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6 International Transmission under Bretton Woods

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It has become commonplace for politicians and journalists to assert that the world economy is integrated and that no modern economy operates in isolation. International connections between economies are the focus of political campaigns and cocktail-party discussions. World economic integration is not a new idea to economists, although there has been increased attention to these issues in recent years. But while we economists have considerable theory and evidence about the causes and effects of international trade in isolated markets, little is yet known about the nature of macroeconomic connections between national economies. To what extent are common macroeconomic movements associated with common disturbances, and to what extent are they associated with international *transmission* of disturbances from some countries to others? Through what channels does international transmission mainly operate? Similarly, to the extent that macroeconomic movements in different countries are *not* common, to what extent is this due to different disturbances, and to what extent does it reflect channels of international transmission that create divergent movements in national economies? These issues are important for short-term macroeconomic policies and for more basic policy decisions such as the exchange-rate system. To what extent does international transmission differ across alternative exchange-rate systems?

One of the main theoretical arguments among economists for the adoption of floating exchange rates to replace the Bretton Woods system was that floating rates would allow countries to follow independent monetary policies. The argument was that fixed exchange rates required the international transmission

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of monetary disturbances and restricted the independence of macroeconomic policies under Bretton Woods. According to this view, the international transmission of monetary disturbances keeps inflation the same across countries with pegged exchange rates, and this international transmission would change under a floating-rate system. With hindsight, it is clear that the Bretton Woods system played a role in limiting the variability of *real* as well as nominal exchange rates. There is considerable evidence that international relative prices became greater when the Bretton Woods system was abandoned and that the exchange-rate system plays a causal role in the variability of relative prices (see Stockman 1983; Mussa 1986; Baxter and Stockman 1989; and Engel 1991). On the other hand, there is little evidence that *quantities* such as real production, consumption, or investment were so dramatically affected by the abandonment of Bretton Woods (see Baxter and Stockman 1989). The first observation suggests that the international transmission of real disturbances (or the cross-country correlation of those disturbances) may have changed dramatically with the abandonment of Bretton Woods. The second observation, in contrast, suggests little change.

The issue of international transmission is broad, partly because it can refer to a wide variety of exogenous changes in variables such as technology, tastes for one country's goods versus another country's goods, tastes for goods now versus future goods (savings/consumption decisions), tastes for working (labor supply decisions), tax rates, government spending of various kinds (and on domestic or foreign goods), the money supply, the demand for money, or other variables. Moreover, any of the disturbances could be temporary or permanent, anticipated or unanticipated. The transmission can occur through a variety of channels, such as arbitrage in product markets or asset markets, substitution in product markets (e.g., substitution of one country's goods for the goods of another country), changes in demand for foreign products, changes in supply due to changes in the costs of imported inputs, externalities in production, changes in foreign wealth due to changes in domestic asset prices, and so on.

Some channels of international transmission operate regardless of the exchange-rate system; others are dependent on the form of that system. Rather than discuss a catalog of shocks and their international transmission under Bretton woods, it is useful to develop a framework that can be used and modified to examine a variety of shocks and transmission channels, and it is also useful to discuss the role of the Bretton Woods system in affecting transmission in that framework. For example, in a completely neoclassical model with perfectly flexible prices, the exchange-rate system may be unrelated to the international transmission of a whole variety of real disturbances, although it may affect the transmission of nominal disturbances. Adding rigidities and imperfections to that model affects the way a whole set of real disturbances is transmitted internationally under a pegged exchange-rate system, so development of the framework permits us to address international transmission under

Bretton Woods without the repetition involved in sequentially analyzing a long list of possible shocks.

Any basic framework that is to be useful in thinking about international transmission should be able to explain the main features that we observe in macroeconomic data under *any* exchange-rate system. These observations include the facts that output is positively correlated across countries, consumption is positively correlated across countries, consumption is less well correlated across countries than output, Solow residuals are positively correlated across countries but less positively correlated than output, and the balance of trade surplus is countercyclical (see, e.g., Backus, Kehoe, and Kydland, in press; Costello 1991; Stockman and Tesar 1991; and Waldmann 1990).

This paper presents a simple framework for analyzing the channels of international transmission of a wide variety of disturbances and discusses international transmission of real and monetary disturbances within several variants of that basic framework.[1] The paper then turns to evidence from the Bretton Woods system. Because the Bretton Woods system operated with full currency convertibility for only a relatively short time, the system provided limited evidence about international transmission. Previous studies have indicated not only that real exchange rates were less variable under Bretton Woods than under the subsequent system of floating rates but also that the behavior of real macroeconomic *quantities* was *not* substantially different across the exchange-rate systems (Baxter and Stockman 1989). This presents a puzzle and makes it difficult to draw inferences about the international transmission of real disturbances under Bretton Woods. Most economists believe that the difference in the behavior of real exchange rates under the two systems is connected with sluggish price adjustment and related to differences in monetary policy. This paper presents evidence that the international transmission of inflation was limited and that countries had, and used, scope for independence of money-supply growth and inflation under Bretton Woods.

6.1 A Simple Benchmark Model of International Transmission

Consider the simple two-country, two-good endowment model described in Lucas (1982) and Svensson (1985).[2] At each date t, the home country has a random endowment of good X, $2x_t$, and the foreign country has a random endowment of good Y, $2y_t$. Both goods are freely traded internationally. Each country has a fiat money, with supplies M_t and N_t subject to random growth rates through lump-sum transfer payments to home (or foreign) country residents. A representative household in each country maximizes discounted ex-

1. A similar framework has been used in a number of studies such as Cardia (1991), Frenkel and Razin (1987), Lundvik (1990), Mendoza (1991), and Stockman (1988a).

2. Stockman (1980) examines exchange rates in a similar model with incomplete financial markets.

pected utility over an infinite horizon, with time-separable utility and a fixed discount rate. The representative household in the home country maximizes

$$(1) \qquad E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} U(x_\tau^d, y_\tau^d),$$

where x_t^d and y_t^d are the household's consumptions of home and foreign goods. The maximization is subject to a budget constraint and cash-in-advance constraints. The cash-in-advance constraints require households to use sellers' currencies for purchases; for the representative domestic household the first such constraint is

$$(2) \qquad P_t x_t^d \leq M_t = M_{t-1} + (\omega_t - 1)\bar{M}_{t-1}\alpha_{1,t-1} ,$$

where P_t is the home-currency price of home goods at date t, and M_t is the money that the household has available for spending on goods in date-t product markets. The household begins the period with M_{t-1} from last period. The home government increases the home country's money supply (through lump-sum transfers to home residents) by

$$(3) \qquad \bar{M}_t - \bar{M}_{t-1} = (\omega_t - 1)\bar{M}_{t-1} ,$$

where $\bar{M}_{t-1}$ is the home money supply at the end of period $t - 1$. Households have previously traded assets with payoffs contingent on these lump-sum payments, so the home household keeps only a fraction α_1 of this transfer, paying a fraction $(1 - \alpha_1)$ to the foreign household.[3]

The second cash-in-advance constraint that the home household faces is

$$(4) \qquad P_t^* y_t^d \leq N_t = N_{t-1} + (\omega_t^* - 1)\bar{N}_{t-1}\alpha_{2,t-1} ,$$

which has a similar interpretation, where P^* is the foreign-currency price of the foreign good, and α_2 shows the extent to which the household *collects* payments of foreign money from the foreign representative household, contingent on foreign-country lump-sum transfers.

After trading in product markets at date t, households trade in date-t asset markets subject to the constraint

$$(5) \qquad M_t + e_t N_t + \alpha_t q_t = [M_{t-1} + (\omega_t - 1)\bar{M}_{t-1}\alpha_{1,t-1} - P_t x_t^d] + e_t[N_{t-1} + (\omega_t^* - 1)\bar{N}_{t-1}\alpha_{2,t-1} - P_t^* y_t^d] + \alpha_{t-1}(q_t + \delta_t) ,$$

where e_t is the exchange rate, α_t is a vector of four nonmoney assets that the representative domestic household owns at the end of date t, and q_t is the vector of date-t asset prices. The first two assets in the vector α (α_1 and α_2) are the claims to shares of lump-sum transfer payments discussed earlier. The second two assets (α_3 and α_4) are claims to home and foreign endowments

3. I discuss the role of these assets in international transmission below.

(equities). The vector α could be extended to include *any* other assets, but these assets are sufficient for a Pareto-optimal equilibrium in this model. The first two elements of the vector δ are zero (their dividends are included in the cash-in-advance constraints), the third element is the value of the home endowment, $2P_t x_t$, and the fourth element is the value of the foreign endowment, $2e_t P_t^* y_t$. Total assets supplies are normalized at one. There is an analogous maximization problem for the representative household in the foreign country.

