community or national authorities fully understood the situation.[13]

While deteriorating economic conditions weakened financial soundness, the resulting shrinkage in finance in turn exacerbated the economic decline. In

the 1920s, long-term international lending took place largely through the national foreign bond markets, of which the American market was by far the most important. Among the borrowers, Germany was the largest, and the next five in declining order were Australia, Canada, Argentina, Japan, and India.[14] As recession spread throughout the world, foreign issues in the United States fell from $2.1 billion in the first half of 1928 to $900 million in the second half and only $450 million in the second half of 1929.[15] This abrupt decline is generally attributed to the concurrent U.S. stock market boom, which not only reduced U.S. capital outflow but also attracted large volumes of foreign capital inflow into the United States, turning the U.S. into a net importer of long-term capital by 1931. However, the deteriorating economic conditions in outlying countries, and their advance inward to the core industrial countries, undoubtedly also contributed to the sharp decline in long-term international lending.

The experience of economic contraction arising from a compounding of export decline and the international liquidity squeeze was common among many countries prior to 1931. These countries included Argentina, Australia, Brazil, Bolivia, Chile, Venezuela, Spain, and the Eastern European countries.

Australia's experience is illustrative.[16] That country had relied heavily on overdrafts at London banks to finance its foreign trade. It floated long-term bond issues to refinance short-term debts when the sums became large. In 1927, as its export prices declined, it began to pile up external debts and to feel the limits of international funding. In January 1929, an Australian issue in London was subscribed to the extent of only 16 percent. Monetary deflation in Australia then set in. By November, unemployment rose to 13 percent, and sterling had to be rationed to Australian Banks. The Australian currency began to depreciate as a market developed outside the trading banks. By March 1931, Australia's currency had fallen by 30 percent against the sterling and thus shifted the burden of adjustment to its export-competing countries.

A major cause of the gradual deterioration of the world economy in the second half of the 1920s was probably the malfunctioning of the fixed exchange

rate system and its associated international transmission of economic shocks and constraints on national macroeconomic policies. In the first place, after World War I, most nations returned to the gold standard at pre-war parities despite the high inflation that had intervened. Underpricing gold limited the supply of gold for monetary purposes, with the result of a general deflationary pall on the world economy.

Misalignment of currency created additional strains on the international economy. The overvaluation of the sterling after 1925 combined with the undervaluation of the French franc after 1926 gave rise to a large volume of speculative international capital flows that made domestic monetary management much more difficult. While payment-deficit countries, such as Britain, had to adopt restrictive monetary policies to protect their external positions, payment-surplus countries, such as France and the United States, were reluctant to pursue expansionary monetary policies for fear of inflation.

The universal deflationary bias was probably a major reason for slackening world aggregate demand. The decline in demand first hit the primary producing countries — with low elasticities both of demand and supply of their exports — and spread in time to the industrial countries.

Concern over the adequacy of gold reserves acted as a serious constraint on national authorities' choice of appropriate policies for domestic macroeconomic stabilization. Following the sterling's collapse in September 1931, there were heavy withdrawals of gold from the United States as foreign central banks attempted to use the gold reserve to defend their national currencies against speculative capital outflows. To check the gold loss, the Federal Reserve raised its discount rate from 1.5 percent to 3.5 percent in the two weeks ended October 16, 1931, and let banks' nonborrowed reserves fall from $2.1 billion in early September to $1.3 billion to the end of the year. From August 1931 to January 1932, the U.S. money stock fell at an unprecedented annual rate of 31 percent.[17]

In contrast, freed from obligations of defending fixed exchange rates after Britain went off gold in September 1931, the Bank of England was able to reverse its previous deflationary monetary policy. In

six steps over four months, it reduced its discount rate from 6 percent in February 1932 to 2 percent. Bank deposits responded by reversing a prolonged decline, and rose from £1.6 billion in February to £2.0 billion at the end of the year. Stimulated by interest rates declines — the Treasury bill rate falling from 4.94 percent in January to 0.55 percent in September — housing construction began rising in autumn and reached a level in 1933 that was 70 percent above the level two years earlier.[18]

Finally, the collapse of the international financial system in 1931 also can be attributed to the inept international actions to contain the spread of the crisis after its start. The world community was ill-prepared for the task. The only public international financial agency that existed in 1931 was the BIS, which was established only the year before to facilitate the transfer of war reparations and to promote international financial cooperation. With $100 million of capital, of which only $21 million was paid up at the end of 1931, it lacked resources of its own for coping with the crisis.[19]

As described earlier, the major central banks' joint actions to assist distressed national banking systems were indecisive, distracted by extraneous political motives, and were too little too late. Throughout the developing crisis, the heads of the central banks of Britain, France, Germany, and the United States kept in direct touch with one another through letters, telephone calls, cables, and occasional meetings. Nevertheless, they lacked adequate information on the extent of international indebtedness[20] as well as the expertise to deal with it. In addition, there was neither an explicit mandate from their respective governments nor a sense of international solidarity that would have spurred them to effective joint actions.

The international commercial banking community was equally ill-prepared for the crisis. Their stakes were high,[21] and their vast financial resources would have been essential for supplementing the limited means at central banks' disposal to stop the spreading panic. Yet, they dragged their feet in negotiating standstill agreements in the Austrian and German crises, and joined the international rescue operations for Britain only when it was too late.[22]

In 1931, there was some recognition that without

forceful adjustments in domestic economic policies, external credits alone would not be able to ward off speculative attacks on banks. The subject, however, was not broached with the Austrian Government. Negotiations for rescuing the German banks also focused only on securing financial assistance. Only in the British case was the need for economic policy adjustment made an explicit condition for obtaining credits from foreign commercial banks. Throughout August 1931, negotiations for foreign bank loans were thwarted by the foreign banks' insistence that the British government adopt a budgetary reform program for reducing its large budget deficit, and by the Labor government's refusal to cut relief payments to the unemployed at a time of severe recession. Only after a new Conservative-Liberal coalition government agreed to accept a budget cut was a foreign bank loan assured. Throughout the negotiations, there was widespread and bitter resentment by the public toward the pressure exerted by foreign bankers on British domestic economic policies.[23]

In view of the foregoing review of the macroeconomic causes of the 1931 crisis, it is doubtful that domestic policy adjustments and international financial assistance could have held the international financial system together. The fundamental problem was an international monetary order characterized by fixed exchange rates with little international policy coordination, that permitted unobstructed international transmission of economic shocks while severely constraining national macroeconomic policy choices.

Gradually, but steadily, world aggregate demand slackened and international long-term financing dwindled amid swelling international speculative capital flows. National policymakers, strapped to the gold standard, were powerless against these increasingly corrosive forces. Eventually, the world economy disintegrated, crumbling the foundation of the world financial system.

II. Experience Since 1982

The world economy seemed to slide toward another major international financial crisis in 1982. Most of the elements were there for the making of another crisis like that of 1931, and there appeared to be several striking similarities.

Similarities

The world economy suffered a severe and prolonged recession in 1980-82. Moreover, the start of the recession almost coincided with a change in the direction of monetary policy in several major industrial countries. The new policy aimed at controlling a world inflation that had raged with varying intensity in different parts of the world over the previous fifteen years. The anti-inflationary bias in these major industrial countries recalled the same policy bias that preceded and prevailed during the Great Depression. The result was unprecedentedly high real interest rates in world financial markets.

The double shock of high real interest rates and a severe, prolonged worldwide recession drastically changed the world economic environment and simultaneously eroded the debt-servicing capacity of a large number of debtor nations. As a result, individual investment risks became systematic risks for those banks that had vigorously pursued international lending as a strategy to diversify their portfolios and enhance profits. The scope of the adverse impact on international banking portfolios was reminiscent to many observers of the precarious situation faced by international banks prior to the 1931 crisis.

Also recalling the 1931 crisis was the apparent complacency with which nations regarded deteriorating economic conditions. The U.S. recession in 1980 was generally expected to be a short one — lasting perhaps one year, which was the average duration of business cycle downturns in the United States since 1945. Under this expectation, both lenders and debtors believed that the proper strategy would be to keep lending and borrowing because a world economic recovery was "just around the corner." Given optimistic expectations, lenders let the quality of their assets deteriorate, while debtor nations felt no pressure to make adjustments in economic policies that had produced large budget deficits, inflation, and over-valued currencies. In a replay of the scenario prior to 1931, it was business as usual under the common illusion that a world economic recovery would restore the debtor nations' ability to repay their debts.

The illusion was shattered abruptly in September

1982, when Mexico announced that it was no longer able to service its $86 billion external debt and needed relief from its foreign creditors. The announcement sent shock waves through the international banking system.

The world had not been aware of the high concentration of international debt in certain debtors and lenders. At the end of 1982, nearly half of the $700 billion total external debt of the less-developed countries (LDCs) was owed by eight debtor nations: Brazil, Mexico, Argentina, Korea, Venezuela, Indonesia, Chile, and the Philippines. The debt's concentration in U.S. banks' portfolios was even higher, as the same eight debtor nations accounted for seventy percent of U.S. banks' claims on the LDCs. Among U.S. banks, the nine largest accounted for one-half of the total U.S. bank lending to the LDCs at the end of 1982.[24] The fear soon became widespread that debt defaults or moratoria by only two or three of the large debtor nations could seriously damage the capital positions of the world's largest banks, in general, and those in the United States, in particular.

The 1982 Mexican debt shock was followed by a precipitous decline in international lending. From $27 billion in the first half of 1982, net international bank lending to the LDCs declined to $12 billion in the second half of that year and only $9.0 billion during the full year of 1983.[25] This sharp decline recalled the international liquidity squeeze suffered by debtor nations prior to the 1931 catastrophe, and raised the fear that it would again precipitate widespread debt defaults.

Signs of financial fragility quickly grew widespread. From an average of one a year in the late 1970s, the number of less-developed countries' bank-debt rescheduling rose to four in 1982, fourteen in 1983, and twenty in 1984; the total amount of rescheduled bank debt increased from an annual average of $0.9 billion in the late 1970s to $1.7 billion in 1982, $41 billion in 1983, and $113 billion in 1984.[26] Separately, bank failures in the United States rose from an annual average of 8 between 1977 and 1979 to 42 in 1982, 48 in 1983, and 79 in 1984. The total assets of failed banks rose from an annual average of $453 million in 1977-79 to $11.6 billion in 1982. They dropped to $7.0 billion in 1983 and $3.3 billion in 1984, but were still high by historical standards.[27]

Fundamental Differences

The collapse to which these similarities pointed has not materialized. Despite widespread anxiety over its stability, the international financial system has continued to function well four years after the Mexican shock. Debts have been rescheduled many times, but there have been no major defaults. There have been many bank failures, but none attributable to international lending as a primary cause. The numerous manifestations of financial stress, instead of growing and culminating in a crisis, have markedly lessened in recent years.

The perceived parallel between the experience of 1982 and that of 1931, even if to some extent valid, has been misleading. The international financial system and the world economy had changed in three fundamental ways since the early 1930s: industrial nations now operate under a flexible exchange rate regime; they have a mechanism for international cooperation to cope with developing crises; and they have better safeguards to ensure the stability of their banking systems.

Flexible Exchange Rates

Perhaps the most important difference between the two eras has been the international monetary setting. No longer are the world's currencies pegged to gold at fixed exchange rates as they were before 1931. The floating of exchange rates in February 1973 came none too soon as, within a year, the world experienced its first oil shock and widely divergent resulting impacts on the real income and external-payment positions of different nations.

The floating exchange rates did not insulate the oil-import nations from the shock, but they did provide them with a mechanism to adjust to the drastically altered relative-price conditions in ways that accorded with their own national aggregate demand and supply conditions. Had the nations attempted to maintain arbitrarily pegged exchange rates, many payment-deficit nations would have had to pursue deflationary macroeconomic policies to keep their currencies in line. The 1974-75 world recession would then have been much more severe and prolonged. This same analysis can be applied to the second oil shock which took place in the 1979-80 period.

Flexible exchange rates cannot completely insu-

late nations from the impacts of oil price increases. Those developing nations that were unwilling or unable to make the needed adjustments to the price increases and continued to rely on foreign borrowings to sustain their domestic spending saw their external debts rise rapidly and at higher real interest rates. In contrast, the industrial nations underwent severe recessions in the period 1974-75 and again in the period 1980-82 to contain domestic inflation and to adjust to the higher oil prices.

By the time of the Mexican debt shock, the industrial nations had about completed their adjustments and were ready to begin recovery from the 1980-82 recession. Although reducing inflation remained a primary policy objective, they also aimed macroeconomics policies at restoring stable output growth. In none of these countries was there a deflationary bias for the sake of fixed exchange rates, as there was before 1931.

Thus, a generally strong world economy provided a sound base for international banks to cope with sectoral shocks. The LDC-debt problem was a sectoral shock to international banks, just as difficulties in agriculture, construction and energy industries were sectoral shocks for domestic banks. To a varying extent, many international banks have undergone, and are still undergoing, severe stress according to the degree of their asset concentration in LDC, energy, real estate and farm loans.

However, there is an important distinction between individual bank stress and systemwide stress. Individual banks with a large proportion of their assets in problem loan areas see their capital positions seriously eroded. But because the core countries in the world economy had adjusted successfully to the shocks of the 1970s, the sectoral shocks of 1980s did not destabilize the international financial system as a whole. As a result, there have been few signs of a generalized weakening in bank capital positions, as occurred prior to 1931.

International Cooperation

Compared to 1931, international cooperation has been substantially strengthened for ensuring the stability of the international financial system. There are several facets to this development. First, in contrast to 1931, when the newly established and poorly endowed BIS was the only public international financial agency in existence, there are now a host of such agencies: the International Monetary Fund, the World Bank and its affiliates, and various regional development banks. Each has sizable financial resources to assist stranded debtor nations by providing medium- or long-term financial assistance as well as advice on policies needed for reducing payment imbalances. Among these, the pivotal role of the International Monetary Fund cannot be overemphasized.

Second, and also in contrast to 1931, the national central banks of major industrial nations and the BIS have, since 1982, acted jointly in a timely and decisive manner to provide short-term bridge credits to strapped debtor nations pending negotiations for debt rescheduling and longer term new credits from international agencies and commercial banks.

Third, the international rescue packages of the 1980s also contained an essential element missing in 1931: the cooperation of major international commercial banks. These banks were willing to reschedule debts and extend new credits to support the debtor nations' adjustment programs for reducing payment imbalances.

Fourth, since 1974, there has been an agreement among major national central banks to carry out the lender-of-last-resort responsibility in cases where banking operations involving more than one national jurisdiction are in need of assistance.[28] Since then, the central banks have kept in close contact with one another, frequently consulting one another on the international banking situation, and, as stated, undertaken successful joint actions to provide short-term bridge credits to relieve the world debt problem.

National Safeguards

Since the 1930s, national banking systems have been made more crisis-resistant by deposit insurance, government regulation and supervision, and improved availability of information on banking operations. Although these devices may have in turn created problems of their own (such as the "moral hazard" problem involving enhanced risk-taking by financial institutions because external support is available[29]), on balance, they have strengthened national banking systems and hence indirectly the international financial system.

20

III. Conclusion

An analogy with the functioning of a national economy can help bring out the lessons of past international financial crises. National economic integration binds together the various regions of a nation economically and financially through unimpeded flows of goods, services and capital. While benefits accrue to the nation through greater efficiency in resource utilization, the various regions are exposed to risks of economic and financial shocks that originate from other parts of the national economy — especially since one national currency ties the regional economies together.

This does not mean, however, that nationwide banking operations are necessarily riskier. On the contrary, since not all adverse shocks are likely to affect the various regions of the nation at the same time, national asset diversification can reduce the total risk for such banks.

One type of risk, however, cannot be diversified in this manner: credit risk related to unexpectedly prolonged and severe nationwide recessions. Under these circumstances, a general deterioration in the quality of banking assets and in banks' capital positions is hard to avoid. These risks are systematic, macroeconomic risks that individual banks cannot minimize through nationwide portfolio diversification. Nor can governments contain such risk through tighter bank supervision and higher bank capital requirements. Instead, stability in the national financial system requires national authorities to conduct macroeconomic policies to minimize macroeconomic instability and to provide liquidity support to banks when macroeconomic instability results in severe financial stress.

In the global context, international banks can reduce asset risks through international portfolio diversification. Portfolio diversification, however, is not sufficient against systematic, worldwide instability that adversely affects asset quality everywhere. The likelihood of such instability is enhanced under fixed exchange rates, which tie all national economies together like regions in one nation with one national currency — but without the benefit of a single authority to ensure worldwide macroeconomic stability.

When national authorities pursue domestic objectives with little regard to their effects on the rest of the world, stresses often develop in the international monetary system that require countries with a deficit in their international payments to restrain domestic aggregate demand but provide little incentive for countries in surplus to expand it. The resultant deflationary pressure on the world economy is exacerbated if, in addition, the center country (against whose currency other nations peg their exchange rates) itself follows a deflationary policy in order to combat inflation or to maintain an overvalued national currency. Where prices and wages are not perfectly flexible, a worldwide deflation will result and lead to worldwide declines in aggregate demand, with widespread business failures and unemployment. As economic conditions worsen, the basis of the international financial system crumbles.

This sequence of events, in essence, appears to have caused the 1931 crisis. But, the world has learned much from that disaster. Flexible exchange rates have enabled the world economy to weather several major shocks since 1973. As a result, the international financial system in 1982 was in a much sounder condition than in 1931, and thus was able to absorb major disturbances such as the Mexican-debt shock. In addition, the world community also has learned to formulate and carry out a coordinated international strategy to contain the LDC-debt problem in a timely and decisive manner. Thus far, the strategy appears to have worked with considerable success.