One stationary rational expectations equilibrium in this model consists of home and foreign consumptions equal to half the world endowments of $2x_t$ and $2y_t$:

$$x_t^d = x_t, \quad y_t^d = y_t,$$
$$x_t^{d*} = x_t, \quad y_t^{d*} = y_t,$$

where asterisks denote foreign variables, and prices

$$P_t = \frac{M_t}{2x_t} \text{ if } \omega_t \leq \bar{\omega} \equiv \frac{\beta E_t\left[U_1(x_{t+1}, y_{t+1}) \frac{M_{t+1}}{P_{t+1}}\right]}{U_1(x_t, y_t)2x_t},$$

$$P_t = \frac{M_t U_1(x_t, y_t)\omega_t}{\beta E_t\left[U_1(x_{t+1}, y_{t+1}) \frac{M_{t+1}}{P_{t+1}}\right]} \text{ if } \omega_t \geq \bar{\omega},$$

$$P_t^* = \frac{N_t}{2y_t} \text{ if } \omega_t^* \leq \bar{\omega}^* \equiv \frac{\beta E_t\left[U_2(x_{t+1}, y_{t+1}) \frac{N_{t+1}}{P_{t+1}^*}\right]}{U_2(x_t, y_t)2y_t},$$

$$P_t^* = \frac{M_t^* U_2(x_t, y_t)\omega_t^*}{\beta E_t\left[U_2(x_{t+1}, y_{t+1}) \frac{N_{t+1}}{P_{t+1}}\right]} \text{ if } \omega_t^* \geq \bar{\omega}^*,$$

$$e_t = \frac{E_t\left[\frac{U_2(x_{t+1}, y_{t+1})}{P_{t+1}^*}\right]}{E_t\left[\frac{U_1(x_{t+1}, y_{t+1})}{P_{t+1}}\right]}.$$

There are other stationary rational expectations equilibria corresponding to different distributions of wealth between the home and the foreign countries. To the extent that we know about the behavior of these other equilibria (as we do if preferences are members of the HARA class of utility functions), we can expect the international transmission of disturbances to be qualitatively the same in other stationary rational expectations equilibria.

Suppose that transfers of home money are exogenous and that the foreign money supply adjusts to peg the exchange rate. This assumption affects only nominal prices because real allocations are independent of the exchange-rate system—and money supplies—in this benchmark model. Although this model is quite limited, it provides a simple benchmark for the international transmission of real technology (endowment) and money-supply shocks. Obviously, real shocks in the home country are positively transmitted to foreign consumption in this model, and changes in the money supply are positively transmitted to the foreign money supply and nominal prices (under pegged exchange rates).

This leaves the question of how real technology (endowment) shocks are transmitted to the foreign money supply and foreign nominal prices. The answer depends on the size of the (intratemporal) elasticity of substitution in consumption between foreign and domestic goods. To see why, consider the effect of a 1 percent rise in the endowment of the home good (X) at date t, holding fixed the home money supply. This reduces the equilibrium relative price of the home good at date t by more or less than 1 percent depending on whether the elasticity of substitution is smaller or larger than one. Suppose that the money-growth rates exceed their critical values so that in equilibrium $M = P2x$ and $N = P^*2y$; then P falls by 1 percent. Since the exchange rate is pegged, the foreign-currency price of the foreign good must adjust so that the relative price of home and foreign goods, P/eP^*, reaches its new equilibrium level. Since the foreign endowment has not changed, this occurs through a change in the foreign money supply to keep the exchange rate pegged. If the elasticity of substitution in consumption is greater than (less than) one, the equilibrium relative price P/eP^* falls by less (more) than 1 percent, so the foreign money supply N and the foreign-currency price of foreign goods, P^*, must fall (rise) in equilibrium. Since the home price of home goods (P) falls, we can say that there is *positive transmission* to the foreign money supply and foreign nominal prices if N and P^* also fall.[4] So there is positive transmission of the home endowment shock to foreign nominal variables if the (intratemporal) elasticity of substitution in consumption is greater than one and negative transmission if the elasticity of substitution is less than one.[5]

6.2 Incomplete Financial Markets

The model above contains assets α_1 and α_2 that do not exist in any obvious form in real-life economies. (There may, of course, be other assets that provide highly correlated returns so that those assets are not necessary.) Without these two assets, changes in the money supply in either country redistribute

4. That is, we can use the term *positive transmission* as shorthand for a positive comovement of home and foreign variables due to a shock in one country.

5. In general, this criterion also depends on the income elasticity of the demand for money, which is one in the case considered here.

wealth internationally, leading to some negative transmission in consumption. But the fraction of total wealth held as net nominal assets is small in real life, so the international wealth redistribution from unexpected changes in money supplies is probably not a major source of international transmission. (If the redistributions were very large, we might expect to see the assets α_1 and α_2 traded internationally.) The more important redistributions of wealth that are absent in the model above are those associated with changes in real asset values when households have not used financial markets to diversify risks internationally. The model outlined above neglects information costs and other frictions that limit international diversification. The question that concerns us here is, How important is this for international transmission?

Dellas (1986) and Cole and Obstfeld (1991) have shown that, in a barter model like the one described above, incomplete financial markets may not change the equilibrium much. In particular, if utility is Cobb-Douglas, the set of possible equilibria is *exactly* the same with complete financial markets and with *no* financial markets (each equilibrium corresponds to a particular distribution of wealth or utility weights in a social planner's problem). Changes in endowments cause price changes that redistribute income on a period-by-period basis so that each household can afford to buy exactly the equilibrium consumption bundles specified above, and this maximizes the household's utility. For example, a 1 percent increase in the home endowment of X reduces its relative price by exactly 1 percent, raising the amount that foreign households can afford (and choose to buy, with this utility function) by exactly 1 percent. (Notice that the Cobb-Douglas assumption would result in exactly zero international transmission to foreign nominal prices in the monetary model outlined above.)

Cole and Obstfeld show a sense in which the outcome is *close* to the complete-market situation if utility is *close* to Cobb-Douglas. In this situation, the incompleteness of financial markets has little effect on the international transmission of real disturbances to technology: the transmission to foreign consumption remains positive. This is an important issue because there *were* serious restrictions on international financial markets in the Bretton Woods period.

The result that restrictions on international financial markets do not have a major effect on the equilibrium is extremely sensitive to certain features of the model. As Cole and Obstfeld point out, if each country produces a third traded good, an increase in its output in the home country (but not the foreign country) reduces its price and therefore reduces the value of the foreign country's output. When financial markets are incomplete, this redistributes income from the foreign to the home country, causing negative transmission in consumption spending. Similarly, when either country produces and consumes a nontraded good, changes in consumption of that nontraded good can alter the marginal utility of consumption of traded goods unless traded and nontraded goods are separable in utility, destroying the conclusion that the incomplete-markets equilibrium is the same as the complete-markets equilibrium even with Cobb-Douglas preferences. In this case, if traded and nontraded goods are complements in consumption (as the evidence indicates), an increase in the home endowment of nontraded goods is transmitted negatively to foreign consumption of traded goods (see Stockman and Tesar 1991).

The ability to trade on international financial markets also affects the international transmission of real shocks to technology if there is incomplete specialization in production (or endowment) of traded goods and there are *nation-specific* productivity shocks. With complete specialization, there is no distinction between industry-specific and nation-specific shocks to technology. But suppose that there is incomplete specialization: each country produces (or receives endowments of) both traded goods (X and Y). If productivity shocks are *industry specific,* the model's prediction that the incomplete-markets equilibrium is identical with the complete-market equilibrium (with positive transmission of the shock to foreign consumption) continues to hold. If, for example, the home country produces three-fourths of the world's output of X and one-fourth of its output of Y, then technology shocks that are industry specific and worldwide produce the same equilibrium consumption and prices as the complete-specialization model. (In the extreme case, each country produces its own consumption bundle of traded goods, and there is no international trade.) But if there are *nation-specific* productivity shocks, the result changes: an increase in productivity in the home country (in all industries) but *not* in the foreign country redistributes income from the foreign to the home country and causes a fall in foreign consumption relative to home consumption.[6] The magnitude of the income redistribution depends on the price change, which in turn depends on the elasticity of substitution in consumption. If the redistribution is large enough, the positive productivity shock in one country causes a fall in foreign consumption, so there would be negative international transmission in consumption. There is a general tendency for incomplete financial markets to cause negative international transmission because shocks can redistribute income from one country to another, leading to opposite wealth effects in the two countries.