Nevertheless, keeping the LDC-debt problem in check does not mean the problem has been solved. A number of debtor nations continue to have difficulty servicing their external debts. Capital flights from these nations as well as the virtual cessation of voluntary international private lending have put these nations in a crushing liquidity squeeze. More recently, the precipitous decline of oil prices, while providing a welcome relief to most debtor nations, has meant a sharp setback to the debt-servicing capacity of oil exporting nations. More difficult debt negotiations can be expected to lie ahead, and innovative initiatives are needed to help resolve the international debt problem that continues to threaten the long-run stability of the international financial system.[30]

It would be short-sighted to regard the LDC-debt problem as the only threat to the stability of the present international financial system. Numerous innovations in telecommunication technology have made world capital markets more highly integrated than ever before. Also unprecedented is the domination of exchange rate changes by international capital flows. In the meantime, large international payments imbalances continue despite wide swings in exchange rates. As a result, national governments have been concerned about the volatility of exchange rates and the lack of policy coordination among major industrial countries. Uncertainty hangs over what these might mean for the stability of the world economy since flexible exchange rates cannot be a panacea against all world economic shocks.

In short, during the half-century between 1931 and 1982, the world has made significant progress in buttressing the international financial system to keep problems such as LDC debt in check. By comparing the experience of the 1930s and the current international debt situation, this study helps identify the key elements of this progress on which the solutions to future international financial problems can build.

FOOTNOTES

1. League of Nations, *World Economic Survey, 1931-32* (Geneva, 1932), chart inset between pp. 64 and 65.

2. Except Spain, Iran, and Turkey. Leland B. Yeager, *International Monetary Relations: Theory, History and Policy* (Harper and Row, 1976), pp. 338-39.

3. Ninety-eight percent of the £1.7 billion total debt defaults outstanding at the end of 1930 was attributable to the Soviet Union alone, according to the Council of the Corporation of Foreign Bondholders, *The Problem of International Investment*, a report by a Study Group of the Royal Institute of International Affairs (Oxford University Press, 1937), p. 299.

4. "Until the late spring of 1931, . . . the gold standard was still intact in Western Europe and the United States. Steadiness or slight increases in seasonally adjusted figures of industrial production in Germany and the United States even offered some hope during the first few months of the year. In Great Britain and most other countries, however, economic activity kept on sinking." Yeager, *op. cit.*, p. 339.

5. Based on data in League of Nations, *Commercial Banks, 1925-1933*, Geneva, 1934, Appendix I, pp. 48-49. For Chile and Peru, the changes were from 1926.

6. The League of Nations study cites actual cases of major banks in Berlin, Vienna, Italy, and Hungary extending large new credits to industrial concerns or on agricultural bills for the sake of assisting customers in distress. League of Nations, *op. cit.*, pp. 16-17.

7. Milton Friedman and Anna J. Schwartz, *A Monetary History of the United States, 1867-1960* (Princeton University Press, 1963), pp. 308-15.

8. The Bank of England's secret rescue of the failing William Deacon's Bank in Lancashire in 1928-30, costing the Bank of England £3.2 million, is described in R. S. Sayers, *The Bank of England, 1891-1944* (Cambridge University Press, 1976), pp. 253-59. The Bank of Italy and the Bank of England's joint rescue of the Banca Italo-Britannica of Milan in 1929-30 is discussed in Sayers, *op. cit.*, pp. 259-63.

9. The Credit-Anstalt case, the spread of international financial crisis throughout Europe, and the collapse of the international financial system are described in a large number of sources, notably, Yeager, *op. cit.*, pp. 339-49; League of Nations, *Commercial Banks, 1925-1933*, cited above; Charles P. Kindleberger, *The World in Depression, 1929-1939* (University of California Press, 1973); Stephen V.O. Clarke, *Central Bank Cooperation, 1924-31 (Federal Reserve Bank of New York, 1967)*.

10. League of Nations, *World Economic Survey, 1931-32* (Geneva, 1932), pp. 319-22.

11. *The Problem of International Investment, op. cit,* p. 325.

12. U.S. Department of Commerce, *World Economic Review, 1933* (Washington, D.C., 1934), p. 278.

13. However, not all bankers and central bankers were oblivious to the precariousness of situation. In January 1931, a U.S. investment banker told the U.S. Ambassador in Berlin that "short loans to Germany were now in such volume that they could not be called or renewals refused without great danger to the financial situation in the United States." A month later, the President of the Reichsbank sent to the U.S. Ambassador a memo detailing the weakness of Germany's short-term financial position and suggesting, among other things, a long-term loan of $350-475 million to refund Germany's short-term liabilities. The Ambassador duly passed the information and the proposal to Washington, but solicited no response. Clarke, *op. cit.,* pp. 177-78.

14. *The Problem of International Investment, op. cit.,* p. 223.

15. Lester V. Chandler, *America's Greatest Depression, 1929-41* (Harper and Row, 1970), p. 98.

16. Kindleberger, *op. cit.,* pp. 97-100.

17. Yeager, *op. cit.,* pp. 346-47.

18. Kindleberger, *op. cit.,* pp. 180-181.

19. Clarke, *op. cit.,* p. 147.

20. For instance, the Federal Reserve Bank of New York did not know the extent of the foreign liabilities of banks in Austria, Germany and Britain until these countries were in crisis. Clarke, op. cit., p. 185.

21. For instance, it was estimated that foreign commercial banks held 44 percent of the total deposits of the big Berlin banks in 1929. League of Nations, op. cit., pp. 110-111.

22. In the Austrian crisis, the three-week delay in securing the first $14 million credit to the Austrian National Bank was due mainly to the difficulty in negotiating a standstill agreement among the Credit-Anstalt's principal creditors in Berlin, London, New York, and Paris. The foreign creditors formed an Austrian Creditanstalt International Committee to negotiate with the Austrian Government. While negotiations were going on, large fund withdrawals continued. A standstill agreement was not reached until the end of August, after the Government had already instituted exchange controls, so that the agreement achieved no more than the institution of an orderly procedure for liquidating the blocked foreign balances. The German case was similar in that a standstill agreement was not reached until August 1931, also after exchange controls had already been put in place. League of Nations, op. cit., p. 58.

It appears that only in the British crisis did the large international banks agree to extend credit to a besieged foreign central bank. In that case, a $200 million loan by a group of New York banks headed by J.P. Morgan & Co. was extended to the Bank of England on August 28, 1931, and another $200 million was raised in Paris. The loans, however, proved inadequate for meeting the final assault on sterling. Clarke, op. cit., 209-213.

23. Clarke, op. cit., p. 210 and p. 263, especially note 97.

24. The LDC-debt data are from Morgan Guaranty Trust Company, World Financial Markets, February 1983, p. 5; the World Bank, World Debt Tables, 1984-85, Washington, D.C., 1985, p. ix. U.S. bank lending data are from Federal Financial Institutions Examination Council, Statistical Release E16, June 1, 1983; and Federal Reserve Chairman Paul Volcker's statement before the House Foreign Affairs Committee, August 8, 1984, Appendix Table 3.

25. Maxwell Watson, Peter Keller, and Donald Mathieson, International Capital Markets: Developments and Prospects, 1984, International Monetary Fund Occasional Paper No. 31, Washington, D.C., 1984, p. 5.

26. The World Bank, op. cit., pp. xvi-xvii.

27. Federal Deposit Insurance Corporation, Annual Report, 1984 (Washington, D.C., 1985).

28. Federal Reserve Governor Henry Wallich's testimony before the Permanent Subcommittee on Investigations, Senate Committee of Government Operations, Federal Reserve Bulletin, November 1974, pp. 760-62.

29. Michael C. Keeley and Frederick T. Furlong, "Bank Regulation and the Public Interest", Economic Review, Federal Reserve Bank of San Francisco, Spring 1986, pp. 55-71.

30. In this regard, the Baker Plan for aiding the debtor nations in making structural adjustments for improving their economic conditions is a significant step in the right direction. See Hang-Sheng Cheng, "The Baker Plan", Federal Reserve Bank of San Francisco, Weekly Letter, November 22, 1985.

Oil Prices, Exchange Rates and the U.S. Economy: An Empirical Investigation

Bharat Trehan*

In general, research on the impact of oil price shocks on the U.S. economy has assumed that oil price changes are exogenous — determined almost exclusively by the actions of OPEC. This paper uses vector autoregressions to demonstrate that the foreign exchange value of the dollar has a substantial impact on the price of oil. Thus, the practice of using changes in the dollar price of oil as a measure of the underlying supply shocks is likely to exaggerate the effects of exogenous oil price changes.

Research on the effects of oil supply shocks on the United States' economy has assumed that changes in the price of oil are exogenous, determined largely by the actions of OPEC. Significant historical episodes seem to support this assumption. For instance, oil prices approximately tripled in both 1973 and 1979 as a result of OPEC's decision to curtail the supply of oil. This assumption of exogeneity is critical, because it permits researchers to associate changes in the price of oil with shocks to its supply. Researchers can then determine the effects of a shock to the supply of oil simply by looking at the response of the economy to a change in the price of oil.

In this paper, we demonstrate that it is incorrect to treat all changes in the dollar price of oil as exogenous. More specifically, we show that the foreign exchange value of the dollar has a substantial impact on the dollar price of oil. This result has important implications. First, exclusion of the exchange rate in any study of the impact of oil supply shocks will lead to incorrect estimates of the effect of oil price changes on the economy since some of the effects of exchange rate changes will be attributed to oil price changes. Second, the existence of exchange rate effects implies that changes

---

* Economist, Federal Reserve Bank of San Francisco.

in the price of oil cannot always be associated with exogenous supply shocks but must be recognized as the result of a mix of factors. Thus, changes in the price of oil should not be used as a measure of supply shocks.

We examine these issues using a statistical technique known as vector autoregressions (VARs). This approach is "atheoretical" in the sense that it does not use economic theory to impose any restrictions upon how different variables should interact with one another. In addition, it treats all variables as determined within the system itself — a feature whose importance will be evident below. This technique is well-suited for the issues at hand because shocks to oil supply affect the economy through several channels (see the discussion in Section II). Because of the multiplicity of channels and the lack of prior knowledge about their relative importance, the more conventional technique of placing specific restrictions upon the ways that a supply shock will affect the economy is likely to distort the empirical results.

A number of previous empirical studies have examined the relationship between oil price changes and the U.S. economy using VARs but none of them take the exchange rate into account.[1] For instance, Hamilton (1983) showed that the price of oil has predictive power for real GNP, the GNP deflator, and a host of other variables, but that the oil price is

not affected by them. His results suggest that oil price changes are determined by considerations external to the U.S. economy, and that oil price increases have contributed significantly to business cycles in the U.S. in the post World War II period.[2,3] Burbidge and Harrison (1984) also present evidence supporting the view that oil prices have had a significant impact upon both industrial production and the consumer price index in the U.S.

Below, we present some empirical evidence on this issue. Section I focuses on the relationship between the exchange rate and the price of oil. It contains a discussion of why changes in the value of the dollar will have an effect on the price of oil, as well as some empirical tests of this relationship. Section II then demonstrates how the measured impact of oil price changes on the U.S. economy is sensitive to the inclusion of exchange rates. In that section, we first discuss what economic theory tells us about the impact of oil price shocks on the economy and what the historical experience has been in terms of both oil supply shocks and exchange rate changes. Empirical results follow. Section III contains the conclusions.

I. The Dollar and Oil Prices

Crude oil traded in world markets is priced in dollars. This fact has important implications for the relationship between the value of the dollar and the price of oil because oil importers who do not use the dollar as currency must, in effect, obtain dollars to purchase oil. Thus, if the value of the dollar changes, the price they pay in terms of their own currencies will change. For similar reasons, oil exporters will also not be indifferent to fluctuations in the value of the dollar.

To understand the way in which a change in the value of the dollar affects the price of oil, consider the figure below. Assume that the curve labeled D_0 represents the demand for oil by the oil importers and the curve labeled S_0 represents oil supply. The world market for oil is then at equilibrium when the price of oil is $\$P_0$ per barrel.

Now suppose that the dollar falls in value against the currencies of other oil-importing nations and against the currencies of the oil exporters. If the dollar price of oil remains unchanged, the other oil-importing countries will find that the price of oil in terms of their own currencies has declined. Consequently, their consumption of oil will go up. In terms of the diagram, the demand curve for oil will shift to the right. It is worth pointing out that this increase in demand at an unchanged dollar price occurs only because oil is priced in dollars. If oil were priced in yen, for instance, a decrease in the value of the dollar would actually lead to a decrease in the U.S. demand for oil. The demand for oil by other oil-importing countries would not be affected.

A change in the value of the dollar affects the supply of oil as well. If the dollar falls, oil exporters

The Effect of a Decline in the Value of the Dollar on the Price of Oil
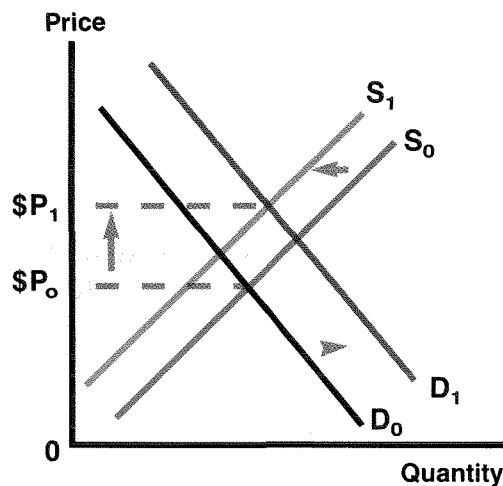
will discover that the price of oil in terms of their own currencies has declined. Consequently there will be a contraction in the quantity of oil supplied at the prevailing dollar price.[4] In the diagram above, this is shown as a leftward shift in the supply curve for oil. To equate demand and supply, the dollar price of oil will then increase from P_0 to P_1. In the same way, increases in the value of the dollar would set into motion declines in the dollar price of oil.

There are, of course, other factors that determine the price of oil. The ability of the members of OPEC to act in concert was the primary reason that oil prices approximately tripled in both 1973 and in

1979. The preceding discussion is not meant to deny a role to OPEC, but to point out a role for the dollar. For instance, it is difficult to believe that OPEC does not take the value of the dollar into account when setting the dollar price of oil.

The discussion above has shown how changes in the value of the dollar affect the price of oil. While we have not discussed what factors influence the value of the dollar itself, this should not be taken to imply that the dollar is immune to developments in the U.S. and the rest of the world. In fact, the dollar reacts to factors such as differences in the rate of inflation between the U.S. and the rest of the world, interest rate differentials, and shocks to productivity. For example, many economists contend that an important reason for the depreciation of the dollar during the two periods 1971-72 and 1978-79 was the relatively loose monetary policy being followed by the U.S. during those years.

The Empirical Relationship

We now present some empirical evidence on the relationship between the dollar and the price of oil.

We use the multilateral trade-weighted nominal exchange rate constructed by the Federal Reserve Board as our proxy for the value of the dollar.[5] This is not the precise empirical counterpart to the exchange rate in the discussion above. The exchange rate relevant to world oil demand would perhaps be one that used oil imports as weights. However, the data necessary to construct such an index is not readily available. Moreover, our results may not be very sensitive to the choice of index.[6] Consequently, the trade-weighted exchange rate is used here.

The measure of the oil price is the crude petroleum component of the producer price index. This measure is probably the most relevant to both real activity and inflation in the U.S. Both the exchange rate and the oil price measures have also been widely used in previous research on the U.S. economy.

Before examining the statistical relationship between oil prices and exchange rates, it seems useful to look at how the two variables have behaved over our sample period. Chart 1 shows the relation-

Chart 1
Quarterly Growth Rates* of the Nominal Exchange Rate of the Price of Oil

*3-quarter moving averages of the first difference of logs.

27
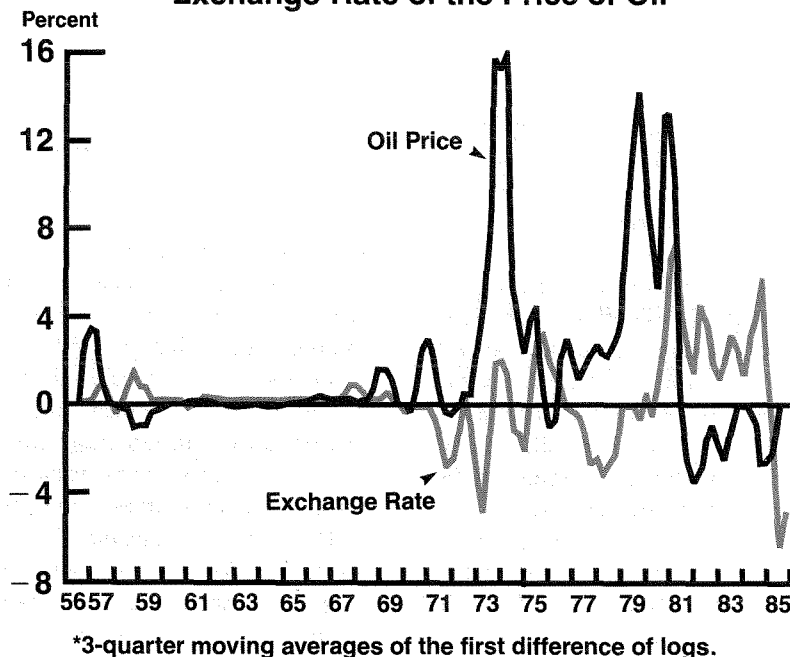
Vector Autoregressions

The techniques employed in this paper were developed by Christopher Sims to analyze interrelated variables. These techniques have been recommended as an alternative to traditional "structural" models, which restrict the relationships between different variables according to economic theory. Sims has argued that these restrictions are arbitrary because they are often imposed piecemeal and with a specific relationship in mind. As a result, structural models may sometimes distort the various interactions that exist in the data. A Vector Autoregression (VAR) imposes no restrictions on the dynamic relationships between different variables in the model, in effect allowing the data to speak for themselves.