6.3 Disturbances to Preferences

The discussion to this point has been limited by the assumption that all real shocks appear on the technology side. We can add preference shocks to this model by respecifying utility as

$$U(\pi_x x^d) + V(\pi_y y^d) \quad \text{and} \quad U(\pi_x^* x^{d*}) + V(\pi_y^* y^{d*}),$$

6. For evidence on nation-specific and industry-specific shocks, see Stockman (1988b), Costello (1991), and Waldmann (1990).

where

$$\pi = (\pi_x, \pi_y, \pi_x^*, \pi_y^*)$$

is a vector of random taste shocks. Then an equilibrium allocation is

$$x^d = x[\pi_x^*/(\pi_x + \pi_x^*)], \quad x^{d*} = x[\pi_x/(\pi_x + \pi_x^*)],$$

and

$$y^d = y[\pi_y^*/(\pi_y + \pi_y^*)], \quad y^{d*} = y[\pi_y/(\pi_y + \pi_y^*)],$$

because this satisfies equality of marginal utilities, which implies $\pi x^d = \pi^* x^{d*}$ such that $x^d + x^{d*} = x$ and the analogous condition for good Y. This implies that a positive taste shock for one of the goods in the home country (a *fall* in α_x, e.g., which raises home consumption of good X) is transmitted *negatively* to foreign consumption of that good. If utility were nonseparable, foreign consumption of the good that is *not* subject to the shock rises or falls depending on the sign of the cross-derivative in utility, which could reinforce or mitigate the negative international transmission in consumption.

6.4 Production

The international transmission of technology disturbances in a model with production has received less attention except within one-sector models or at the microeconomics level for particular industries. Two recent papers, Backus, Kehoe, and Kydland (in press) and Baxter and Crucini (in press), address transmission issues (among other topics) in two-country, one-sector, real-business-cycle models. In these models, nation-specific shocks to technology have some persistence, so a positive technology shock in the home country (alone) raises both current output and the expected marginal product of capital. If factors are sufficiently mobile internationally, factors move from the foreign to the home country, reducing foreign output and creating negative international transmission in production. If people have pooled risk in asset markets to a sufficient degree (as in the models cited), the shock is transmitted positively to foreign consumption: domestic and foreign consumption move together. The negative transmission to foreign production and positive transmission to foreign consumption make it difficult for these models to explain the observation that the international correlation of consumption is positive but smaller than that of production. In fact, the cross-country correlation of industrial production was higher in the Bretton Woods period than after 1973 (see Baxter and Stockman 1989). One explanation is that there were (and are) seriously incomplete international financial markets or that, because of information costs, people did (and do) not make use of available financial markets to diversify internationally. Other explanations include nontraded goods

(Stockman and Dellas 1989)[7] and preference shocks that changed consumption independently across countries (Stockman and Tesar 1991).

Productivity shocks are transmitted internationally even if factors are internationally immobile. There are three main channels of transmission. First, if foreign and domestic goods are perfect substitutes in consumption as in the one-sector models cited above, then increased output in the home country reduces the real interest rate. The fall in the real interest rate can reduce foreign output temporarily through intertemporal substitution in labor supply and in the utilization rate of capital. This interest-rate channel creates *negative* transmission of a home productivity shock to foreign output. This channel of transmission also operates, although with less strength, when home and foreign goods are imperfect substitutes.

A second channel of transmission also occurs through demand. Suppose that leisure and consumption are substitutes in utility in the sense of a negative cross-derivative in the utility function. Then a home productivity disturbance in a risk-pooled world raises foreign consumption. Since this reduces the foreign marginal utility of leisure, it raises foreign employment and output. This tends to create *positive* international transmission to foreign output.

A third channel of transmission occurs through demand for capital inputs. Here temporary and permanent productivity shocks can be transmitted differently to foreign countries. A temporary productivity shock in the home country creates a trade surplus in the home country as domestic consumption and foreign consumption rise. With repeated shocks, consumption tends to be more highly correlated across countries than is output. On the other hand, a permanent or highly persistent productivity shock in the home country can cause a trade deficit because the shock raises the expected marginal product of investment and imports of (or to be used as) capital. If equilibrium investment in the home country rises more than output, the home country can have a trade deficit in the short run. If the productivity shock is persistent but not permanent, then it dies away as time passes, so eventually the increased home output (from higher productivity and a higher capital stock) exceeds the increase in investment. Then the trade deficit can turn to a trade surplus.

When productivity shocks are positively correlated across countries, home and foreign output can move together even without any international *transmission* of disturbances. This creates the difficult empirical issue of distinguishing the *transmission* of shocks from correlated disturbances in different countries. Evidence from Costello (1991) and Waldmann (1990) indicates that the cross-country correlation of Solow residuals, intended to measure technology shocks, is lower than the cross-country correlation of outputs. If this were the

7. Nonseparability in utility between consumption of nontraded and traded goods can create less than perfect correlation in consumption of traded goods even with complete markets because a change in production and consumption of the home nontraded good alters equilibrium home consumption of the traded good, tending to move home and foreign consumption of traded goods in opposite directions.

only source of exogenous disturbances, we might attribute the excess correlation of output (over productivity shocks) to transmission.[8]

6.5 International Transmission in the Presence of Nontraded Goods

Nontraded goods can play an important role in international transmission.[9] Consider a productivity shock in the home country nontraded-goods industry. This is likely to raise home consumption of nontraded goods, and, because traded and nontraded goods are complements in consumption (see above), this raises home demand for traded goods. In equilibrium, home consumption of traded goods rises—partly through increased foreign output of traded goods and partly through decreased foreign consumption of traded goods. (Home output of traded goods might increase because of the increase in demand, or it might decrease because of the increase in factor productivity in the nontraded-goods sector, leading factors to migrate to that sector.) So the productivity disturbance in the home nontraded sector can be transmitted positively to foreign production and negatively to foreign consumption (see Stockman and Tesar 1991).

Similar results follow from preference shocks. Consider a preference shock in the home country that temporarily raises the marginal utility of consumption of all goods. This causes a home-country trade deficit, raises traded-goods output in both countries, and raises nontraded-goods output in the home country (because of complementarity between traded and nontraded goods in consumption). Output of nontraded goods in the foreign country falls both because foreign factors move from the nontraded- to the traded-goods industry in response to the higher relative price of traded goods (due to the taste shock) and because foreign consumption of traded goods falls and (through complementarity) reduces foreign demand for nontraded goods. So the shock is transmitted *positively* to foreign output of traded goods, *negatively* to foreign output of nontraded goods, and *negatively* to foreign consumption. The taste shock also raises the relative price of the domestic consumption bundle, which includes home nontraded goods, so it causes real appreciation in the home country that appears under a pegged exchange-rate system as a rise in the home price level relative to the foreign price level. The importance of nontraded goods for international transmission is enhanced when governments "create" nontraded goods out of traded goods through restrictions on international trade; overall, trade restrictions were somewhat higher under Bretton Woods (particularly before the Kennedy Round tariff reductions) than they are today.

8. This runs into problems associated with differences across countries in the timing of the effects of productivity shocks on output. The response to a common shock may occur more rapidly in one country than another despite the absence of "transmission" across countries.

9. For an entirely different channel of international transmission of monetary disturbances in the presence of nontraded goods than that summarized below, see Miller and Todd (1991).

6.6 International Transmission with Sticky Prices

Sticky prices are widely regarded as an important feature of macroeconomic data. Svensson (1986) added short-run price stickiness to a model similar to the one discussed above, using it to investigate the international transmission of fiscal policy in Svensson (1987) and the international transmission of monetary disturbances under *floating* exchange rates in Svensson and van Wijnbergen (1989). To discuss international transmission under Bretton Woods, I will examine the effects of monetary disturbances with fixed exchange rates in Svensson's model.

The setup of the model remains mostly the same: the representative household in the home country maximizes (1) subject to the sequence of constraints (2), (4), and (5), and there is an analogous problem for the foreign representative household. Now, however, firms set nominal prices one period in advance as in Svensson (1986) and Svensson and van Wijnbergen (1989). Output in each country per capita is determined by demand subject to the capacity constraints

$$2x_t \leq 2\bar{x}_t, \quad 2y_t \leq 2\bar{y}_t.$$

The capacity constraints imply that, if demand exceeds capacity, there is rationing:

$$x_t^d \leq x_t \quad \text{and} \quad y_t^d \leq y_t.$$

The foreign money supply adjusts to keep the exchange rate pegged at

$$e_t \equiv e \quad \forall\, t.$$

Define the exogenous part of the state vector by

$$s_t = (x_t, y_t, \omega_t).$$

Assume that the vector s is random and independently drawn over time.