Estimating a VAR is essentially a method of examining the relationship between a set of variables (a *vector*) and their past values (*autoregression*). Thus, estimating a two-variable VAR containing, say, the oil price and the exchange rate, involves estimating two equations: one for each variable, with each equation including past values of both variables on the right hand side. Notice that this implies that all variables in a VAR system are determined within the system. Provided certain assumptions are met, this method of estimation will lead to results with desirable statistical properties.

One issue that arises in estimation concerns the number of lags that must be included in the system. There are several tests available for determining the proper lag length, one of which is used in the text. However, alternative tests may not always provide the same answer. Data availability is sometimes an important constraint on lag selection as well, since the number of coefficients in a VAR increases rapidly as the lag length is increased. Consequently, econometricians may sometimes work with a small number of lags even if statistical tests suggest otherwise. Thus, selection of the number of lags to be included remains a subjective decision.

Statistical tests are used to check whether past values of a given variable are significant in a particular equation. For example, in the text, these tests are used to determine whether the lagged values of the exchange rate have predictive power in the oil price equation. If past values of the exchange rate are useful in predicting oil prices then the exchange rate is said to "Granger cause" the price of oil. The existence of Granger causality does not imply causation as it is commonly understood. Instead, it is possible for past values of one variable to have predictive power for another without the existence of a causal relationship.

The VARs estimated above are not easy to use in interpreting the dynamics of the system, often because of oscillating coefficients on the lags. A more useful way to study the dynamics is to examine how each variable responds to different disturbances to the system. But because the disturbance estimated from any one equation may affect several variables simultaneously, the measured disturbance cannot be treated as the disturbance to a particular variable. The researcher must choose a method to obtain disturbances that can be associated with specific variables.

The method employed in this paper is best illustrated in terms of a 3-variable VAR consisting of real GNP, the price of oil, and the GNP deflator. We first choose a particular ordering for the disturbance terms obtained from these equations. For instance, the disturbance to the oil price equation may be placed first, that to the GNP deflator second, and the disturbance to the real GNP equation last. Leaving the disturbance to the oil price equation unaltered, we then strip the disturbance to the GNP deflator equation of whatever variation it has in common with the first disturbance (that is, the oil-price disturbance). Next, we purge the third disturbance term

28

(that is, the disturbance to the real GNP equation) of the variation it has in common with the first two disturbances.

The procedure outlined is one way of imposing a specific relationship upon contemporaneous values of the different variables in the VAR. In terms of the three variables in our example, it is equivalent to the assumption that an unpredicted change in the price of oil affects both real GNP and the GNP deflator in the same quarter, but that the price of oil is not affected by contemporaneous unpredicted changes in these two variables. Unpredicted changes in the GNP deflator (which is placed second) are allowed to affect real GNP in the current quarter, but unpredicted changes in real GNP have no contemporaneous impact on the GNP deflator.

Each of these modified disturbance terms can now be treated as the unpredicted change in one of the variables in the VAR. We then study how the different variables in the system react over time to these disturbances. The variables' responses are plotted in Charts 2 through 5 with one additional modification. To make it easier to compare the effect of different disturbances on a particular variable, the size of each disturbance has been set equal to its standard deviation over the sample period. Thus, each plot shows the dynamic response of a given variable to a particular standardized disturbance, with all other variables held fixed. For example, the left hand panel of Chart 2 shows the response of the price of oil over time to an unpredicted increase in the value of the dollar.

Clearly, the ordering imposed upon the disturbances is important. Reversing the ordering will change the disturbances obtained above, and, consequently, also change the estimated responses. Generally speaking, the results will be sensitive to whatever method the researcher uses to extract the "true" from the measured disturbances: the closer the relationship between the measured disturbances, the greater the sensitivity of the results to the method employed.

The tests discussed above provide a way to measure whether lagged values of a particular variable are significant in predicting any given variable. For example, one can test whether past changes in the price of oil are significant in predicting real output. However, even if they were found to be significant, the tests do not rule out the possibility that changes in the price of oil constitute only a small proportion of the total variation in real GNP. Useful information on this issue comes from the errors that the estimated VARs make in forecasting different variables. In particular, we look at how much of the forecast error for any variable in the VAR is due to a given disturbance.

The information obtained from this exercise is succinctly described by Sims (1982):

> A natural measure of the degree to which Granger causal priority holds is the percentage of forecast error variance accounted for by a variable's own future disturbances in a multivariate linear autoregressive model. In such a system, the k-step ahead forecast error for each variable is a linear combination of forecast errors 1 through k steps ahead in the variable itself and in other variables in the system. A variable that is optimally forecast from its own lagged values will have all its forecast error variance accounted for by its own disturbances.

In general, any variable that accounts for a large percentage of the forecast error variance of another variable will be useful in predicting the latter.

Early work using VARs is contained in Sims (1980) and Sargent and Sims (1977). For a technical introduction to VARs, the reader is referred to Hakkio and Morris (1984). For a critique of the VAR approach, see Cooley and LeRoy (1985).

ship between the growth rate of the oil price and the exchange rate using quarterly data from the second quarter of 1956 to the fourth quarter of 1985. Three-quarter moving averages have been used in the chart to smooth out fluctuations.

The chart shows that the price of oil was much more stable in the fixed exchange rate period than in the floating exchange rate period. Growth rates of both the exchange rate and the price of oil were close to zero prior to 1970 but have been much more volatile since then. In addition, both periods of extended drops in the dollar (approximately the periods 1970-73 and 1977-79 in the chart) were followed by substantial increases in the price of oil — the two oil price "shocks" — while the appreciation of the dollar in the first half of the eighties has been accompanied by falling oil prices. This pattern of co-movement between these two variables is

TABLE 1A

Summary Statistics
VAR Equations for Exchange Rates and Oil Prices

(Sample Period: 1959Q2 — 1985Q4)

Equation for:	Exchange Rate	Oil Price
F-test		
Explanatory Variables[1]	F-ratio (M.S.L.)[2]	F-ratio (M.S.L.)
Exchange Rates	1.44 (.16)	4.99 (.39 E-5)
Oil Prices	1.47 (.15)	1.67 (.09)
$R^2/\bar{R}^2$	.35/.15	.58/.46
SEE[3]	.0267	.039

[1]Regressions contain 12 lags of each variable.

[2]The F-statistic is calculated for the null hypothesis that the coefficients on all the lags of the variable in question are zero. M.S.L. is the Marginal Significance Level, which is the probability of finding an F-statistic greater than the computed statistic given that the null hypothesis is true. Conventionally used M.S.L.s are .05 and .10.

[3]SEE is the standard error of the estimate.

TABLE 1B

Decomposition of Variance

Forecasting Oil Prices

Percentage of variance of error due to disturbances to:

Quarters Ahead	Oil Prices	Exchange Rates
0	100	0
5	79	21
20	58	42

Forecasting Exchange Rates

Percentage of variance of error due to disturbances to:

Quarters Ahead	Oil Prices	Exchange Rates
0	9	91
5	15	85
20	23	77

what the analysis above would suggest.

The increase in the volatility of oil prices in the floating rate era is one piece of evidence supporting our hypothesis. Stronger confirmation is provided by the fact that periods of dollar depreciation have been followed by increases in the dollar price of oil, while an appreciation of the dollar has been followed by decreases in the dollar price of oil.

Results from VARs

We now employ VARs to present some formal evidence for our hypothesis.[7] The results of the estimation are in Table 1A. They reveal that the exchange rate has predictive power for the price of oil, while the oil price is not very useful in predicting exchange rates. Approximately half of the variation in oil prices is unpredictable on the basis of past values of the exchange rate and the price of oil.

Chart 2 transforms the VARs in Table 1A and shows how exchange rates and oil prices react over time to a disturbance that could not have been predicted on the basis of their past values. The right hand panel, for instance, shows how the exchange rate reacts to a disturbance in the price of oil. One example of such a disturbance would be the Iran-Iraq war. The disturbances actually used in Chart 2 have been set equal to the standard deviation of the disturbances in each variable over the sample period. Thus, the plots represent the dynamic responses of each of the two variables to an "average" disturbance in the other variable.

The charts reveal that an unpredicted increase in the value of the dollar leads to a decline in the price of oil with a lag of approximately two quarters. The price of oil remains low for about three years after the shock, after which the response damps out. By contrast, the response of the exchange rate to a shock to the price of oil is relatively weak, although the dollar does show some evidence of appreciation.[8]

The evidence in Table 1A and Chart 2 demonstrates that changes in the dollar's value have a statistically significant impact on the dollar price of oil, and that an increase in the value of the dollar leads to a decline in the dollar price of oil. However, the results do not rule out the possibility that exchange-rate-induced changes in the price of oil constitute only a small proportion of the total varia-

Chart 2
Dynamic Responses

(Obtained from VARs in Table 1)

A. Response of Oil Price to an Increase in the Value of the Dollar

Percent

Quarters

B. Response of the Exchange Rate to an Increase in the Price of Oil

Percent

Quarters
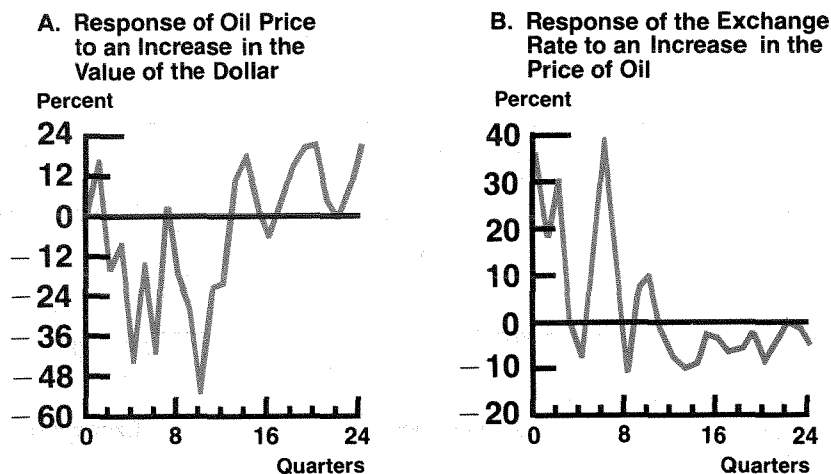
tion in the price of oil over the sample period. To examine this issue, consider the results in Table 1B. Disturbances to the exchange rate account for a progressively greater proportion of the variance of the error in forecasting the price of oil. At the twenty-quarter horizon, for instance, exchange rate disturbances account for 42 percent of the forecast error variance of oil prices.[9] These results imply that shocks to the exchange rate have been an important source of variations in the price of oil over the sample period.

Since exchange rate changes account for a substantial proportion of the changes in oil prices over the period sampled, it is natural to wonder about the role played by exchange rate changes during particular episodes within the period. More specifically, how much of the two oil price shocks of the 1970s can be predicted on the basis of past changes in exchange rates *alone*?

To answer this question, the growth rate of oil prices was regressed on past growth rates of the exchange rate.[10] Chart 3 shows the growth rate of oil

prices and the fitted values obtained from estimating the equation over 1959Q2-1985Q4. The equation tracks changes in the growth rate of oil prices reasonably well. It reveals that oil prices would have been expected to increase over the periods 1973-74 and 1978-81 on the basis of the relationship between oil prices and exchange rates alone. Needless to say, the equation does not explain the entire increase in oil prices during those periods. The equation also suggests that oil prices should have declined over the period 1981-1985.

A common criticism of exercises of this sort is that the estimated equation has simply correlated changes in the two variables. Consequently, while such an equation provides a reasonable fit over the sample period, it is not likely to perform very well in explaining events beyond the period over which it was estimated. To test this proposition, the same equation was estimated from 1959Q2 to 1978Q4, that is, up to the year before the second "oil shock".[11] The coefficients from this equation and the actual values of the exchange rate from 1979Q1

Chart 3
Actual and Fitted* Values of the Growth
Rate of the Price of Oil
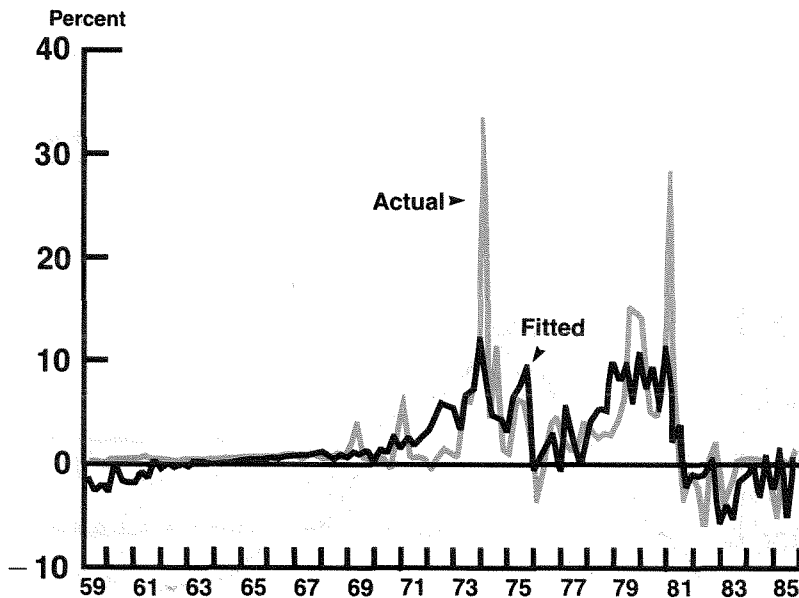
Fitted values obtained by regressing oil price on lags
of exchange rate only.
See footnote 10 for details.

onwards were used to "predict" the price of oil through the second quarter of 1986.

Chart 4A shows the results of this exercise. The equation predicts increases in the price of oil through the end of 1981, and decreases in the price of oil through the first quarter of 1986. This pattern is consistent with the actual changes in oil prices over this period, although the equation does under-predict the increases in the pre-1982 period (most noticeably in the first quarter of 1981) and predicts sharper decreases in the price of oil than actually occurred in the three years afterward. The equation

Chart 4

Actual and Predicted* Values of the Price of Oil

A. Quarterly Growth Rates

Percent

B. Levels

Level of Oil Price Index

33
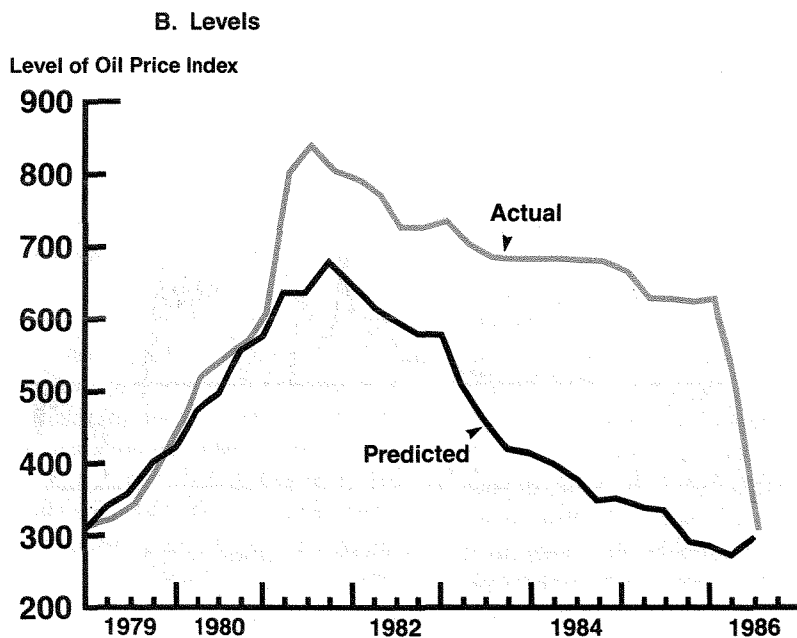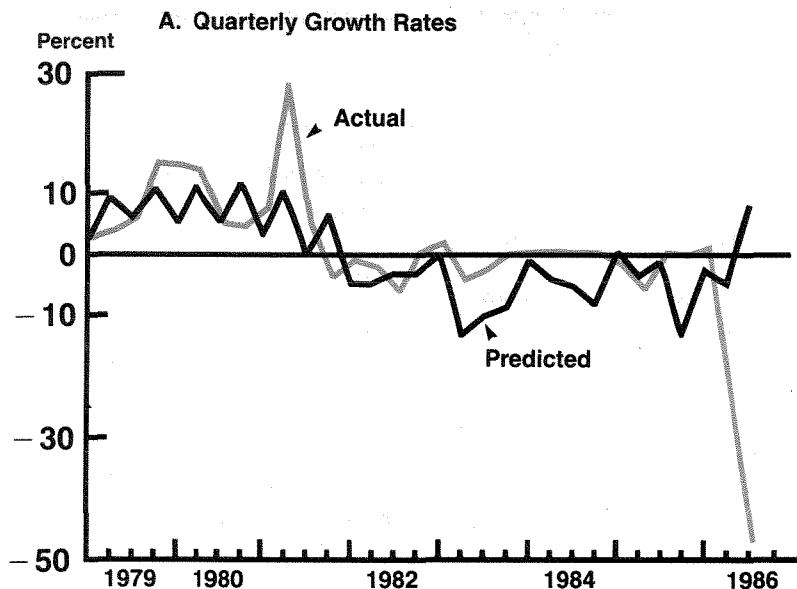
also misses the large fall in oil prices in the second quarter of 1986, when it predicts a small increase.