An equilibrium is a set of functions of the state vector s and the predetermined variables—nominal prices and the levels of the beginning-of-period money stocks of each country—used to describe output and each country's consumption of each good, nominal goods prices set for the following period, the foreign money-growth rate, asset holdings, and asset prices, such that each representative consumer maximizes utility subject to its budget and cash-in-advance constraints, firms maximize market value by choice of nominal prices, and markets clear with a fixed exchange rate. Assume that firms operate in the monopolistically competitive environment described in Svensson (1986), which builds on Dixit and Stiglitz (1977), and assume that a stationary rational expectations equilibrium exists.

Although many of the characteristics of the equilibrium of this model are similar to those discussed by Svensson in his model with flexible exchange rates, international transmission under the pegged-rate system considered here differs from the discussion by Svensson and van Wijnbergen for a flexible exchange-rate system. Notice that the price-setting problem facing firms is a stationary problem. Svensson's proof that firms set nominal prices proportionally to the current money supply applies to this model, so at time $t - 1$ firms set period-t prices by the formulas

$$P_t = \frac{\bar{M}_{t-1}}{k} = \frac{\bar{M}_t}{\omega_t k} \quad \text{and} \quad P^*_t = \frac{\bar{N}_{t-1}}{k^*} = \frac{\bar{N}_t}{\omega^*_t k^*},$$

where k and k^* are constants.

The possible stationary equilibria of the model divide into three parameter regions for each country, depending on whether the cash-in-advance constraint binds, the output-capacity (full-employment) constraint binds, or neither constraint binds (so there are nine regions in all because there are two countries). Obviously, small changes in monetary policy have no effects on output if the full-capacity constraint is binding (except at the border of that region). But monetary policy has real effects in the other regions. First suppose that the cash-in-advance constraint for spending on the domestic good but *not* the domestic full-capacity constraint binds. Then home output is

$$2x_t = \frac{\bar{M}_t}{P_t} = \omega_t k.$$

Similarly, if the cash-in-advance constraint for spending on the foreign good but *not* the foreign full-capacity constraint binds, then foreign output is

$$2y_t = \frac{\bar{N}_t}{P^*_t} = \omega^*_t k^*.$$

Now consider the equilibrium region in which neither the cash-in-advance constraint nor the full-capacity constraint binds for either good. In the interior of this region, home output and foreign output per capita solve the equations

$$U_1(x_t, y_t) = \frac{\lambda_t}{P_t} = \frac{A}{\omega_t} \quad \text{and} \quad U_2(x_t, y_t) = \frac{\lambda^*_t}{P^*_t} = \frac{A^*}{\omega^*_t},$$

where A and A^* are positive constants that come from the first-order conditions for choices of end-of-period money holdings. A and A^* are constants because of the assumption that shocks are i.i.d. (so that expected future variables are independent of the current state).

Now consider the international transmission of monetary policy in this fixed-exchange-rate model with sticky prices. First suppose that, for each good, the cash-in-advance constraint binds but that the full-capacity constraint does not. In this region, a permanent rise in the home money supply (a positive i.i.d. shock to the home country's money-growth rate) raises home output. It has no effect on foreign output unless it affects the foreign money supply. Since the exchange rate in period-t asset markets (after the close of period-t product markets is

$$e_t = \frac{\bar{M}_t A^* k}{\bar{N}_t A k^*} = \frac{\omega_t \bar{M}_{t-1} A^* k}{\omega_t^* \bar{N}_{t-1} A k^*},$$

an increase in the home money supply leads to an equal proportional increase in the foreign money supply to keep the exchange rate pegged:

$$\omega_t^* = \omega_t \bar{e}_t \frac{\bar{M}_{t-1} A^* k}{\bar{N}_{t-1} A k^*}.$$

So in this region—where for each good the cash-in-advance constraint binds but the full-capacity constraint does not—an increase in the home money supply raises real output in both countries: there is positive international transmission to foreign output. (Under a flexible-exchange-rate system, in contrast, there is no transmission to foreign output in this region if the home monetary expansion leaves the foreign money supply unaffected.)

Now consider the region in which neither the cash-in-advance constraint nor the liquidity constraint binds for either good. Svensson and van Wijnbergen demonstrate that, under a floating-exchange-rate system, a home monetary expansion has two effects, with opposite signs, on foreign output. A home monetary expansion raises output and consumption of the home good, while, *given* the foreign rate of money growth, the effect on foreign output depends on the sign of the cross-derivative in the utility function, U_{12}. Foreign output rises, remains the same, or falls depending on whether U_{12} is positive, zero, or negative.[10] This cross-derivative is positive (or negative) if and only if the intertemporal elasticity of substitution in aggregate consumption is greater (or less) than the intratemporal elasticity of substitution between consumption of home and foreign goods. So under flexible exchange rates there is positive international transmission of output in response to a permanent monetary disturbance if the elasticity of intertemporal substitution exceeds the elasticity of intratemporal substitution between home and foreign goods. Otherwise, a permanent increase in the home money supply is transmitted negatively to foreign output.

Under pegged exchange rates, there is a third effect. The foreign money supply rises proportionally to the increase in the home money supply, implying equal percentage changes in the marginal utility of consumption of home

10. This follows directly from the expressions for home and foreign output in this region. Suppose, e.g., that output and consumption of the home good increases. If $U_{12} > 0$, this raises the marginal utility of consumption of the foreign good, so we require an increase in output and consumption of the foreign good to bring its marginal utility back to the unchanged equilibrium level (for given foreign money growth).

output and the marginal utility of consumption of foreign output. This implies that foreign output rises *regardless* of the relative magnitudes of the intertemporal and intratemporal elasticities of substitution in consumption:

$$\frac{dy}{d \ln \omega} = \frac{-U_{22}U_1 + U_{12}U_2}{U_{11}U_{22} - U_{12}^2} > 0$$

and

$$\frac{dx}{d \ln \omega} = \frac{-U_{11}U_2 + U_{12}U_1}{U_{11}U_{22} - U_{12}^2} > 0.$$

While this model predicts short-run real effects of monetary disturbances, it does not predict differences in inflation across countries under pegged exchange rates. Figures 6.1–6.3 below show that, despite a period of stable nominal exchange rates from 1962 until the end of the decade, there were sizable differences in inflation across countries (measured using consumer price indexes). Even during the period before the devaluation of sterling in 1967, the average inflation rate was higher in Japan, Italy, and the Netherlands than in Canada, Germany, France, the United Kingdom, and Belgium and lower in the United States. From 1962 to 1967, inflation in the United States averaged 1.9 percent per year, while inflation in Japan, Italy, and the Netherlands was above 4 percent per year.

In the model discussed here, nominal prices are predetermined each period, so there is no short-run effect of the home monetary expansion on nominal prices in this model. But prices change in the periods following a monetary disturbance. Since nominal prices for date $t + 1$ are set at date t in proportion to the period-t money supply, an increase in the home money supply at date t could in principle affect the *relative* price of home and foreign goods starting at date $t + 1$. The assumption of i.i.d. shocks, however, prevents this from occurring: the foreign money supply and the foreign nominal price of the foreign good rise in proportion to the change in the home money supply, to keep the exchange rate pegged. So this model produces real effects of monetary disturbances through sticky prices, but it cannot (in this form) explain why short-run inflation rates may differ across countries with pegged exchange rates. To do that probably requires a model with real costs of short-run arbitrage, as in Dumas (1987), where arbitrage occurs with a delay because of the time required to ship goods from one country to another. For some time following an unexpected disturbance (but not permanently), nominal prices in the home country can differ from nominal prices in the foreign country. Although Dumas's model is real, it is reasonable to conjecture that a monetary version of his model would imply that monetary shocks in a country can have short-term effects on domestic inflation even under a pegged exchange-rate system. Further theoretical study of this issue would be worthwhile because the next section presents evidence that suggests that monetary policy was able to affect inflation in the short run under the Bretton Woods system despite pegged exchange rates.

6.7 Evidence of the International Transmission of Inflation

The Bretton Woods system consisted of an initial phase in which most currencies were nonconvertible, international trade in goods and financial assets was severely restricted, and international trade that did occur was mainly bilateral barter. Because of the peculiar difficulties arising from inconvertibility and extensive controls as well as an absence of reliable data, the analysis below concentrates on the second period of Bretton Woods, after 1958, in which currencies were convertible and for which more reliable data become available. For much of the analysis, the sample period is restricted further.

Figure 6.1 shows nominal exchange rates against the U.S. dollar for a set of eight countries under this second phase of the Bretton Woods system. There is no long period of fixed exchange rates: the longest such period is from 1962:3, when Canada pegged to the U.S. dollar (or 1961:2, after Germany's revaluation), through 1967:3, before the devaluation of the pound sterling. Figure 6.2 shows inflation under Bretton Woods in the same nine countries (measured with consumer price indexes). Even for subperiods during which nominal exchange rates were pegged, inflation differentials across countries were large. Average inflation during 1963–67, shown in figure 6.3, ranged from 1.9 percent per year in the United States to rates above 4 percent in the Netherlands, Italy, and Japan. Figure 6.4 shows real exchange rates, defined as the relative price of the U.S. CPI bundle of goods in terms of the home country's CPI bundle (i.e., as e^*P[United States]/$P[n]$ for nation n). The most striking aspect of the figure is that these relative prices change dramatically when nominal exchange rates change with currency devaluations or revaluations. This fact is well known and often cited as evidence that nominal prices are sticky, so that devaluations cause changes in relative prices. A further striking observation is that there appears to be little tendency for the relative price changes accompanying devaluations to reverse themselves in subsequent months or years.[11]

Because the Bretton Woods experience was brief after the restoration of currency convertibility in 1958, the evidence on international transmission available from the Bretton Woods period is quite limited. To draw inferences with as much evidence as possible from these limited data, this paper makes use of the combined cross-sectional/time-series feature of the data by testing and imposing constraints on coefficients across equations for various coun-

11. These revelations and devaluations are, in one sense, the biggest economic shocks to occur under the Bretton Woods system. They had major effects on real exchange rates. By far the largest changes in real exchange rates during this period occurred with these changes in official pegs. Yet they appear to have had little effect on international trade, output, employment, and other variables (see Baxter and Stockman 1989).

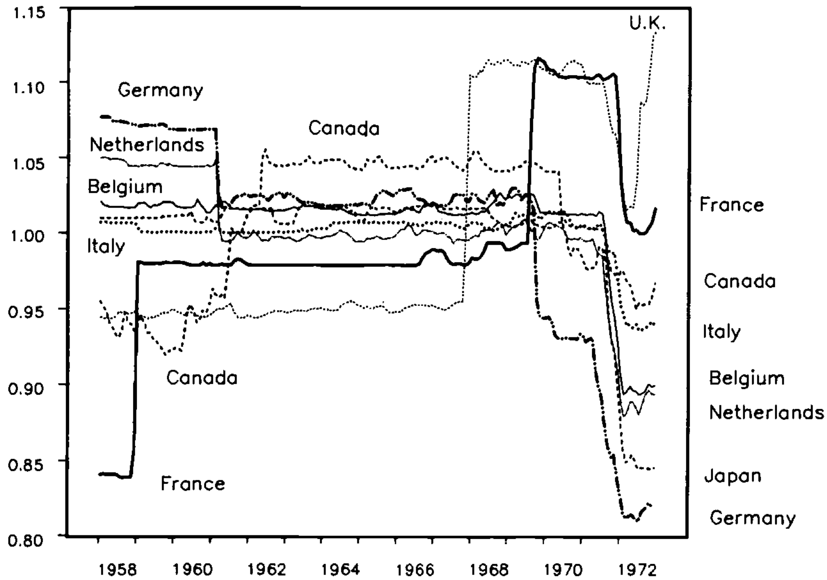

Fig. 6.1 Exchange rates under Bretton Woods, 1958–72

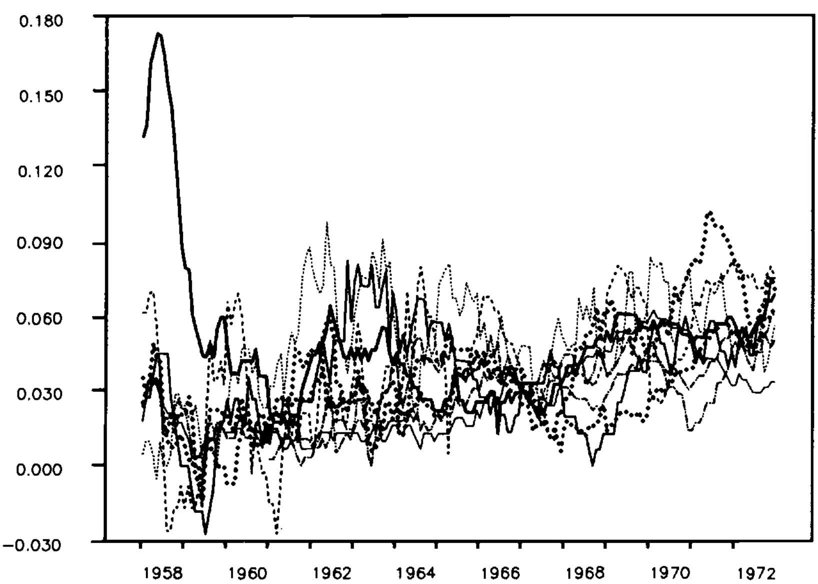

Fig. 6.2 Inflation under Bretton Woods, 1958–72 (monthly series on twelve-month inflation rates)

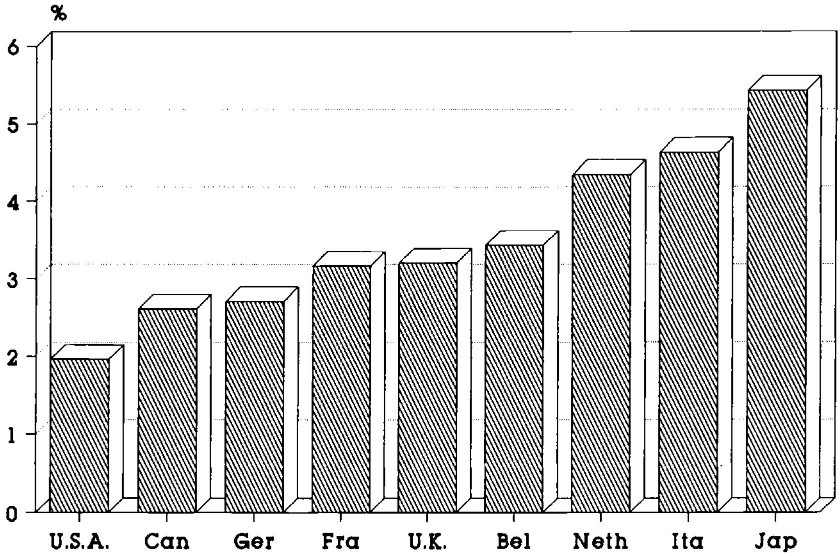

Fig. 6.3 Average inflation, 1962–67

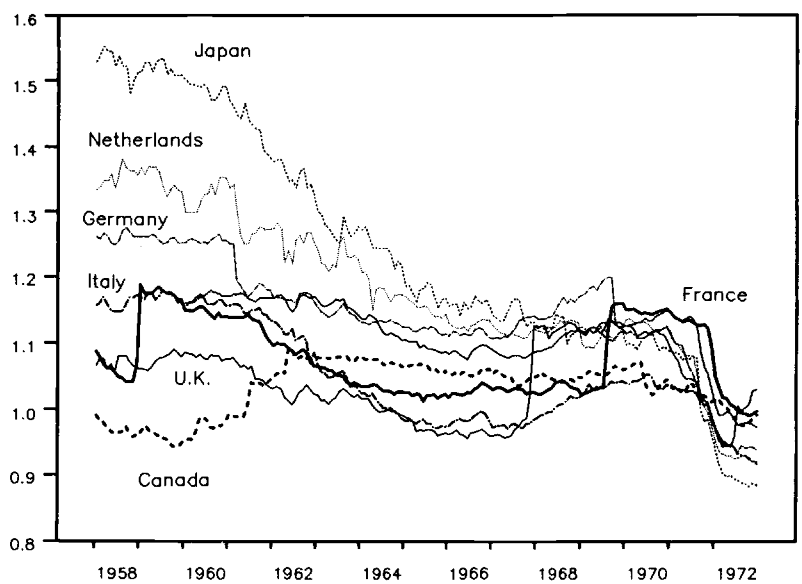

Fig. 6.4 Real exchange rates under Bretton Woods, 1958–72 (U.S. CPI divided by national CPI, adjusted by exchange rate)

tries. Furthermore, the discussion below focuses on international differences in inflation across countries rather than on the level of inflation in each country. By examining differences between pairs of countries, the analysis can abstract from issues concerning worldwide price changes that affected countries equally and focus on the limits to international transmission of inflation during this period.