Chart 4B transforms these results to express them in terms of the level of oil prices. The predicted values track the actual price of oil quite closely until the fourth quarter of 1980, but miss the large increase that took place in the first quarter of 1981. It is perhaps significant that the Iran-Iraq war began in September 1980. The equation correctly predicts declining oil prices from the third quarter of 1981 onwards, but a faster pace of decline than what actually occurred. The large drop in oil prices that took place over the first half of this year actually brings oil prices back into line with those predicted by the equation.

While these results should not be interpreted to imply that the exchange rate is the only variable that matters for the price of oil, they do offer strong evidence that the exchange rate is an important determinant of oil prices. Since it is well-known that the exchange rate itself is influenced by a host of developments both in the U.S. and abroad, the results imply that oil price changes cannot always be regarded as exogenous to economic developments.

II. Oil Prices and Economic Activity

The results demonstrating that changes in the exchange rate have a substantial effect on the price of oil have, in turn, important implications for studies that attempt to estimate the impact of oil supply shocks on the U.S. economy. They imply, first, that studies that omit exchange rates will mismeasure the impact that oil supply shocks have on the economy since some of the impact of exchange rate changes will be attributed to oil price changes. Second, they imply that it is incorrect to use changes in the price of oil as a measure of the underlying supply shock because some of these price changes are caused by other factors. Thus, studies that attempt to analyze the effects of oil supply shocks must first isolate the component of oil price changes that is not due to these factors. Before proceeding to an empirical examination of these issues, we review the channels through which a shock to the supply of oil will affect the economy.

Effects of Oil Supply Shocks

Along with labor and capital, energy is an input to the production process. Oil in turn is an important component of total energy sources. An increase in the price of oil due to an OPEC shock to supply will force business firms to economize on the use of oil. Since close substitutes for oil are not readily available, this will lead to a reduction in energy input and a consequent decline in aggregate supply.

There will be other effects as well. Analysts have often likened exogenous increases in the price of oil to a tax increase for consumers that leads to a reduction in demand. An increase in the price of oil also redistributes income between the U.S. and the rest of the world because the U.S. is a net importer of oil. Within industry, profits are redistributed from oil-consuming to oil-producing firms.

The last effect reveals an aspect that is potentially important when trying to determine the net impact of oil supply shocks on economy-wide output. Just as oil consuming industries react to an exogenous increase in the price of oil by reducing output, industries involved in the production of oil will react by increasing output. They do so because the higher price of oil makes it profitable to engage in both exploration and drilling for oil in locations where it was previously unprofitable to do so. An increase in the level of activity by firms directly engaged in the production of oil leads, in turn, to increased production in industries that supply these firms with inputs. Similarly, an exogenous decrease in the price of oil will force a contraction in the output of industries involved in producing oil.

Thus, the overall effects of any exogenous change in the price of oil on real output will depend upon the relative magnitude of the effects on the oil-consuming and oil-producing sectors. While previous research has focused upon the impact of exogenous oil price changes on oil-consuming sectors of the economy, recent evidence suggests that the impact upon the oil-producing sector may be substantial as well. In particular, experience over the short period since the oil price decline in early 1986 suggests that the immediate impact on oil producers may be large enough to outweigh the impact on oil consumers.

These considerations imply that using theory alone to predict the exact response of aggregate output to an exogenous change in the supply of oil would lead to a somewhat ambiguous answer. In contrast, the effect on the price level is unambiguous. An exogenous reduction in the oil supply leads to an increase in the price of oil and in the aggregate price level. (It is this increase in the price of oil that causes domestic oil producers to increase their output.)

We have contended that the omission of exchange rates will bias the measured impact that oil price changes have on the economy. To see what the precise effects will be, it is necessary to examine what economic theory tells us about the impact of exchange rate changes on the economy. Recall, first, that the sample period of this study includes two episodes of sharp increases in the price of oil. Oil prices almost tripled in 1973 and then again over the 1979-81 period. As Chart 1 indicates, both episodes were preceded by declines in the value of the dollar. The proximity of these dollar declines suggests that omitting the effects of the exchange rate changes would exaggerate the effect of oil price shocks.

For instance, theory tells us that an increase in the value of the dollar will lead to lower inflation. A higher dollar implies that the price of U.S. imports declines and that domestic producers must lower prices on goods sold in the U.S. In addition, if domestic producers are to remain competitive in world markets, they must reduce export prices as well. Similarly, when the dollar falls, the price of imports goes up. In addition to the direct impact on the price level, a decline in the dollar's value also allows domestic producers to raise prices on products that compete with imports. For our purposes, this implies that ignoring exchange rate effects will lead one to attribute the inflation that followed the dollar's depreciation in both the early and late 1970s largely to the oil price increases.[12]

Empirical Results

We now turn to a discussion of the formal empirical tests. In Table 2, we examine whether changes in the price of oil help predict changes in real output. To isolate the role played by different variables, we present a series of VARs. The first VAR looks at the relationship between real GNP and the price of oil alone and indicates that the price of oil is extremely significant in predicting real GNP. The reverse is true as well, that is, real GNP predicts the price of oil. Similarly, in the system consisting of oil prices and the GNP deflator, both variables "cause" each other. These conclusions hold up in the three-variable system as well, although in not as strong a form. The results reported in these VARs on the effect of oil prices on both real GNP and the price level are essentially similar to what has been reported in earlier studies.

To test our major hypothesis, we added the exchange rate to the VAR. The result of this addition is that the price of oil is no longer significant at conventional statistical levels in predicting real output. This finding is consistent with our discussion above since it demonstrates that the significance of the measured impact of oil price changes on real output depends on whether exchange rates are included in the VAR. While oil prices are still significant in predicting the GNP deflator, the dynamic response functions show that their impact is considerably smaller once exchange rates are included. These results are discussed below. Table 2 also reveals that both real GNP and the exchange rate provide information about future values of the price of oil.

A problem in interpreting the results above is that the dollar is a financial asset. Since financial markets react to new information much more rapidly than goods markets, results from causality tests often show that financial market variables have considerable predictive power for other variables in the model. (See Sims, 1982, for a discussion of this issue and an example.) Thus, it is possible that the exchange rate is significant in the above equations because it is "picking up" information about the future course of events in the economy.

In Section I, we showed that changes in the value of the dollar predict a reasonable percentage of the oil price increases in both 1973 and 1979. This result suggests that the relationship between the dollar and oil prices is not due to the anticipation by asset markets of increases in the price of oil because it is generally agreed that the dollar's depreciation prior to both these episodes was due to factors such as the difference between the policy stance of the

United States and other industrialized countries.

As a formal test of whether the exchange rate is falsely significant in the above equations, we replaced the exchange rate by the Standard and Poor's 500 stock price index in the VAR. The change does not alter the significance of the oil price variable in the real GNP equation at all (that is, it remains the same as in the three-variable VAR). Nor does the stock price index predict changes in the price of oil.[13]

As a final check, the last system shown in Table 2 adds the Standard and Poor 500 stock index to the VAR that also contains the exchange rate. If the exchange rate were significant only because the dollar is a financial asset, this experiment should reduce its predictive power. Table 2 reveals that the addition of the S&P index does not materially alter the significance of the exchange rate.[14] Together, the results from these tests suggest it is unlikely that the exchange rate is significant in the VAR simply because it is acting as a proxy for developments in the financial market.

The different VARs reported above appear to represent robust results. Slope dummies were used in order to test for stability. For each variable on the right-hand side of a given equation, another variable was created that takes the value of that particular variable up to 1973Q1 and zero after that. These new variables were then included in all equations in addition to the original variables.

TABLE 2

Causality Tests — Marginal Significance Levels

(Sample Period: 1959Q2 — 1985Q4)

Dependent Variable	Explanatory Variables*				
	Oil Price	Real GNP	GNP Deflator	Exchange Rate	S&P 500
Bivariate GNP system					
Oil Price	.00002	.008			
Real GNP	.004	.51			
Bivariate Deflator system					
Oil Price	.03	—	.006		
GNP Deflator	.008	—	.00004		
3-variable system					
Oil Price	.01	.02	.02		
Real GNP	.06	.56	.61		
GNP Deflator	.005	.17	.00002		
4-variable system					
Oil Price	.10	.02	.56	.004	
Real GNP	.19	.69	.26	.06	
GNP Deflator	.0007	.33	.004	.03	
Exchange Rate	.40	.83	.79	.003	
5-variable system					
Oil Price	.07	.03	.54	.007	.18
Real GNP	.26	.94	.28	.10	.03
GNP Deflator	.002	.34	.006	.03	.81
Exchange Rate	.46	.94	.59	.003	.84
S&P 500	.12	.3	.46	.18	.04

*Four lags of each variable are included in all the equations.

If the relationships under study changed between the periods 1959Q2-1973Q1 and 1973Q2-1985Q4, then including these variables would significantly alter the pattern of unpredicted changes in the variables (such as real GNP and oil prices) whose behavior is being explained. The tests show that there is no significant difference between the two periods for either the five-variable system or the four-variable system (which contains real GNP, the GNP deflator, the exchange rate, and the oil price).

However, when the exchange rate is dropped from the VAR, the test reveals a significant difference between the two periods. A second test involving an examination of the individual equations shows that the source of this difference lies in the oil price equation. This finding implies that there is a significant difference in unpredictable oil price changes between the two periods if exchange rates are excluded from the oil price equation but not when they are included.[15]

We now examine the responses of output and the price level to an oil price shock. Chart 5 shows how the responses of both these variables change when the exchange rate is included in the system. In the left-hand panel, we show that the effect of an increase in the price of oil on the GNP deflator becomes noticeably smaller once the exchange rate is included in the VAR. In particular, including the exchange rate reduces both the magnitude of the initial impact and the duration of the effect. The response of real GNP to an oil price shock changes in a similar manner. That is, including the exchange rate in the VAR reduces both the size as well as the duration of the real GNP response to an oil price shock. (Notice also that in the system excluding the exchange rate, an oil price shock leads to a contemporaneous increase in real GNP. This anomaly is removed when the exchange rate is added to the system.)

It is interesting to examine the implications of these results for specific episodes such as the 1973-1975 period of oil price increases. Using two of the VARs shown in Table 2, we examine the impact on real GNP.

Chart 6A shows the forecasts we would have made using the three-variable system containing real GNP, the GNP deflator, and the price of oil with the model used to generate these forecasts estimated

Chart 5
Dynamic Effects of an Increase in the Price of Oil
(Obtained from VARs in Table 2)

A. Response of the GNP Deflator

Percent Change

B. Response of Real GNP

Percent Change
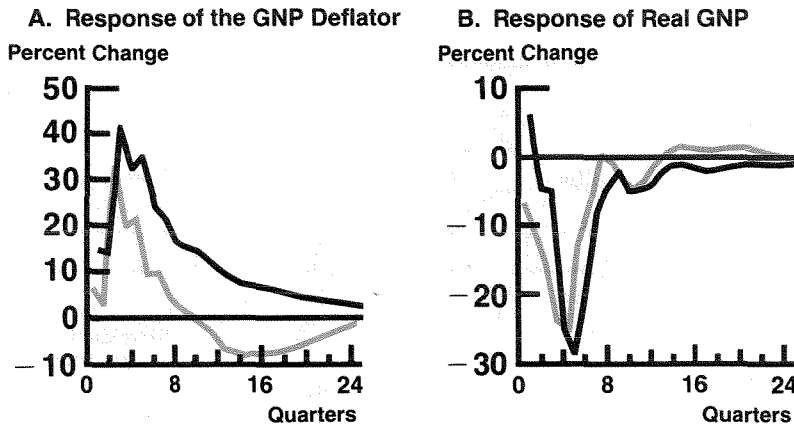
Chart 6
Actual and Forecast Real GNP Growth*

Growth Rate* (Percent)

A. Forecasts From the Three-Variable VAR

Pure Forecast

Pure Forecast
Plus Oil

Actual

Q1 2 3 4 1 2 3 4 1 2 3 4
1973 1974 1975

Growth Rate* (Percent)

B. Forecasts From Four-Variable VAR

Pure Forecast and
Exchange Rate

Actual

Pure Forecast
Plus Oil

Pure Forecast
Plus Oil From
Chart Above

Q1 2 3 4 1 2 3 4 1 2 3 4
1973 1974 1975
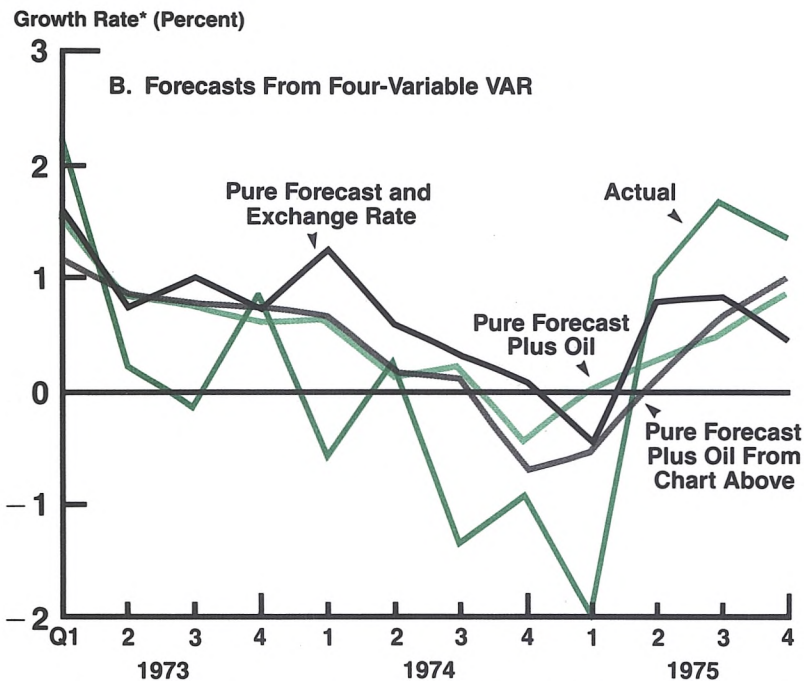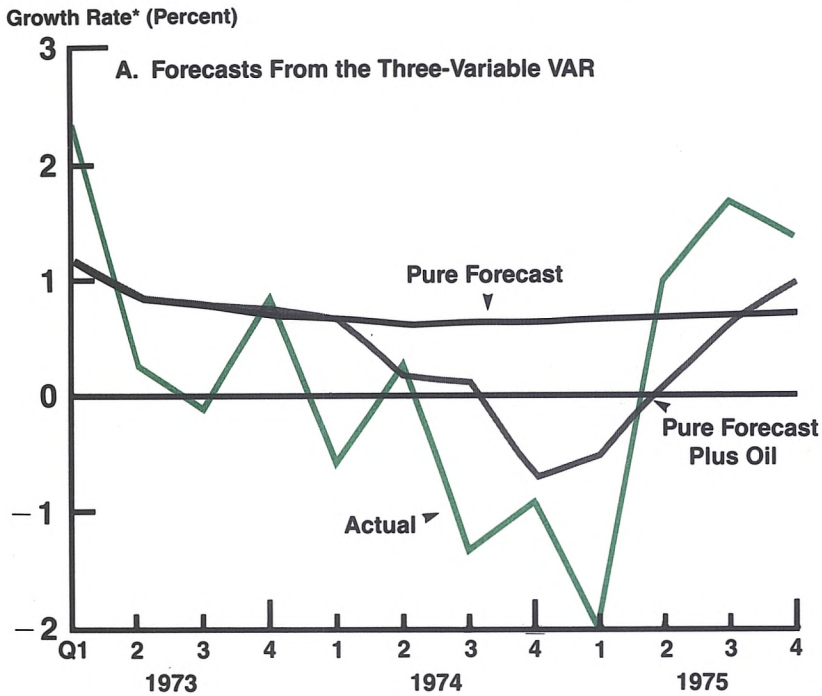
*Growth Rates are measured quarter over quarter.

38

using data up to 1985Q4. The line labeled "Pure Forecast" is the real GNP we would have predicted before any data for 1973 became available. The line labeled "Pure Forecast Plus Oil" adds the effects of the oil price shocks. We see that including the oil price shocks improves the forecast, most noticeably during the fourth quarter of 1974 and the first quarter of 1975 when real GNP was contracting.

Chart 6B shows the results from a similar exercise using the four-variable system consisting of real GNP, the GNP deflator, the price of oil, and the exchange rate. The line labeled "Pure Forecast Plus Oil" shows what we would have predicted at the end of 1972 had we known the behavior of oil prices over the next two years. The continuous line is reproduced from Chart 6A for comparison. Comparing the two lines reveals that the effect of the oil price shock on real GNP growth is smaller in the four-variable system, most noticeably in the first quarter of 1975. The smaller impact is due to unpredictable exchange rate changes, captured in the line labeled "Pure Forecast Plus Exchange Rate." This outcome supports our contention that

omitting the exchange rate will cause the effect of exchange rate changes to be attributed to changes in the price of oil.