At first glance, it appears that there is no relation between differences in inflation across countries and differences in money-supply growth rates across countries (measured by any monetary aggregates). Simple correlations are all close to zero. The average correlation between contemporaneous differences of quarterly growth rates of M1 and CPIs—across all pairs of countries in a sample including Canada, France, Germany, Italy, the United Kingdom, and the United States for periods during which the exchange rate was fixed—is negative. Correlations close to zero also appear at most leads and lags, except when one of the countries in the pair is the United States. Similarly, bivariate Granger-causality tests show no relation between international differences in inflation and money-growth rates. For the sample of countries including Canada, France, Germany, Italy, the United Kingdom, and the United States, almost every pairing shows no Granger causality in either direction. These results are consistent with the monetary approach to the balance of payments if differences in inflation across countries reflect measurement error, in which case they are unrelated to changes in nominal money demand and, as a result, nominal money supply. They are not clearly supportive of the monetary approach if international differences in inflation result from changes in the relative prices of nontraded goods, in which case higher-inflation countries might be expected to have greater growth rates of nominal money demand and so nominal money supplies.

But the implications of the data change dramatically when other relevant variables are included in the analysis: there is evidence that changes in the money supply in one country led to subsequent changes in that country's inflation rate (given foreign inflation) in the short run. That is, there was only *partial* international transmission of foreign inflation to the domestic country in the short run. The short sample of data is not able to provide strong evidence about the long run; the evidence reported here is not inconsistent with the idea that the effects of domestic money growth on domestic inflation vanished in the long run so that the international transmission of foreign inflation to each country was complete in the long run. On the other hand, the data for the Bretton Woods period do not provide strong evidence for or against *any* hypothesis about the long run.

Because the time series are short but there are data for several nations, the results reported below are estimated jointly across country pairs, allowing disturbances to be contemporaneously correlated (although uncorrelated at all leads and lags), and impose restrictions that certain coefficients are identical across equations. (The coefficient restrictions were also tested as described below.) Specifically, let

$$\delta(a, b, x) = x(a) - x(b)$$

be an operator that takes the difference in the variable x between countries a and b. For example, $\delta[\text{France, Germany}, d\log(p)] = d\log(p)_{\text{France}} - d\log(p)_{\text{Germany}}$. Denote the price level measured by the CPI (other measures give results similar to those reported below) by p, the narrow money supply by M1, the three-month nominal interest rate by i, and real GDP by y. Consider joint estimation of the equations

$$\begin{aligned} &\delta\left[\text{nation, US}, d\log(p)\right] = \alpha(L)\delta\left[\text{nation, US}, d\log(p)\right] \\ (6)\quad &+ \mu(L)\delta\left[\text{nation, US}, d\log(\text{M1})\right] + \Gamma(L, \text{nation})\delta(\text{nation, US}, i) \\ &+ \eta(L, \text{nation})\,\delta\left[\text{nation, US}, d\log(y)\right] + \varepsilon(\text{nation}) \end{aligned}$$

for nation = Canada, France, Germany, Italy, and the United Kingdom. All variables are quarterly and expressed as deviations from means. They are seasonally adjusted at the source, although the equation also included seasonal dummies.

Begin by imposing the restriction that all coefficients are identical across nations. A test of this restriction for each set of coefficients (one set at a time) showed that some of these restrictions were rejected. Consider, for example, the hypothesis that $\Gamma(L, \text{nation})$ and $\eta(L, \text{nation})$ are the same for all nations except Canada; that is, $\Gamma(L, \text{nation}) = \Gamma(L)$ and $\eta(L, \text{nation}) = \eta(L)$ for all nations except Canada (where $\Gamma[L]$ and $\eta[L]$ do not depend on the nation). Wald tests of these hypotheses generate chi-square statistics with degrees of freedom equal to the number of restrictions. Almost all these tests led to rejections at p-values smaller than .0001.[12] As a result, these coefficients are left unconstrained in the results reported below. (Those estimates show clearly that $\Gamma[L]$ and $\eta[L]$ differ across nations.)

On the other hand, one cannot reject (at any reasonable significance level) the hypothesis that the coefficients $\alpha(L)$ and $\mu(L)$ are independent of the nation, with one exception: $\alpha(4)$ for Canada is significantly different than $\alpha(4)$ for other countries. So, with this exception, the estimates reported below impose the restrictions that the vectors α and μ are independent of the nation. They also assume that $V(\varepsilon) = \Sigma$ is a symmetric positive definite matrix and that $V(u_t, u_{t-s}) = 0$ for all t and s. While $\alpha(0) = 0$, the parameters $\mu(0)$, $\Gamma(0)$, and $\eta(0)$ were estimated along with the other parameters. Because standard models imply that the differentials in money-growth rates are endogenous and

12. The Canadian-French case was an exception: the p-value was .18. This might suggest that the coefficients for Canada and France could be constrained to be identical, although the estimates reported here do not impose this constraint.

could be correlated with the disturbances, the estimates reported below were obtained using instrumental variables. The instruments were—in addition to all lagged variables in the equation—current and lagged values of the U.S. federal funds rate and the growth rate of the U.S. monetary base. The lag length for each variable is four quarters (experiments indicated that longer lags do not affect the results).

The first results, for the period 1960:1–1971:2, appear in table 6.1. The actual period differs across countries because of data availability (see the data appendix). The estimates show strong effects of lagged differentials in money growth on the inflation differential.[13] The sum of the coefficients on the money-growth differential is .28, indicating (subject to the usual caveats on this interpretation) that a sustained 1 percent rise in domestic money growth relative to foreign money growth leads to a .28 percent rise in the inflation differential under pegged exchange rates. The effect of the contemporaneous money-growth differential is small; most of the effect is associated with lagged money-growth differentials.[14]

Estimated coefficients on interest-rate differentials and income-growth differentials vary significantly from country to country. Wald tests of the null hypothesis that the (lagged or current and lagged) money-differential coefficients are jointly zero are rejected at more than the .0001 level. There is little evidence of autocorrelation of residuals, as the table shows, and tests that the disturbances are normally distributed fail to reject that hypothesis at the usual significance levels. The results are nearly identical when the equations are estimated for a shorter sample period that excludes Canadian data before 1962:3, when the Canadian dollar floated against the U.S. dollar, and after 1970:1, when it floated again; German data starting in 1969:4, when the deutsche mark was revalued; and U.K. data starting in 1967:4, when the pound was devalued. Again, there is a strong connection between inflation differentials and lagged money-growth differentials.

The natural interpretation of these results is that the governments of these countries had some control over money growth despite pegging their exchange rates: central banks were able to and sometimes did "sterilize" changes in international reserves to affect domestic money growth.[15] Moreover, these differential rates of growth of money appear to have affected inflation differentials. One cannot, however, rule out other (reverse-causality) interpretations

13. When the equation is reestimated allowing for eight lags of money-growth differentials, the chi-square statistic for the hypothesis that the coefficients on lags 5–8 are jointly zero is only 2.08 (p-value = .72). And all four of these coefficients were very close to zero individually. So only the four lags were included in subsequent estimates.

14. The equation also includes nominal-interest differentials and GDP-growth differentials. Full results were reported in the first draft of this paper and are available on request from the author.

15. Iwami (1991) discusses monetary policies under Bretton Woods and compares that system to the gold standard; he argues that U.S. policy under Bretton Woods did not follow the analogous "rules of the game" for a gold standard. Iwami argues that U.S. neglect of the rules of the game allowed other countries to pursue expansionary policies and that this system was viable for the short run but not the long run, so it eventually broke down after its credibility had been strained.

Table 6.1 Effects of Money-Growth Differentials on Inflation Differentials

		Coeff.	SE	t-Stat.	p-Value
δd log $(M1)_t$		.020	.019	1.03	.32
δd log $(M1)_{t-1}$		.098	.016	6.15	.00
δd log $(M1)_{t-2}$		.056	.017	3.24	.01
δd log $(M1)_{t-3}$		.062	.018	3.36	.00
δd log $(M1)_{t-4}$		.039	.020	1.90	.08
δd log $(p)_{t-1}$		.098	.073	1.35	.20
δd log $(p)_{t-2}$		−.029	.068	−.42	.67
δd log $(p)_{t-3}$		.120	.066	1.81	.09
δd log $(p)_{t-4}$, others		.081	.071	1.14	.27
δd log $(p)_{t-4}$, Canada		.610	.144	4.22	.00
	Canada	France	Germany	Italy	UK
R^2	.64	.58	.79	.74	.68
	Autocorrelations of Residuals				
	Canada	France	Germany	Italy	UK
1st	.10	−.03	.11	−.23	.13
2d	.16	−.31	.28	−.01	−.18
3d	.04	.15	.06	.18	−.28
4th	.03	.04	−.06	−.07	−.11
SE	.16	.19	.17	.17	.19
p-value[a]	.82	.52	.55	.38	.50

Note: These are joint instrumental variables estimates of eqq. (6): the dependent variable is δ[nation, US, d log(p)]. The equation also includes current and lagged values of interest-rate differentials and differentials of GDP growth rates; the coefficients of these variables were allowed to differ across countries.

When money-growth differentials are *excluded* from the equations, the R^2 vector is .35 for Canada, .54 for France, .76 for Germany, .72 for Italy, and .54 for the United Kingdom.

[a]p-value refers to the Box-Pierce Q-statistic for the first four autocorrelations.

of the results. For example, it is possible that differentials in inflation were caused by changes in relative prices of nontraded goods (which show up in retail prices of traded goods because of nontraded components of value added such as retailing and transportation). To explain the correlation between inflation differentials and lagged money-growth differentials, the real disturbances would have to raise the monetary aggregates through their effects on demands for money and credit *before* raising the prices of nontraded goods (raising the international inflation differential).

There is very little difference between the estimates reported in table 4.1 and ordinary least squares (seemingly unrelated regression) estimates of the equations. Tests of exogeneity of contemporaneous money-growth differentials, interest differentials, and income-growth differentials (using Hausman's specification test) fail to reject exogeneity at any reasonable significance level.

This provides some evidence that the relation between money-growth differentials and inflation differentials reflects some degree of monetary-policy autonomy under the Bretton Woods system rather than feedback from inflation differentials (induced by real shocks) to money growth differentials as predicted by the monetary approach to the balance of payments.

Figure 6.5 plots the residuals from these equations, and figure 6.6 plots the actual and fitted values. Although the period includes dates of revaluations and devaluations, there is no visual indication of unusual behavior of residuals around—before or after—those dates. This result parallels the finding in Baxter and Stockman (1989) that changes in the exchange-rate system, and in the variability of real exchange rates, seem to be unconnected with macroeconomic or international-trade quantity variables. In this case, the major changes in real exchange rates that occur at the time of finite revaluations seem to have little effect on inflation differentials or the relation between inflation differentials and money-growth differentials.

Experimentation with the data revealed that the connection between money-growth and inflation differentials varies with the overall level of nominal interest rates. Table 6.2 presents results from an equation that adds the contemporaneous level of the U.S. short-term interest rate (three-month Treasury-bill rate) to the equation, with a coefficient that differs across countries. The set of instrumental variables remains unchanged from previous tables: the only contemporaneous variables included among instruments were the growth rate of the U.S. monetary base and the U.S. Federal funds rate. The contemporaneous level of interest rates has a statistically significant effect on the interest differential between the United States and France and between the United States and Germany (although in opposite directions in the two cases). A Wald test that the coefficients of the U.S. nominal interest rate are jointly zero leads to rejection of that hypothesis at the .0001 level. Holding the level of the nominal interest rate fixed strengthens the effects of lagged money-growth differentials on inflation differentials. The sum of coefficients on money-growth differentials rises from .28 to .48, and the sum on lagged differentials rises from .26 to .44.

Table 6.3 presents estimates of a similar set of equations for the inflation differential between Germany and other nations in the sample. France is excluded from this sample because chi-square tests indicated that the French coefficients differed from the coefficients of other countries. The U.S. nominal interest rate is included as in table 6.2. The results continue to show a positive effect of lagged money-growth differentials on the inflation differential and virtually no contemporaneous effect. The sum of the money coefficient is .26. Similar results appear when other countries are used for comparison. As before, there is little evidence of misbehavior of the residuals of the equations in the form of autocorrelation or departures from normality. Nor do the residuals behave any differently around periods of devaluations.