To obtain an idea of how much of the total variation in both real GNP and the price level over the entire sample period is due to oil price shocks, consider the results shown in Tables 3 and 4. Table 3 shows the results for real GNP. Once again, we first consider a system consisting of only real GNP and the price of oil and successively add the GNP deflator and the exchange rate.

While disturbances to the price of oil have a relatively large impact on real GNP when only these two variables are included in the VAR, the addition of other variables noticeably reduces their explanatory power. The results for the GNP deflator in Table 4 tell a similar story. Oil price disturbances do account for a relatively large percentage of the variance of the error made in predicting the GNP deflator in the first two systems. However, adding the exchange rate lowers their relative importance.

The results reported here maximize the role played by oil price shocks because only oil price

TABLE 3

Variance Decompositions — Forecasting Real GNP

(Sample Period: 1959Q2 — 1985Q4)

Percentage of variance of error due to:

	Quarters Ahead	Explanatory Variables*			
		Oil Price	GNP Deflator	Real GNP	Exchange Rate
2-variable system	0	0	—	100	—
	5	18	—	82	—
	20	19	—	81	—
3-variable system	0	0	1	99	—
	5	15	4	81	—
	20	15	7	77	—
4-variable system	0	0	0	99	0
	5	12	4	77	7
	20	11	5	65	20

*Variables are arranged according to their ordering in the VARs.

TABLE 4

Variance Decompositions — Forecasting the GNP Deflator

(Sample Period: 1959Q2 — 1985Q4)

Percentage of variance of error due to:

	Quarters Ahead	Explanatory Variables*			
		Oil Price	GNP Deflator	Real GNP	Exchange Rate
2-variable system	0	3	97	—	—
	5	26	74	—	—
	20	31	69	—	—
3-variable system	0	2	98	0	—
	5	24	72	4	—
	20	24	68	8	—
4-variable system	0	1	99	0	0
	5	11	58	1	29
	20	8	38	1	52

*Variables are arranged according to their ordering in the VARs.

shocks are allowed to affect everything else in the VAR contemporaneously. Removing the restriction on other variables noticeably reduces the response of both real GNP and the deflator to oil price shocks, especially when the exchange rate is included in the VAR. The effects of an oil price shock are also susceptible to an increase in the lag length used in the VAR. For instance, an increase in the number of lags in the VAR from 4 to 8 causes the real GNP response to an oil price shock to become even

smaller (while the real GNP response to an exchange rate shock becomes somewhat larger).[16]

Finally, while the results are not shown, disturbances to the exchange rate account for a relatively large proportion of the variance of the oil price forecast error in the larger systems as well. For example, in the four-variable system, the percentage of the oil price forecast error variance due to exchange rate disturbances is 38 at the ten-quarter horizon and 40 at the twenty-quarter horizon.[17]

III. Interpretation and Conclusions

The empirical results in Section I above demonstrate that changes in the value of the dollar have a substantial impact upon the dollar price of oil. However, we must emphasize that the estimated equations do not explain all the variation in oil prices over the period studied. The results do not imply that OPEC was unable to increase oil prices above what they otherwise would have been. They do suggest that the dollar price of oil would have risen in the 1970s as the dollar depreciated and would have fallen in the 1980s as the dollar appreciated even without the existence of OPEC. This contradicts the common view that changes in the price of oil are generally exogenous. Such a view may have resulted from an excessive focus on the role of OPEC in setting oil prices and the belief that OPEC's decisions are made independently of economic developments.

The analysis suggests that a considerable proportion of the changes in the price of oil during the so-called oil price shocks were simply discontinuous price adjustments to changes in the economic environment. This discontinuity is probably the result of the cartel's mode of operation, which has been one of making large adjustments in output while adhering to a pre-announced dollar price.

Of particular interest in this context was the steep fall in oil prices in early 1986. While disagreements within the cartel were the proximate cause of the large decline in prices, it is likely that the appreciation of the dollar until early 1985 played an important part. The appreciating dollar tended to reduce non-U.S. demand for oil while increasing supply from countries other than OPEC. Since OPEC was trying to maintain a constant dollar price of oil, it was forced to make large reductions in output. Disagreements about how these reductions in output were to be allocated led to a collapse in OPEC's agreements. In all likelihood, the output reductions forced upon the cartel would have been smaller in the absence of the dollar's appreciation.

Viewed differently, the evidence (especially Chart 4) suggests that, during the early 1980s, the cartel succeeded in keeping prices above what the historical relationship between exchange rates and oil prices would suggest. However, pressures that arose from doing so led to a breakdown of the cartel. The large oil price decline in early 1986 then brought prices back to more "normal" levels.

While our analysis ignores other factors that may affect the price of oil, our interpretation is consistent with the behavior of other commodity prices. In general, commodity prices have been declining since the dollar began to appreciate. Were it not for the cartel, oil prices probably would have declined significantly more prior to 1986.

The relationship between oil prices and the value of the dollar is the basis for questioning studies that purportedly measure the impact of oil price shocks on the economy while ignoring either the impact of the exchange rate on the price of oil or the impact of the exchange rate on the economy. In Section II, we demonstrated that once the exchange rate is taken into account, changes in the price of oil no longer have a significant impact on real GNP. An examination of the 1973 "oil shock" episode also reveals that omitting the exchange rate exaggerates the contraction in real GNP following the oil price increase. Furthermore, the results in Table 3 suggest that output variations induced by oil price changes have not constituted a large proportion of the total variation in real output over the sample period as a whole. Taken together, this evidence suggests that the large decline in oil prices in the beginning of 1986 is not likely to provide as big a boost to real GNP as would be predicted on the basis of previous studies.

Finally, the results in Section II also show that inclusion of the exchange rate in the VAR reduces the impact of changes in the oil price on the GNP deflator. Most noticeable is the reduction in the length of time for which oil price changes continue to have an effect on the price level. Apparently, the effect of oil price changes is concentrated in the first few quarters following an oil price shock. This finding reinforces our point that omitting the exchange rate causes the oil price variable to pick up the inflation that may actually have been due to the dollar's depreciation.

FOOTNOTES

1. Structural models that take the exchange rate into account when studying the effects of oil shocks on the economy assume that the price of oil is determined exogenously (which is halfway between including and excluding exchange rates in the corresponding VAR). An exception is Hooper and Lowrey (1979), which studies the impact of exchange rate changes under two alternative assumptions: first, that exchange rate changes have no impact on the price of oil, and second, that half of the oil price increase in 1979 was due to the fall in the value of the dollar.

2. In view of the results to follow, it is interesting that he found that the price of imports (which reflects the value of the dollar) had a significant impact on the price of oil and yet dismissed the finding as inconsequential.

3. Gisser and Goodwin (1986) build upon the "exogeneity" results of Hamilton, and use the price of oil in a reduced form, St. Louis-type equation to show that the price of oil affects output, inflation, etc.

4. Oil exporters will be indifferent to changes in the value of the dollar only if the entire proceeds from the sale of oil are used to purchase dollar-denominated products — a condition that is hardly likely to be satisfied in practice.

5. An exchange rate index for the dollar measures the value of the dollar against a weighted average of a basket of currencies. A multilateral trade-weighted index uses the ratio of a country's total trade (exports plus imports) to the total trade of all countries in the basket as weights.

6. It appears that alternative dollar indices will move together as long as changes in these indices originate from changes in the value of the dollar. However, the indices will move differently if non-dollar currency realignments tend to be larger or more common. For our purposes, it is probably sufficient that the dollar depreciation during the early, as well as late 1970s, was not accompanied by large changes in the value of nondollar currencies against each other.

See Brown and Phillips (1986) for a study that uses oil consumption weights to construct an index for the dollar. They show that an increase in the value of the dollar leads to a decline in the dollar price of Saudi Arabian oil.

7. Sample size and data frequency were dictated by the availability of exchange rate data. Data on the Federal Reserve Board's trade-weighted exchange rate is available in quarterly average form starting in 1956.

All variables are included as the first difference of logs. All VARs include a constant and a time trend. Lag lengths were chosen as follows. I started with a specification of 12 lags. A likelihood ratio test was then used to compare this with lag lengths of 4, 8 and 16 lags. (The test used is discussed in Sims 1980, and includes a correction for the number of explanatory variables in each equation.) For the VAR containing the price of oil and the exchange rate, the tests reveal that the 12-lag specification is different from the 4- and 8-lag specifications at the 1 percent level, but is no different from the 16-lag specification. The lag of 12 quarters implies that estimation begins from 1959Q2. To keep the results comparable, all other VARs are estimated over the same period, even though each of them contains only four lags of each variable.

8. The moving average representations and the variance decompositions shown here — and in the rest of the paper — have all been obtained by placing oil prices first and exchange rates last in the ordering imposed upon the error terms. In other words, it is assumed that any shock common to oil prices and other variables in the VAR is due entirely to a change in oil prices. This ordering will, in general, maximize the role played by oil price shocks and minimize that of exchange rate shocks.

9. Placing exchange rates first in the ordering substantially increases the effect of exchange rate disturbances. Exchange rate shocks account for 33 percent of the forecast error variance of oil prices at the 5-quarter horizon, 51 percent at the 10-quarter horizon, and 54 percent at the 20-quarter horizon. The effect of oil price shocks becomes correspondingly and noticeably smaller. Oil prices shocks account for 5 percent of the forecast error variance of exchange rates at the 5-quarter horizon, 11 percent at the 10-quarter horizon, and 11 percent at the 20-quarter horizon.

10. The first difference of the log of the price of oil is regressed on 12 lags of the first difference of the log of the exchange rate. The equation also contains a constant and a time trend. The R^2 for the equation is .48, the adjusted R^2 is .41. The Standard Error is .041, and the Durbin-Watson statistic is 1.66.

11. The R^2 from this exercise is .47, the adjusted R^2 is .37. The Standard Error of the equation is .034 and the D.W. statistic is 1.86.

12. Theory also tells us that a fall in the value of the dollar will lead to an increase in output. However, the empirical results indicate that this increase is only temporary and that it is followed by a contraction in real output.

While this result is counterintuitive, it has been reported by other researchers as well. Simulations with the Board of Governors MPS model suggest that a fall in the value of the dollar first raises real output but then reduces it, so that two years later, the level of real GNP is below its initial level. An important assumption in their simulation is that monetary policy remains unchanged. In our analysis, the results are not significantly altered when the money supply is included in the VAR.

13. When the S&P 500 is included (and the exchange rate dropped from the VAR), the oil price has a marginal significance level (M.S.L.) of .06 in the real GNP equation, which is the same as when the VAR contains only real GNP, the real GNP deflator, and the price of oil. The S&P 500 has a M.S.L. of .11 in the oil price equation, .81 in the GNP deflator equation, and .02 in the real GNP equation. In the variance decompositions, the S&P 500 accounts for no more than (a) 7 percent of the forecast error variance of the oil price; (b) 4 percent of the forecast error variance of the GNP deflator, and (c) 10 percent of the variance of real GNP, at forecast horizons up to 20 quarters.

14. The variance decompositions reveal that the share of forecast error variances explained by the S&P 500 is no more than 4 percent for oil prices, 4 percent for the GNP deflator, and 9 percent for real GNP at any forecast horizon. Inclusion of either the 10-year or the 20-year Treasury bond rate also does not alter the significance levels of the

exchange rate in the VAR, although the long rates do explain a considerable proportion of the GNP deflator's forecast error variance. Finally, the nature of the results is unaffected by the inclusion of M1 in the VAR.

15. For the system stability tests, a likelihood ratio test, discussed in Sims (1980), was used. F-tests were carried out on the individual equations. For the 5-variable system in Table 2, the Chi-square statistic — calculated under the null hypothesis of no change between the two periods — had a marginal significance level of .85. For the 4-variable system, the computed Chi-square has a marginal significance level of .41. Finally, for the 3-variable system, the test statistic has a marginal significance level of .02. In this system, the oil price equation has a $F_{(12,81)}$ statistic of 2.5, which is significant at 5 percent.

16. The effect of increasing the lag length is especially noticeable in an examination of the 1973 "oil shock" episode. While the impact of the change in oil prices in the 3-variable VAR is more or less the same in both the 4 and 8 lag versions, it becomes much smaller once the exchange rate is included. Specifically, knowledge of the oil price shocks does not appear to be useful in "predicting" much of the decline in real GNP over 1974Q3-1975Q1.

17. To test the robustness of this result with respect to other output and inflation measures, a system containing industrial production and the producer price index was also estimated. While the oil price is significant at less than one percent in the industrial production equation when only oil prices and industrial production are included, its marginal significance level increases to .76 when both the producer price index and the exchange rate are added to the system.

In the variance decompositions, the oil price variable accounts for a maximum of 6 percent of the forecast error variance of industrial production even when it is placed first (in a four-variable VAR which included the exchange rate). With oil prices placed last, this number falls to 4 percent. In the same system, oil prices (when placed first) account for 13 percent of the variance of the error in predicting producer prices in the contemporaneous quarter. This falls to 8 percent at the ten-quarter horizon. When oil prices are placed last, they account for more than 5 percent of the forecast error variance of the PPI only once.

REFERENCES

Brayton, F. and E. Mauskopf. "The MPS Model of the United States Economy." Board of Governors of the Federal Reserve System, February 1985.

Brown, S.P.A. and K.R. Phillips. "Exchange Rates and World Oil Prices," *Economic Review*. Federal Reserve Bank of Dallas, March 1986.

Burbidge, J. and A. Harrison. "Testing for the Effects of Oil-Price Rises Using Vector Autoregressions," *International Economic Review*, June 1984, pp. 459-484.

Cooley, T.F. and S.F. LeRoy. "Atheoretical Macroeconometrics: A Critique," *Journal of Monetary Economics*, November 1985, pp. 283-308.

Gisser, M. and T.H. Goodwin. "Crude Oil and the Macroeconomy: Tests of Some Popular Notions," *Journal of Money, Credit and Banking*, February 1986, pp. 95-103.

Hamilton, J.D. "Oil and the Macroeconomy Since World War II," *Journal of Political Economy*, April 1983, pp. 228-48.

Hooper, P. and B.R. Lowrey. "Impact of the Dollar Depreciation on the U.S. Price Level: An Analytical Survey of Empirical Estimates," Staff Studies 103. Washington: Board of Governors of the Federal Reserve System, 1979.

Sargent, T.J. and C.A. Sims. "Business Cycle Modeling Without Pretending to Have Too Much A Priori Theory," in C.A. Sims, ed., New Methods of Business Cycle Research: Proceedings from a Conference, Federal Reserve Bank of Minneapolis 1977.

Sims, C.A. "Econometrics and Reality," *Econometrica*, 1980, pp. 1-48.

Sims, C.A. "Policy Analysis With Econometric Models," Brookings Papers on Economic Activity, 1:1982.

Real Exchange Rates, Imperfect Information, and Economic Disturbances

Reuven Glick*

This paper provides theoretical and empirical explanations for short-term fluctuations in the real value of the dollar. It formulates a model in which the imperfect information of economic agents about disturbances causes the real exchange rate to respond to monetary as well as real shocks. Empirical evidence from vector autoregressions support the hypothesis that increases in the U.S. money supply induce declines in the real value of the dollar, while increases in real demand in the U.S. generate rises in the dollar's value. Foreign disturbances were also found in some instances to influence the value of the dollar.

Since 1973 the relative values of the currencies of major industrial countries have been determined primarily by free-market forces in a floating exchange rate system. Fluctuations in nominal exchange rates over this period have been substantial. Real exchange rates — nominal exchange rates adjusted for differences in national price levels — have been almost as volatile, since nominal exchange rate movements have exceeded those of national price levels.[1]

The chart graphs an index of the real dollar value of the yen and German mark, defined as the dollar "value" of the foreign wholesale price index divided by the U.S. wholesale price index. A rise in this index represents an increase in the dollar price of foreign goods relative to the price of U.S. goods and hence a real dollar depreciation. The chart shows substantial fluctuations of the dollar in real terms over the entire floating rate period.

Variation in underlying economic conditions has undoubtedly contributed directly to exchange rate fluctuations. Indeed, the floating exchange rate period has been characterized by frequent and varied economic disturbances. In the 1970s, when

nations were first freed from the constraint of pegging exchange rates by coordinating their monetary policies, great variations in money supply growth emerged. Oil-related price shocks also occurred in that decade. In the 1980s, differences in real aggregate demand among countries, in part related to differences in fiscal policy stimuli, have been apparent.

This paper seeks to explain movements in real exchange rates in terms of these underlying determinants. In particular, it provides both a theoretical and empirical analysis of the role of monetary and real disturbances in explaining the direction and magnitude of exchange rate changes. Real exchange rate fluctuations, because of their implications for the international competitiveness of countries, have important resource and output effects. A real dollar appreciation, for example, raises the relative international cost of U.S. goods and thereby dampens the demand for U.S. output. Understanding the magnitude and origin of causes of real exchange rate changes is thus important for formulating effective policies to reduce exchange rate variability.

Section I contains the formulation of a model of real exchange rate determination based on the assumption that economic agents possess imperfect information about disturbances such as changes in money supply growth or in real demand and supply

conditions.[2] The resulting confusion among agents about the relative magnitudes of monetary and real disturbances implies that the real exchange rate will be influenced by monetary as well as real disturbances. The model provides indications of both the direction and magnitude of response of the real exchange rate to such disturbances.[3]

Section II examines several hypotheses suggested by the theoretical framework using the technique of vector autoregressions. Real depreciations of the dollar are found to be associated with U.S. money supply increases, and appreciations of the dollar with fluctuations in expansionary U.S. real demand. The section also provides estimates of the relative amounts of exchange rate variability that can be attributed to various disturbances. Conclusions are presented in the final section.

Real Dollar Value of Foreign Exchange
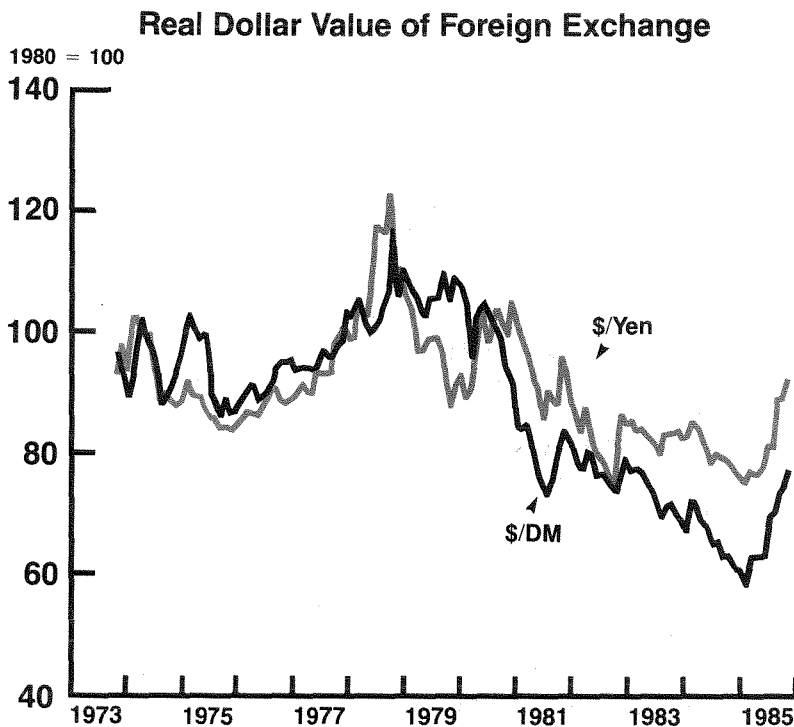
Note: An increase in the real $/Yen(deutschemark) rate represents a decrease in the real value of the dollar in terms of the yen(mark).

I. A Model of Exchange Rates and Disturbances

As mentioned, real exchange rate fluctuations may be viewed as reflections of variations in underlying economic conditions. This section formulates a small-country model of the equilibrium response of the real exchange rate to domestic real demand, real cost, and nominal money supply disturbances. The small-country assumption is employed for convenience to simplify the structure of the model formulated. How the results can be generalized to include foreign disturbances as well is discussed briefly at the end of this section.

The key feature of the model is its treatment of information among economic agents. Within the model, economic agents are aware that different disturbances to the economy occur each period but cannot observe them directly and are unable to determine their magnitudes. Agents are assumed to form rational expectations of each period's disturbances on the basis of available past information and current "signals" obtained by observing current goods and asset market prices and conditions. These signals enable agents to infer information about the underlying disturbances.

In the model, observation of market prices and conditions provides partial, but not perfect, information about the current magnitudes of disturbances. Thus, for example, observation of domestic interest rate and money market conditions may indicate the presence of an excess supply of money but not reveal the extent to which the excess is due to a positive money supply disturbance or a negative real demand disturbance that has dampened money demand. Within this framework, we show how the real exchange rate is affected by both monetary and real disturbances.

The formal model is constructed by first specifying relationships for aggregate supply and demand in the domestic goods market, a domestic money market equilibrium condition, and an international interest rate relation linking domestic and foreign interest rates. All variables are defined in log terms (except for interest rates). These relationships are then used to obtain an expression relating the real exchange rate to the disturbances as well as to expectations of the future exchange rate. We complete the theoretical analysis by showing how expectations of the future exchange rate in turn depend on expectations of disturbances, and then deriving an expression indicating how the equilibrium real exchange rate responds to each individual disturbance.

The Goods Market

The supply of domestic output, y_t, is assumed to depend positively on the real domestic interest rate, r_t, and negatively on a random supply cost disturbance, c_t:

$$y_t = a_0 + a_1 r_t - c_t \tag{1}$$

$$r_t = i_t - (E_t p_{t+1} - p_t) \tag{2}$$

$$c_t = \rho_c c_{t-1} + \epsilon_{ct} \tag{3}$$

The specification of supply (equation 1) as a function of the real interest rate reflects the intertemporal decision of producers concerning how much of their product to supply in the current period and how much to supply in the future. The real interest rate, given by equation 2, is defined as the difference between the domestic nominal interest rate, i_t, and the expected change in the overall domestic price level, p_t, where E_t denotes expectations formed at time t. The real rate may be interpreted as the price of current goods relative to the discounted price of future goods. An increase in r represents a rise in the price of current goods relative to the discounted return to selling in the future and, as implied by equation 1, induces producers to supply more current output.[4]

The supply cost disturbance at time t, described by equation 3, consists of two components: a serially correlated term, $\rho_c c_{t-1}$, linking the current disturbance to lagged shocks, and a current (white-noise) shock term, ϵ_{ct}. This disturbance can be associated with exogenous factor cost increases or adverse productivity movements.

The overall domestic price level, p_t, is expressed by equation 4 as a weighted average of the domestic currency price of domestic goods and foreign goods:

$$p_t = a p_t^d + (1 - a)(p_t^f + s_t), \tag{4}$$

where p_t^d is the domestic currency price of domestic goods, p_t^f is the foreign currency price of foreign goods, s_t is the nominal exchange rate defined as the domestic currency price of foreign currency, and a is the share (assumed constant) of domestic goods in domestic consumption. Note that a *rise* in s represents an increase in the amount of domestic currency necessary to buy a unit of foreign currency and hence a nominal *depreciation* in domestic currency value.

The real exchange rate, q_t, is defined by equation 5 as the nominal exchange rate plus the difference between the foreign price level of foreign goods and the domestic price level of domestic goods:

$$q_t = s_t + p_t^f - p_t^d \tag{5}$$

A *rise* in q represents an increase in the relative domestic currency price of foreign goods and hence a real domestic *depreciation*.

Aggregate real demand for the domestic good (equation 6) depends negatively on the real interest rate, r_t, and positively on the real exchange rate, q_t, and a random demand disturbance term, d_t:[5]

$$y_t = b_0 - b_1 r_t + b_2 q_t + d_t \tag{6}$$

$$d_t = \rho_d d_{t-1} + \epsilon_{dt} \tag{7}$$

A higher real interest rate induces reduced current consumption (and investment) and hence current demand, while a rise in the real exchange rate, that is, a real depreciation of the domestic currency, induces greater demand for domestic output. The demand disturbance term, as described by equation 7, is serially correlated with a (white-noise) shock term, ϵ_{dt}. It may be interpreted as representing the effects on domestic demand of autonomous private and foreign spending, or of domestic fiscal expenditures.

The Asset Market

Money market equilibrium requires the domestic real money supply to balance domestic real money demand, where the latter depends positively on domestic output and negatively on the domestic nominal interest rate:

$$m_t - p_t = c_0 y_t - c_1 i_t \tag{8}$$

We assume that m_t, the nominal money supply, is determined exogenously as the sum of a serially-correlated term and a white-noise term, ϵ_{mt}:

$$m_t = \rho_m m_{t-1} + \epsilon_{mt} \tag{9}$$

A more general formulation would allow the money supply to be determined in part by considerations of domestic or international policy targets. Such a formulation would include the addition of terms related to current deviations from, for example, output or exchange rate targets to the right-hand side of equation 9.

Assuming risk neutrality on the part of agents and perfect capital mobility, equilibrium in the international bond market requires that the domestic nominal interest rate, i_t, equal the foreign nominal interest rate, i_t^f, plus the expected depreciation of the domestic currency:

$$i_t = i_t^f + (E_t s_{t+1} - s_t) \tag{10}$$

This condition implies that the returns, in terms of domestic currency, to holding domestic and foreign assets become equal. An exogenous risk-premium term could be introduced without affecting the analysis.

For the remainder of this analysis, we will use the small-country assumption, and treat the foreign country variables p_t^f and i_t^f as exogenous, constant, and, for convenience, equal to zero.

Equilibrium Conditions

We are now in position to address the implications of the equilibrium conditions in the goods and asset markets for the determination of the real exchange rate and for the response of the real exchange rate to the various lagged disturbances — d_{t-1}, c_{t-1}, and m_{t-1} — and current shocks — ϵ_{dt}, ϵ_{ct}, and ϵ_{mt}. Note that the term "shock" is used to refer to the random, unserially correlated component of each disturbance occurring in a given period. In the absence of any shocks prior to the previous period, any lagged disturbances can be associated entirely with lagged shocks, since in that case, for example, $d_{t-1} = \epsilon_{dt-1}$.

Observe first that equations 4 and 5 imply the following relationship between the nominal and real

47

exchange rates and the overall domestic price level (assuming $p_t^f = 0$):[6]

$$s_t - p_t = aq_t \qquad (11)$$

Consequently equations 2, 10, and 11 imply that the real domestic interest rate is positively related to the expected change in the real exchange rate (assuming $i_t^f = 0$):[7]

$$r_t = a(E_t q_{t+1} - q_t) \qquad (12)$$

The domestic goods market equilibrium condition implies, upon substitution of equations 3 and 12 in 1, and equations 7 and 12 in 6, and simultaneous solution for q_t:

$$q_t(b_2 + e_0) = a_0 - b_0 + e_0 E_t q_{t+1} \qquad (13)$$
$$- (\rho_c c_{t-1} + \rho_d d_{t-1} + \epsilon_{dt} + \epsilon_{ct})$$

where $e_0 = a(a_1 + b_1) > 0$.

The current real exchange rate, q_t, depends negatively on (positive) current and lagged real demand and cost shocks, and positively on the expected future real exchange rate. Intuitively, an increase in domestic demand or costs creates excess demand pressure in the domestic goods market. This induces a lower real exchange rate, that is, a stronger domestic currency, to shift demand away from domestic output and to maintain goods market equilibrium. A higher expected future real exchange rate, that is, an expected depreciation of the domestic currency, implies a higher domestic real interest rate due to the international mobility of capital (see equation 12). This creates excess supply pressure by inducing greater current supply and lower current demand for domestic output. Consequently, a higher current real exchange rate, that is, a current domestic currency depreciation, is necessary to stimulate current demand.

The money market equilibrium expression (equation 8) yields the following relationship for the nominal exchange rate upon substitution of equations 6, 7, 9, 10, 11 and 12 for d_t, y_t, m_t, i_t, p_t, and r_t, respectively:

$$s_t(1 + c_1) = e_1 q_t + c_1 E_t s_{t+1} + \rho_m m_{t-1} \qquad (14)$$
$$+ \epsilon_{mt} - c_0(\rho_d d_{t-1} + \epsilon_{dt})$$

where $e_1 = a + c_0(b_1 a - b_2) > 0$ by assumption. The current nominal exchange rate depends positively on the current real exchange rate, the expected future nominal exchange rate, and (positive) current and lagged money shocks; it depends negatively on current and lagged real demand shocks.

Intuitively, a rise in the expected future nominal exchange rate implies a greater domestic interest rate because of the mobility of international capital and, consequently, a dampening of real money demand. A higher current exchange rate is then necessary to raise the domestic price of foreign goods and the overall domestic price level, and implies a decline in the real money supply. Current or lagged money supply shocks induce an excess supply of money and hence a rise in s_t, that is, a nominal depreciation of the domestic currency. Current or lagged demand shocks in the goods market correspondingly raise money demand, induce excess money demand, and cause a fall in s_t.

Expectations and Equilibrium Solution

Equations 13 and 14 describe how the current real and nominal exchange rates each depend on current and lagged shocks and on expectations of the future exchange rate. Determining the overall equilibrium response of the current real exchange rate to these shocks thus requires specifying how the shocks in turn affect expectations of the future exchange rate.

It should be apparent that only current and lagged shocks should have any influence on future expectations through the serial-correlated disturbance component because any further shocks occurring in the future are assumed to be random (white-noise) and therefore unforeseeable. This implies that the equilibrium real exchange rate depends only on current and lagged shocks, which, in turn, suggests that the equilibrium real exchange rate may be expressed as a function of these shocks in the following way:

$$q_t = \bar{q} + B_d d_{t-1} + B_{\epsilon d} \epsilon_{dt} + B_c c_{t-1} \qquad (15)$$
$$+ B_{\epsilon c} \epsilon_{ct} + B_m m_{t-1} + B_{\epsilon m} \epsilon_{mt}$$

where $\bar{q}$ is the long-run average real exchange rate and the B coefficients indicating the sensitivity of the exchange rate to current and lagged disturbances depend on the parameters of the structural relationships in the model already specified.

48

Equation 15 implies that the equilibrium current real exchange rate will differ from its long-run average level only with the occurrence of current and lagged shocks. To ascertain the direction of change of the equilibrium exchange rate to each of these shocks, it is necessary to determine the signs of the B coefficients.[8]

We proceed to determining the signs of the B coefficients by first discussing the formation of expectations. According to the assumption of rational expectations, current expectations of the future exchange rate should be consistent with the equilibrium exchange rate prevailing in the next period. In particular, expectations in period t of the forward-dated equivalent of equation 15 for period $t+1$ are given by

$$E_t q_{t+1} = \bar{q} + E_t(B_d d_t + B_c c_t + B_m m_t), \quad (16)$$

or, after substituting equations 7, 3, and 9 for d_t, c_t, and m_t, respectively,

$$E_t q_{t+1} = \bar{q} + E_t(\rho_d B_d d_{t-1} + \rho_c B_c c_{t-1} + \rho_m B_m m_{t-1})$$
$$+ E_t(B_{\epsilon d}\epsilon_{dt} + B_{\epsilon c}\epsilon_{ct} + B_{\epsilon m}\epsilon_{mt})$$

Note that expectations formed in period t of the white-noise shocks in period $t+1$ — ϵ_{dt+1}, ϵ_{ct+1}, and ϵ_{mt+1} — are zero.

To proceed further, it is necessary to discuss the information sets of agents at the time their expectations are formed in any given period t. For simplicity, agents are assumed to have full information about the magnitudes of the lagged disturbances — d_{t-1}, c_{t-1}, and m_{t-1}. While they cannot directly observe current shocks at time t, they may infer partial knowledge of these shocks by extracting information from "signals" provided by observable market conditions and prices, including q_t, the real exchange rate; s_t, the nominal exchange rate; i_t, the domestic interest rate; and p_t, the price level. We also assume that their information sets include the parameters of all structural equations and the moments of all random variables. Neither current output quantities nor the money supply are treated as observable. This distinction between observable and unobservable market variables is intended to capture the property that market prices convey at least partially useful information to agents about underlying conditions.

The content of the signals provided to an agent at any time t may be determined from inspection of the output and asset market equilibrium expressions, equations 13 and 14, both of which are known to agents. Given the knowledge of lagged disturbances and market prices by agents, each expression implies knowledge of a residual term related to the underlying current shocks. Specifically, knowledge of c_{t-1}, d_{t-1}, q_t, and $E_t q_{t+1}$ in equation 13 reveals to agents the term $Z^G \equiv \epsilon_{dt} + \epsilon_{ct}$, a composite signal of the current real demand and cost shocks.

While agents cannot observe the demand and cost shocks individually, the knowledge of Z_t^G obtained from observing market conditions provides a signal of excess domestic demand that reflects their net effect in the goods market. For example, observation of a high value of Z_t^G by agents provides a signal of excess demand in the goods market, information which is of value to agents even though it is not sufficient to reveal precisely how much of the excess demand is due to a demand shock boosting demand as opposed to a cost shock reducing supply.

Analogously, the condition in equation 14 reveals to agents the composite signal $Z_t^M \equiv \epsilon_{mt} - c_0\epsilon_{dt}$. Z_t^M may be interpreted as a signal of excess money supply reflecting the net effect of money supply shocks and disturbances to money demand caused by real demand and income shocks.[9]

Agents are able to form expectations of each of the current shocks conditional on the information set including these signals. In the appendix, we show how these expectations take the following form:

$$E_t\epsilon_{dt} = C_{dG}Z_t^G - C_{dM}Z_t^M \qquad (17)$$

$$E_t\epsilon_{ct} = C_{cG}Z_t^G + C_{cM}Z_t^M \qquad \cdot(18)$$

$$E_t\epsilon_{mt} = C_{mG}Z_t^G + C_{mM}Z_t^M, \qquad (19)$$

where the C coefficients are positive parameters indicating the extent to which the expectations of each current shock are attributed by agents to the goods and money market signals that they observe.

Intuitively, the stronger the signal of excess

49

demand in the goods market (the higher is Z_t^G) the stronger the perception of both positive real demand and cost shocks. A stronger excess money supply signal (higher Z_t^M) leads to the inference of a more positive money supply shock, but also to the inference that a more negative real demand shock may have occurred and dampened money demand. Correspondingly, the excess money market signal implies expectation of a more positive cost shock. A stronger goods market signal leads to the expectation of larger money supply shock, since, to the extent that it is attributed to a positive real demand shock, a signal of a stronger goods market lessens the extent to which an excess money supply signal is perceived to have resulted from a negative real demand shock.

The extent to which the signals influence expectations of the current shocks is reflected in the magnitude of the C coefficients. To understand this, it is helpful to view equations 17-19 as the result of regressing historical observations of realizations of each of the individual shocks (which are known with a lag) on the goods and money market signals. The magnitudes of the C coefficients obtained from these regressions depend on the relative variability of the different disturbances. Thus, for example, if demand shocks have been relatively more prevalent historically than cost and money supply shocks, then agents will attribute relatively more of any

current excess demand signal to a current demand shock. This implies that the coefficient C_{dG} will be of greater magnitude than C_{cG}.

Equilibrium Response of the Real Exchange Rate

We are now in a position to determine the equilibrium response of the real exchange rate to individual shocks. The appendix describes in detail how this is done by deriving the explicit values of the B coefficients in equation 15, denoting the sensitivity of the exchange rate to individual shocks. Table 1 indicates the signs of these coefficients under the conditions of imperfect information, positively correlated disturbances (ρ_d, ρ_c, $\rho_m > 0$), and demand disturbances that persist more strongly than cost disturbances ($\rho_d > \rho_c$).

A current positive real demand or cost shock induces real appreciation of the domestic currency, that is, a fall in q ($B_{\epsilon d}$, $B_{\epsilon c} < 0$). Intuitively, either shock creates an excess demand for domestic output — the former by boosting demand and the latter by dampening production. Excess demand then induces an increase in the real value of domestic currency to shift demand away from the domestic market. Lagged demand or cost disturbances, when they are positively correlated over time, induce a real appreciation (B_d, $B_c < 0$) as well.

TABLE 1

Real Exchange Rate Response Coefficients to Domestic Market Shocks

$$q_t = \bar{q} + \overset{(-)}{B_d d_{t-1}} + \overset{(-)}{B_{\epsilon d}\epsilon_{dt}} + \overset{(-)}{B_c c_{t-1}} + \overset{(-)}{B_{\epsilon c}\epsilon_{ct}} + \overset{(0)}{B_m m_{t-1}} + \overset{(+)}{B_{\epsilon m}\epsilon_{mt}}$$

Domestic currency *Appreciates* (q falls) in response to a positive

- lagged demand shock
- current demand shock
- lagged cost shock
- current cost shock

Domestic currency *Depreciates* (q rises) in response to a positive

- current money supply shock

Note: Effect of foreign market shocks are the opposite of those above.

In the case of imperfect information, current money supply shocks also influence the real exchange rate (since $B_{em} \neq 0$). The reason is that without the ability to distinguish perfectly among individual shocks, agents confuse money and real disturbances. If, for example, a positive money supply has occurred, agents will attribute the resulting excess money signal observed in part to negative real demand shocks. The perception of a demand shock, even if none has actually occurred, implies that the money supply shock will have real effects.[10] More particularly, the perception of lower current real demand arising from a positive money supply shock causes the domestic currency to depreciate to stimulate domestic demand ($B_{em} > 0$).

Note that in this model, lagged money disturbances have no effect on the exchange rate ($B_m = 0$). The reason is related to the assumption that agents know all past disturbances with a one period lag. That assumption implies that lagged money is not a source of confusion when agents attempt to infer the magnitudes of current shocks to the real exchange rate.

The analysis above yields implications about the effect of domestic real and money supply disturbances on the exchange rate within a small-country framework. It is fairly straightforward to incorporate the effects of foreign real and money supply disturbances into a two-country framework. By intuition, these disturbances should have effects opposite those of the domestic disturbances described in Table 1. In particular, positive real shocks creating an excess demand for foreign output should lead to a real appreciation of the foreign currency and hence a depreciation of the domestic currency. Under imperfect information, positive foreign money supply shocks should lead to a domestic appreciation.

II.   Vector Autoregression Analysis

The model formulated in Section I suggests how fluctuations of real exchange rates can be attributed to fluctuations in various underlying disturbances, both monetary and real. In this section, empirical evidence is provided concerning the extent to which monthly bilateral real exchange rate movements of the dollar against the yen and German mark can be related to changes in monetary and real conditions in the United States and abroad.

Description of the VAR Method

To analyze the interrelationship of the real exchange rate with changing economic conditions, we employed the technique of vector autoregressions (VAR). The VAR technique imposes no restrictions on the relationships between different variables and treats them all as potentially endogenous. VARs are best thought of as a convenient way of summarizing empirical regularities and suggesting the predominant channels through which relations work.[11] While several other studies (for example, Branson, 1984; Kuszczak and Murray, 1986) have used the VAR approach to analyze exchange rate movements, they focus on nominal rather than real changes and effective rather than bilateral rates.

Applying the VAR technique involves transforming all data into first differences of natural logs (equivalent to forming percentage changes) and individually regressing each variable in the system (the vector) on lagged values of itself and of the other variables in the system (the autoregression) and on a common set of other terms including a constant, linear and quadratic time trends, and seasonal dummies.[12] A common lag length is imposed on all endogenous variables.[13]

The resulting estimates provide several useful insights. First, they indicate whether past values of other endogenous variable have a significant effect on a given variable through Granger-causality statistical tests on the values of lagged coefficients. If past values of, say, money supply changes have a significant effect on the real exchange rate, then the money supply is said to "Granger cause" the exchange rate.[14]

Secondly, since the autoregressive equations extract the effects of past movements of variables, the residuals from each of these equations provide measures of unanticipated movements of variables in the system and thus act as proxies for shocks. Correlations of these residuals may be interpreted as measures of the association of unanticipated vari-

able movements. Thus, for example, a positive correlation between the U.S. money supply and the real dollar exchange rate residuals, or a negative correlation between U.S. demand disturbances and the real dollar exchange rate residuals, provide suggestive evidence for the theoretical prediction that the current real dollar should depreciate in response to a current domestic money shock and appreciate in response to a current domestic demand shock.[15]

Lastly, the VAR estimates may be transformed in a manner to yield estimates of how much of the variance of any variable in the system is attributable to itself and other variables in the system.[16] These so-called "variance decompositions" can be used to infer the relative effect of money and real disturbances on exchange rate fluctuations.[17]

Results

Two VAR systems were estimated with monthly data, each containing six variables. The first consisted of the real dollar/yen rate, the real price of oil, and money supplies and industrial production for

TABLE 2

VAR Equation Estimates for United States - Japan[a]

Dependent Variable[b]:	United States Money Supply	Japan Money Supply	Real Price of Oil	United States Industrial Production	Japan Industrial Production	Real Exchange Rate
Significance of lagged variables[c]						
United States Money Supply	.06	.66	.07	.07	.29	.17
Japan Money Supply	.28	.00	.27	.74	.16	.64
Real Price of Oil	.52	.39	.46	.23	.07	.79
United States Industrial Production	.06	.24	.30	.35	.06	.63
Japan Industrial Production	.75	.14	.38	.01	.05	.86
Real Exchange Rate	.39	.96	.21	.30	.52	.69
R^2	.89	.86	.21	.86	.97	−.16
SEE	.006	.017	.023	.011	.012	.034

Correlation Matrix of Residuals[d]

	United States Money Supply	Japan Money Supply	Real Price of Oil	United States Industrial Production	Japan Industrial Production	Real Exchange Rate
United States Money Supply	—	−.14*	.15*	−.06	−.09	.19*
Japan Money Supply		—	−.13*	−.31***	−.17*	.07
Real Price of Oil			—	.21**	−.04	−.11
United States Industrial Production				—	.43***	−.23**
Japan Industrial Production					—	.17*
Real Exchange Rate						—

[a]Monthly data, Nov. 1973 - Oct. 1985

[b]All variables expressed in percentage change form. Note the real exchange rate is defined as the real dollar price of foreign exchange.

[c]Regressions contain 12 lags of each variable, as well as a constant, linear and quadratic time trends, and monthly seasonal dummies. Joint significance of the lagged coefficients for each variable is measured by the marginal significance level of the F-statistic. A marginal significance level smaller than .10 indicates a greater than ninety percent probability of rejection of the null hypothesis that the lagged coefficients have no effect.

[d]Correlation levels significant at marginal significance levels greater than .05, .1, and .2 are indicated by ***, **, and *, respectively. For example, a correlation level marked by * indicates there is less than a twenty percent probability of obtaining that level if the null hypothesis that no correlation exists is true.

TABLE 3

VAR Equation Estimates for U.S. - Germany[a]

Dependent Variable[b]:	United States Money Supply	West German Monetary Base	Real Price of Oil	United States Industrial Production	West German Industrial Production	Real Exchange Rate
Significance of lagged variables[c]						
United States Money Supply	.67	.25	.35	.59	.88	.14
West German Monetary Base	.51	.00	.57	.51	.93	.76
Real Price of Oil	.85	.13	.08	.79	.67	.71
United States Industrial Production	.05	.93	.83	.27	.14	.54
West German Industrial Production	.94	.44	.66	.90	.01	.44
Real Exchange Rate	.91	.08	.87	.84	.87	.69
R²	.88	.58	.02	.83	.88	−.01
SEE	.006	.027	.026	.013	.032	.033

Correlation Matrix of Residuals[d]

	United States Money Supply	West German Monetary Base	Real Price of Oil	United States Industrial Production	West German Industrial Production	Real Exchange Rate
United States Money Supply	—	−.16*	.04	.02	.02	.15*
West German Monetary Base		—	−.31***	−.01	.01	−.28***
Real Price of Oil			—	.03	.09	−.03
United States Industrial Production				—	.34***	−.13*
West German Industrial Production					—	−.09
Real Exchange Rate						—

[a]Monthly data, Nov. 1973 - Oct. 1985

[b]All variables expressed in percentage change form. The real exchange rate is defined as the real dollar price of foreign exchange.

[c]See Table 2, note c.

[d]See Table 2, note d.

TABLE 4

Decomposition of Variance

	Percentage of Variance in Exchange Rate Explained by[a]					
	United States Money Supply	Foreign Money Supply[b]	Real Price of Oil	United States Industrial Production	Foreign Industrial Production[b]	Real Exchange Rate[b]
Japan	11	16	9	12	14	38
West Germany	17	9	8	15	8	43

[a]Figures represent percentage of variance of (48-month ahead forecast errors in predicting) exchange rate attributable to each variable. For example, 11% of the variance in real dollar/yen rate is due to U.S. money. Note that figures sum to 100% when added horizontally.

[b]Of country in first column.

both the United States and Japan. The second consisted of the dollar/German mark rate, the real price of oil, and money supplies and industrial production for the United States and Germany.[18] Difficulties in obtaining data with monthly frequency limited the inclusion of other possibly relevant variables, such as government spending.

Note that the real exchange rate was defined as the real dollar price of foreign exchange, with an increase in the real exchange rate indicating a real depreciation of the dollar. To provide an adequate time period for adjustment to the system of floating exchange rates, the observation period began in November 1973 and ended with October 1985. Concern about degrees of freedom limitations precluded the examination of results for subperiods.

The results of the VAR equation estimates for the U.S.-Japan and U.S.-Germany systems are presented in Tables 2 and 3, respectively. Observe in the last column of each table that the real dollar/yen and dollar/mark rates were not significantly influenced (Granger-caused) by lagged values of any of the variables in the system (the marginal significance levels were .17 or much higher). For the other equations, lagged values of particular sets of variables are occasionally seen to influence (Granger-cause) either themselves or other variables, using a ten percent marginal significance standard.

The bottom panels of Tables 2 and 3 present the correlations of the residuals from the estimated VAR equation. Of primary interest are the correlations of the real exchange rate with those of other variables of the system, reported in the last column. Here we find some suggestive evidence for the association of real exchange rate movements and money and real shocks that accords with the theoretical implications of the model in Section I.

Observe first that U.S. money supply residuals are positively and significantly correlated with residuals in both the real dollar/yen and dollar/mark rates, while German money supply residuals are negatively correlated with the dollar/mark rate. The industrial production residuals may be interpreted as business-cycle demand shocks since, through the

VAR estimates, they have been "purged" of the effects of money changes and supply disturbances, such as oil price changes, as well as of trend effects. Observe that U.S. industrial production residuals are negatively correlated with each bilateral real exchange rate, while Japanese industrial production residuals are positively correlated with the dollar/yen rate, as expected.[19]

Table 3 presents results from the decomposition of variances.[20] Observe first that foreign money and industrial production innovations account for relatively more of the variance of the dollar/yen rate (16 percent + 14 percent = 30 percent), while U.S. money and industrial production innovations account for relatively more of that of the dollar/mark (17 percent + 15 percent = 32 percent). In other words, foreign disturbances appear to have played a greater role in influencing movements of the dollar/yen rate; U.S. disturbances were more significant for dollar/mark fluctuations.

Note second that, for the dollar/yen rate, U.S. and Japanese monetary disturbances account for (11 percent + 16 percent =) 27 percent and U.S. and Japanese demand disturbances for (12 percent + 14 percent =) 26 percent of the exchange rate variance. For the dollar/mark rate, money and demand disturbances account for 26 percent and 23 percent, respectively, of the exchange rate variance. Thus, for both bilateral rates, money and real shocks appear separately to account for a roughly comparable proportion of the exchange rate variance.

Observe finally that the variance of the dollar/yen and dollar/mark rates explained by themselves are rather large (38 and 43 percent respectively). These figures represent the part of the real exchange rate that cannot be forecast by the other variables in the analysis and which reflects the influence of unincluded variables and pure innovations in the exchange rate itself. Their magnitude suggests that a sizeable proportion of real exchange rate fluctuations still remains to be explained by other variables and better proxies for monetary and demand conditions.

III. Conclusions

This paper has provided both a theoretical and empirical framework for analyzing the response of the real exchange rate to monetary and real disturbances. The sensitivity of the real exchange rate to these disturbances was shown to depend on the degree of information possessed by economic agents. When agents have imperfect information and are confused about the relative magnitudes of monetary and real disturbances, the real exchange rate depends on monetary as well as real disturbances.

The empirical analysis indicates that movements in the real value of the dollar can indeed be associated with real and monetary disturbances. In particular, support was found for hypotheses suggested by the theory that U.S. money supply increases induce falls in the real value of the dollar while real demand expansions generate rises in real dollar value. Foreign shocks were also seen in some instances to influence the value of the dollar. They were found to play a greater role in influencing fluctuations in the real dollar/yen rate than in the dollar/mark rate.

Our analysis suggests that governments can and do influence the real exchange rate through policies affecting money and goods market conditions. We conclude that policies designed to reduce money and real market disturbances should also reduce the variability of the real exchange rate. Our findings also suggest an alternative means of achieving such a goal of stability, namely, increasing the extent of knowledge in the economy about underlying economic conditions. In particular, policies that result in less confusion and more information about the relative magnitudes of money and real disturbances may decrease the sensitivity of the real exchange rate to existing money shocks.

APPENDIX

This appendix describes the derivation of expressions for the rational expectations of current disturbances from existing market signals, and also of the equilibrium real exchange rate response coefficients.

The general expression for rational expectations of any given disturbance ϵ_{kt}, $k = d, c, m$, formed conditionally on an information set containing the signals Z_t^G and Z_t^M is given by (see Sargent, 1979, pp. 208-209)

$$E_t[\epsilon_{kt}| Z_t^G, Z_t^M] = E_t[\epsilon_{kt} | Z_t^G] +$$
$$E_t[(\epsilon_{kt} - E_t[\epsilon_{kt}| Z_t^G])|(Z_t^M - E_t[Z_t^M| Z_t^G])]$$

where for any variable X and Y

$$E_t[X_t|Y_t] = (Cov[X_t, Y_t]/Var[Y_t])Y_t,$$

and Cov and Var represent the covariance and variance operators. Evaluation of this expression for $k = d, c, m$ implies

(A.1) $E_t\epsilon_{dt} = (\sigma_d^2\sigma_m^2/\Delta)Z_t^G - (c_0\sigma_c^2\sigma_d^2/\Delta)Z_t^M$

(A.2) $E_t\epsilon_{ct} = [(\sigma_c^2\sigma_m^2 + c_0^2\sigma_d^2\sigma_c^2)/\Delta]Z_t^G$
$$+ (c_0\sigma_c^2\sigma_d^2/\Delta)Z_t^M$$

(A.3) $E_t\epsilon_{mt} = (c_0\sigma_d^2\sigma_m^2/\Delta)Z_t^G + [\sigma_m^2(\sigma_d^2 + \sigma_c^2)/\Delta]Z_t^M$

where $\Delta = \sigma_m^2\sigma_d^2 + \sigma_m^2\sigma_c^2 + c_0^2\sigma_d^2\sigma_c^2$; and σ_d^2, σ_c^2, and σ_m^2 are the absolute variances of the demand, cost, and money shocks, respectively. The coefficients in these expressions represent the explicit formulas for the C coefficients in equations 17-19 in the text. Substitution by $Z_t^G = \epsilon_{dt} + \epsilon_{ct}$ and $Z_t^M = \epsilon_{mt} - c_0\epsilon_{dt}$ and rearrangement gives:

(A.4) $E_t\epsilon_{dt} = \epsilon_{dt} - (\theta_d\epsilon_{dt} - \theta_c\epsilon_{ct} + \theta_m\epsilon_{mt})$

(A.5) $E_t\epsilon_{ct} = \epsilon_{ct} + (\theta_d\epsilon_{dt} - \theta_c\epsilon_{ct} + \theta_m\epsilon_{mt})$

(A.6) $E_t\epsilon_{mt} = \epsilon_{mt} - c_0(\theta_d\epsilon_{dt} - \theta_c\epsilon_{ct} + \theta_m\epsilon_{mt})$

where $\theta_d = \sigma_c^2\sigma_m^2/\Delta$, $\theta_c = \sigma_d^2\sigma_m^2/\Delta$,
$$\theta_m = c_0\sigma_d^2\sigma_c^2/\Delta; \ 0 \leq \theta_d, \ \theta_c, \ \theta_m \leq 1.$$

Equations A.4-A.6 relate the conditional expectations of current disturbances to their actual levels. The parameters θ_d, θ_c, and θ_m represent the relative variances of demand, cost, money shocks, respectively. They reflect the noisiness of market conditions and hence the degree of confusion by agents about the shocks that they cannot directly observe. Thus, for example, θ_d measures the degree of confusion about demand conditions. The definition of θ_d indicates that such confusion is high when the variances of cost and money shocks (σ_c^2, σ_m^2) are relatively large since, in that case, market conditions primarily reflect fluctuations due to cost and money disturbances, and reveal relatively little about demand conditions.

In the absence of any confusion about current shocks, θ_d, θ_c, and θ_m equal zero, and equations A.4-A.6 imply that agents will fully perceive all shocks. In general, however, confusion will exist and agents will misperceive shocks. Equation A.4, for example, describes how agents misperceive demand shocks. The extent of the misperception diminishes the smaller are the variances of cost and

money supply shocks since the confusion about demand disturbances (θ_d) then diminishes.

Equation A.4 also says that, with imperfect information, expectations of real demand shocks will depend on money (and cost) shocks. More specifically, positive money shocks result in lower expectations of demand shocks. The effect of a given money shock on perceptions of real demand disturbances is magnified the greater are the relative variances of real disturbances (the greater is θ_m). Expectations of cost and money shocks may be interpreted similarly.

To solve explicitly for the B coefficients whose signs are given in Table 1 in the text, note that at time t, d_{t-1}, c_{t-1}, and m_{t-1} are assumed to be known. Substitution of Equations A.4-A.6 in Equation 16 subsequently implies

$$
\begin{aligned}
E_t q_{t+1} = \bar{q} &+ \rho_d B_d d_{t-1} + \rho_c B_c c_{t-1} + \rho_m B_m m_{t-1} \\
&+ B_{ed}[\epsilon_{dt} - (\theta_d \epsilon_{dt} - \theta_c \dot{\epsilon}_{ct} + \theta_m \epsilon_{mt})] \\
&+ B_{ec}[\epsilon_{ct} + (\theta_d \epsilon_{dt} - \theta_c \epsilon_{ct} + \theta_m \epsilon_{mt})] \\
&+ B_{em}[\epsilon_{mt} - c_0(\theta_d \epsilon_{dt} - \theta_c \epsilon_{ct} + \theta_m \epsilon_{mt})]
\end{aligned}
$$

TABLE A

Real Exchange Rate Response Coefficients

$$q_t = \bar{q} + B_d d_{t-1} + B_{ed}\epsilon_{dt} + B_c c_{t-1} + B_{ec}\epsilon_{ct} + B_m m_{t-1} + B_{em}\epsilon_{mt}$$

$\bar{q} = (a_0 - b_0)/(b_2 + e_0)$

$B_d = -\rho_d D_d$ $\lessgtr 0$ as $\rho_d \gtrless 0$

$B_{ed} = -D_d + a_2\theta_d(\rho_d D_d - \rho_c D_c)$ < 0 if $\rho_d, \rho_c > 0$

$B_c = -\rho_c D_c$ $\lessgtr$ as $\rho_c \gtrless 0$

$B_{ec} = -D_c - a_2\theta_c(\rho_d D_d - \rho_c D_c)$ < 0 if $\rho_d, \rho_c > 0$

$B_m = 0$

$B_{em} = a_2\theta_m(\rho_d D_d - \rho_c D_c)$ $\gtrless 0$ as $\rho_d \gtrless \rho_c \gtrless 0$

where $a_2 = e_0/(b_2 + e_0) < 1$

$D_d = 1/(b_2 + e_0(1 - \rho_d))$

$D_c = 1/(b_2 + e_0(1 - \rho_c))$

$\theta_d = \sigma_c^2 \sigma_m^2 / \Delta, \; 0 \leqslant \theta_d \leqslant 1$

$\theta_c = \sigma_d^2 \sigma_m^2 / \Delta, \; 0 \leqslant \theta_c \leqslant 1$

$\theta_m = c_0 \sigma_d^2 \sigma_c^2 / \Delta, \; 0 \leqslant \theta_m \leqslant 1$

$\Delta = \sigma_c^2 \sigma_m^2 + \sigma_d^2 \sigma_m^2 + c_0^2 \sigma_d^2 \sigma_c^2$

Substituting the above expression in turn into Equation 13 yields, upon rearrangement:

$$q_t(b_2 + e_0) = a_0 - b_0 + e_0\bar{q} + \rho_d(e_0 B_d - 1)d_{t-1}$$

$$+ \{e_0[B_{\epsilon d} - \theta_d(B_{\epsilon d} - B_{\epsilon c} + c_0 B_{\epsilon m})] - 1\}\epsilon_{dt}$$

$$+ \rho_c(e_0 B_c - 1)c_{t-1} +$$

$$\{e_0[B_{\epsilon c} + \theta_c(B_{\epsilon d} - B_{\epsilon c} + c_0 B_{\epsilon m})] - 1\}\epsilon_{ct}$$

$$+ \rho_m e_0 B_m m_{t-1} +$$

$$[e_0(B_{\epsilon m} - \theta_m(B_{\epsilon d} - B_{\epsilon c} + c_0 B_{\epsilon m})]\epsilon_{mt}$$

Dividing through by $b_2 + e_0$, equating coefficients term-by-term with Equation 15, and solving for the B coefficients gives the expressions in Table A.

The perfect information case is characterized when the relative confusion parameters θ_d, θ_c, and θ_m in the coefficients are equal to zero. In this instance, the real exchange rate depends only on real demand and cost shocks, and not on current or lagged money shocks ($B_m = B_{\epsilon m} = 0$). In the case of imperfect information, current money supply shocks will influence the real exchange rate (since $B_{\epsilon m} \neq 0$). If demand disturbances persist more strongly than cost disturbances ($\rho_d > \rho_c > 0$) then a positive money supply shock causes a real depreciation ($B_{\epsilon m} > 0$). The larger is θ_m and the degree of confusion about money disturbances, the greater is the response of the real exchange rate. Finally, note that the response of q to current demand and cost shocks differs from the full information response and also depends on the degree of confusion about these shocks (θ_d, θ_c) and on the serial correlation parameters (ρ_d, ρ_c).

FOOTNOTES

1. The variability of real exchange rates over the floating rate period has been well documented. See, for example, Frenkel (1981) and Cumby and Obstfeld (1984). For discussion of the welfare effects of exchange rate variability, see Obstfeld (1985) and Frankel (1985, pp. 23-32).

2. The assumption that agents have imperfect information because they are unable to observe directly or to infer from market conditions the magnitude of current disturbances to the economy is characteristic of so-called "island" models first developed by Phelps (1970) and Lucas (1972, 1975) to analyze domestic macroeconomic adjustment. More recently, this approach has been employed in international macroeconomic models as well, for example, Bhandari (1982), Kimbrough (1983, 1984), Flood and Hodrick (1985a, 1985b), and Glick and Wihlborg (1986). These models, however, have generally focused on issues other than real exchange rate behavior.

3. Other explanations exist for real exchange fluctuations in response to both monetary and real disturbances. For example, in so-called "sticky-price" models, it is assumed that domestic and foreign goods prices adjust more slowly than the exchange rate to disturbances because of labor and/or goods market rigidities, such as fixed wage contracts (see Dornbusch, 1976; Obstfeld, 1985). When domestic and foreign prices are relatively rigid in the short run, real as well as nominal exchange rates will be affected by disturbances. This paper does not attempt to distinguish among competing hypotheses.

4. This particular specification emphasizes the role of expected price changes in current supply decisions. If the price level in natural units is denoted by P_t, then the relevant price ratio is $P_t/[E_t P_{t+1}/(1+i)]$. The logarithmic analogue to this price ratio is $p_t + \ln(1+i) - E_t p_{t+1}$, or, noting that $\ln(1+i) \approx i$, by $i - (E_t p_{t+1} - p_t)$, which is the definition of the real interest rate. Work employing this specification includes Barro (1980), Bhandari (1982), and Kimbrough (1984). Note that this specification, which emphasizes the role of anticipated price changes in supply decisions, differs from the Lucas-type supply function which depends on $p_t - E_{t-1}p_t$ and emphasizes the role of unanticipated price changes.

5. Note that, in addition to the effect of the real exchange rate on demand by foreigners for domestic output, the constant b_0 and the disturbance term d_t may also be interpreted as including foreign influences.

6. With $p_t^f = 0$, equation 4 implies that $p_t = a(p_t^d - s_t) + s_t$ and equation 5 that $q_t = s_t - p_t^d$. Substitution of the latter expression in the former and rearrangement gives equation 11 in the text.

7. Substituting equation 10 in equation 2 and assuming $i_t^f = 0$ gives $r_t = E_t(s_{t+1} - p_{t+1}) - (s_t - p_t)$. Use of equation 11 gives equation 12 in the text. The parameter a, the share of domestic goods in consumption, appears in equation 12 since the real domestic interest rate is defined in terms of the expected inflation rate in the *overall* domestic price level, while the real exchange rate is defined in terms of the price of domestic goods alone.

8. Equation 15 may be interpreted as a "guess" about the general form of the equilibrium expression for the real exchange rate. The technique of "guessing" the general form of the equilibrium solution and then determining the values of the coefficients in this equilibrium explicitly is standardly employed in linear stochastic difference models of the type formulated in this paper. See, for example, Bhandari (1982) Flood and Hodrick (1985a, 1985b), Glick and Wihlborg (1986), and Kimbrough (1983, 1984). A similar procedure could also have been applied to the determination of the equilibrium nominal exchange rate.

9. Note that the model contains two signals and three disturbances. This implies that agents cannot perfectly infer the magnitudes of the individual disturbances merely from observing market conditions. See Glick and Wihlborg (1986) for a model of exchange rates which illustrates how

under these circumstances a demand for information purchase can arise.

It should also be pointed out that if in any period t agents lack full information about the disturbances in periods t-1 or earlier, then lagged disturbances will pose an additional source of confusion for agents when they attempt to infer the magnitude of current shocks and to form expectations about the future exchange rate. In such cases, the signals obtained in period t will reflect not only current shocks but also unobservable lagged shocks. Correspondingly, the equilibrium exchange rate will depend on the same lagged shocks as well as whatever disturbances in the past are observable and useful for inferring the magnitudes of subsequent shocks.

10. That monetary disturbances affect real variables under imperfect information is a feature of the closed-economy macro models of Lucas (1972, 1975) and the open-economy macro models of Bhandari (1982), Flood and Hodrick (1985a, 1985b), Glick and Wihlborg (1986) and Kimbrough (1983, 1984).

11. The VAR technique presumes that the variables in the system are covariance stationary and that any relationships among them are linear. The procedure of transforming variables into percentage changes, described below, is the standard means of achieving covariance stationarity. Discussions of the VAR technique may be found in Sims (1980) and Hakkio and Morris (1984).

12. An alternative approach is to use pre-whitened data in the VAR system by, in addition to taking first differences of logs, further filtering the data to remove all trend and seasonality before performing the regressions. A difficulty with this procedure is that the detrending and deseasonalization may remove evidence of the interrelationships among variables that one is seeking.

13. The assumption of a common lag length is necessary for the VARs to provide consistent estimates. There are several tests available for determining the proper lag length, but alternative tests often provide different results. In addition, degrees of freedom must be considered. Thus, ultimately, the choice of lag length is a subjective matter. A 12-month lag specification is employed in this paper.

14. There are a number of difficulties with interpreting Granger causality tests. First, the test may indicate a causal relation when in fact each variable is reacting to a common third variable but with a different lag, or anticipating a common third variable but with a different lead. Second, the tests cannot detect contemporaneous relations among variables.

15. Note that, to the extent government monetary policy is determined by a reaction to undesired exchange rate changes, the positive correlation between money shocks and the exchange rate will be dampened.

16. The transformation involves obtaining the moving average representation of the VAR system whereby each of the variables in the system is expressed as a moving average function of the residuals.

17. One potential problem in interpreting the variance decomposition results is that the use of lagged endogenous variables only in each equation of the VAR system forces all contemporaneous shocks that affect the endogenous variables to feed through the residuals of each equation. While this poses no problem in the estimation stage of the analysis, if the estimated residuals have high contemporaneous correlations, the order in which the variables are entered in the system could cause certain variables to take on exaggerated importance in the variance decompositions, while other, perhaps more significant, variables take on little or no weight.

This problem arises because the Choleski decomposition (see Hakkio and Morris, 1984) used to convert the VAR model into its moving average form attributes all of the contemporaneous correlation between any two variables to the one ordered first. To minimize this problem, the order of any variables that were highly correlated was switched to check the sensitivity of results. No major problems resulted.

18. The money supply figures were derived from end-of-month M1 stock data for the United States and Japan and monetary base data for Germany. The real value of the dollar was defined as the U.S. producer price of oil divided by the U.S. wholesale price. The real value of the dollar was defined as the monthly foreign wholesale price times the end-of-month dollar price of foreign exchange divided by the U.S. wholesale price. All data came from the *IMF International Financial Statistics*.

19. The correlation levels corresponding to marginal significance levels (with the 46 degrees of freedom in the VAR estimates) of .2, .1 and .05 are given by .12, .18, and .24, respectively. Thus, for example, there is a less than twenty percent probability of observing a correlation larger than .12 if the null hypothesis that no correlation exists were true.

20. Technically, the figures given are the percentage of variance of the 48-month ahead forecast errors in predicting the exchange rate attributable to individual variables. The errors over this long a horizon, it can be shown, approximate the variance of the predicted variable.

REFERENCES

Barro, R., "A Capital Market in an Equilibrium Business Cycle Model," *Econometrica,* Vol. 48, September 1980, pp. 1393-1417.

Bhandari, Jagdish, "Informational Efficiency and the Open Economy," *Journal of Money, Credit and Banking,* Vol. 14, Nov. 1982, pp. 457-78.

Branson, William, "Exchange Rate Policy After a Decade of 'Floating'," in John Bilson and Richard Marston, eds., *Exchange Rate Theory and Practice.* Chicago: University of Chicago Press, 1984.

Cumby, Robert and Maurice Obstfeld, "International Interest Rate and Price Level Linkages Under Flexible Exchange Rates: A Review of Recent Evidence," in John Bilson and Richard Marston, eds., *Exchange Rate Theory and Practice.* Chicago: University of Chicago Press, 1984

Dornbusch, Rudiger, "Expectations and Exchange Rate Dynamics," *Journal of Political Economy,* Vol. 84, Dec. 1976, pp. 1161-76.

Flood, Robert and Robert Hodrick, "Central Bank Intervention in a Rational Open Economy: A Model with Asymmetric Information," in J. Bhandari, ed., *Exchange Rate Management and Uncertainty.* Cambridge: The MIT Press, 1985a.

Flood, Robert and Robert Hodrick, "Optimal Price and Inventory Adjustment in an Open-Economy Model of the Business Cycle," *Quarterly Journal of Economics,* Vol. 98, Aug. 1985b, pp. 887-914.

Frankel, Jeffrey, "Six Possible Meanings of 'Overvaluation': The 1981-85 Dollar," Princeton Essay in International Finance No. 159, December 1985.

Frenkel, Jacob, "Flexible Exchange Rates, Prices, and the Role of 'News': Lessons from the 1970s", *Journal of Political Economy,* Vol. 89, Aug. 1981, pp. 665-705.

Glick, Reuven and Clas Wihlborg, "The Role of Information Acquisition and Financial Markets in International Macroeconomic Adjustment," *Journal of International Money and Finance,* Vol. 5, September 1986, pp. 257-83.

Hakkio, Craig and Charles Morris, "Vector Autoregressions: A User's Guide", Federal Reserve Bank of Kansas City Research Working Paper 84-10, November 1984.

Kimbrough, Kent, "The Information Content of the Exchange Rate and the Stability of Real Output Under Alternative Exchange Rate Regimes," *Journal of International Money and Finance,* Vol. 2, April 1983, pp. 27-38.

Kimbrough, Kent, "Aggregate Information and the Role of Monetary Policy in an Open Economy," *Journal of Political Economy,* Vol. 92, April 1984, pp. 268-80.

Kuszczak, John and John Murray, "A VAR Analysis of Economic Interdependence: Canada, the United States, and the Rest of the World," in R. Hafer, ed., *How Open is the U.S. Economy?.* Lexington: Lexington Books, 1986.

Lucas, Robert E., "Expectations and the Neutrality of Money," *Journal of Economic Theory,* Vol. 4, April 1972, pp. 103-24.

Lucas, Robert E., "An Equilibrium Model of the Business Cycle," *Journal of Political Economy,* Vol. 83, Dec. 1975, pp. 1113-24.

Obstfeld, Maurice, "Floating Exchange Rates: Experience and Prospects, *Brookings Papers on Economic Activity,* No. 2, 1985.

Sargent, Thomas, *Macroeconomic Theory,* New York: Academic Press, 1979.

Sims, Christopher, "Macroeconomics and Reality", *Econometrica,* Vol. 48, January 1980, pp. 1-48.