These results suggest that, when central banks engaged in sterilization pol-

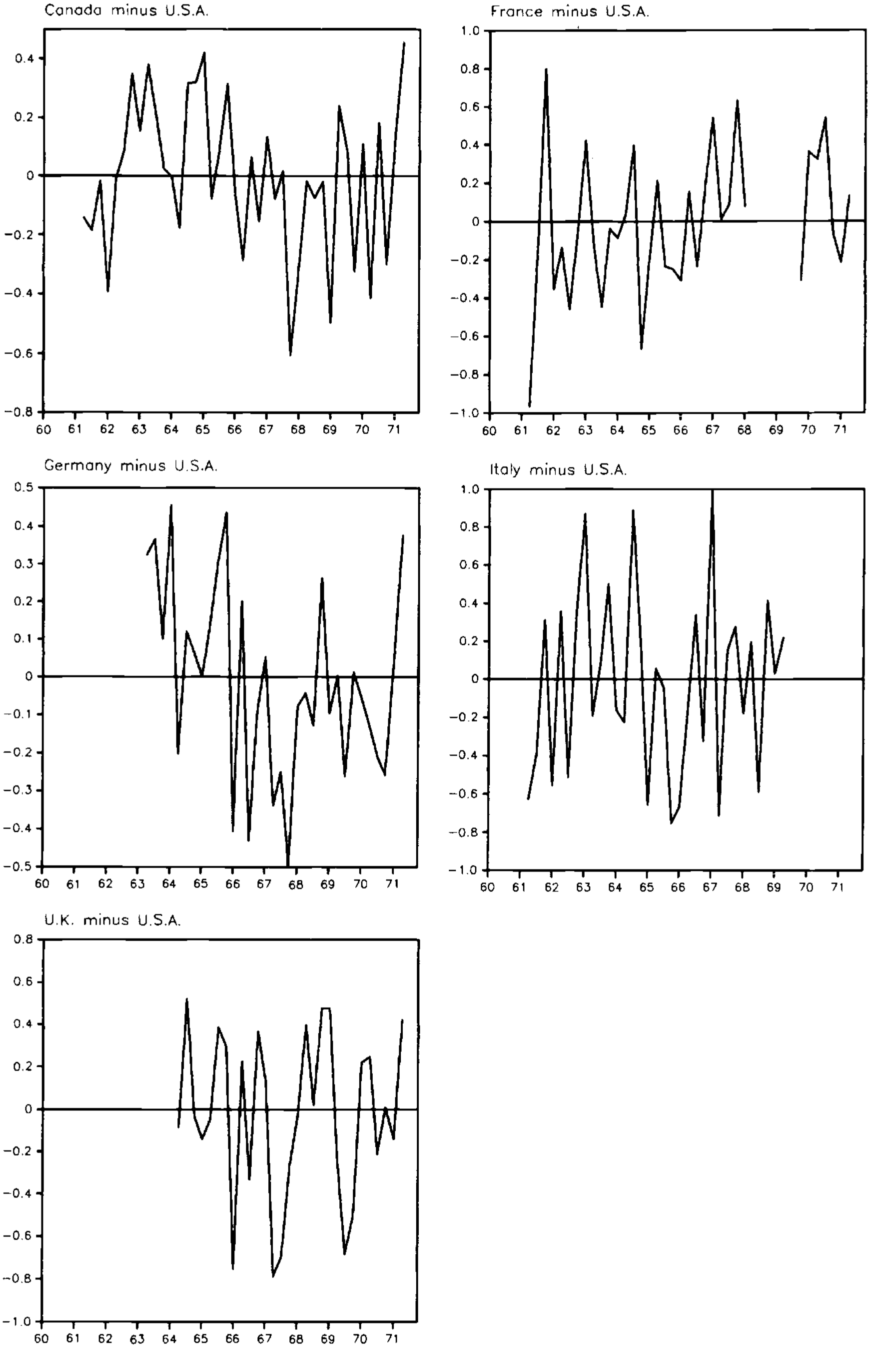

Fig. 6.5 Plots of residuals from table 6.1

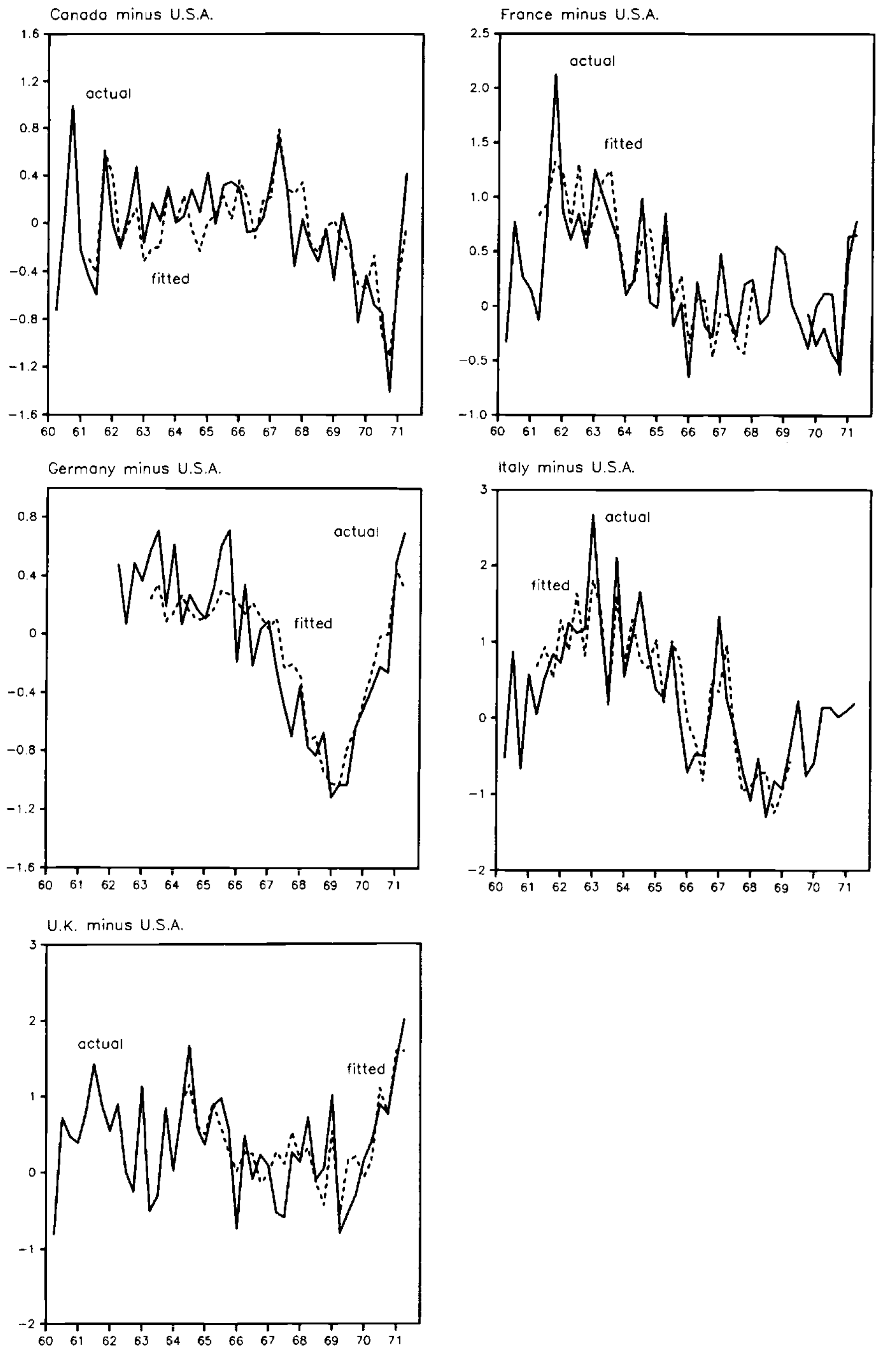

Fig. 6.6 Inflation differentials: actual and fitted values (actual inflation differentials and fitted values of equations from table 6.1)

Table 6.2 Inflation Differentials and Money-Growth Differentials with the Level of the U.S. Interest Rate Included

	Coeff.	SE	t-Stat.	p-Value
δd log $(M1)_t$	.040	.021	1.89	.07
δd log $(M1)_{t-1}$	.117	.019	6.12	.00
δd log $(M1)_{t-2}$	.076	.019	3.88	.00
δd log $(M1)_{t-3}$	.088	.021	4.03	.00
δd log $(M1)_{t-4}$	.057	.021	2.70	.01
δd log $(p)_{t-1}$	.059	.070	.83	.41
δd log $(p)_{t-2}$	−.046	.070	−.65	.52
δd log $(p)_{t-3}$	.094	.065	1.45	.16
δd log $(p)_{t-4}$, others	.017	.071	.24	.81
δd log $(p)_{t-4}$, Canada	.688	.151	4.54	.00

	Canada	France	Germany	Italy	UK
R^2	.67	.60	.88	.72	.68

Note: These are joint instrumental variables estimates of eqq. (6) as in table 6.1, except the U.S. three-month Treasury-bill rate is included in each equation with a coefficient that can differ across equations.

icies under the Bretton Woods system, they were able to affect not only the domestic money supply in the short run but also the domestic inflation rate in the short run. This sterilization limited the extent to which changes in foreign inflation were transmitted in the short run to the country. (Because the sample is short, the estimates cannot provide much evidence about long-run effects of sterilization.) The question then arises as to whether these short-run limits on the international transmission of inflation spilled over to real variables.

First, notice that the estimates given above imply that there were *predictable* differences in inflation across countries under Bretton Woods, related to prior differences in money-growth rates. But these predictable changes in inflation differentials appear not to have been fully reflected in changes in nominal-interest differentials. Instead, they occurred mainly as changes in ex post real interest-rate differentials. Because these interest differentials were predictable, it may be reasonable to interpret them as ex ante real interest-rate differentials. (Such ex ante real interest differentials are not necessarily ruled out by arbitrage; they are consistent with expected changes in relative prices of the CPI bundles of goods in different countries.)

Table 6.4 shows estimates of a set of nominal-interest-differential equations specified in accordance with the earlier equations for inflation differentials. There is some evidence of a positive effect of lagged money-growth differentials on nominal-interest differentials. (The hypothesis that the coefficients on the money-growth differentials are jointly zero is rejected at the .0001 level.) But the positive effect of lagged money differentials is small. Money growth rates are *quarterly* growth rates, while the nominal interest differential is in

Table 6.3 **Germany as the Comparison Country**

	Coeff.	SE	t-Stat.	p-Value
$\delta d \log(\text{M1})_t$	−.007	.023	−.30	.78
$\delta d \log(\text{M1})_{t-1}$	.125	.024	5.21	.01
$\delta d \log(\text{M1})_{t-2}$	.029	.027	1.06	.35
$\delta d \log(\text{M1})_{t-3}$	.075	.034	2.19	.09
$\delta d \log(\text{M1})_{t-4}$	.035	.026	1.31	.26
$\delta d \log(\text{p})_{t-1}$	.100	.089	1.12	.32
$\delta d \log(p)_{t-2}$	−.031	.085	.36	.73
$\delta d \log(p)_{t-3}$	.067	.082	.82	.46
$\delta d \log(p)_{t-4}$, others	−.272	.085	−3.17	.03
$\delta d \log(p)_{t-4}$, Canada	.059	.141	.42	.68

	Canada	Italy	UK	US
R^2	.75	.37	.64	.89

Note: These are joint instrumental variables estimates of eqq. (6) as in table 6.2, except the base country against which differentials are computed is Germany rather than the U.S.

Table 6.4 **Money and Nominal-Interest Differentials**

	Coeff.	SE	t-Stat.	Two-Tail p-Value
$\delta d \log(\text{M1})_t$	−.027	.023	−1.16	.26
$\delta d \log(\text{M1})_{t-1}$	.007	.018	.37	.71
$\delta d \log(\text{M1})_{t-2}$	.040	.019	2.04	.06
$\delta d \log(\text{M1})_{t-3}$	.044	.019	2.32	.03
$\delta d \log(\text{M1})_{t-4}$	.065	.028	2.32	.03
$\delta d \log(p)_{t-1}$	.013	.076	.16	.87
$\delta d \log(p)_{t-2}$	−.069	.069	−1.00	.33
$\delta d \log(p)_{t-3}$	−.185	.073	−2.51	.02
$\delta d \log(p)_{t-4}$, others	−.030	.071	−.41	.68
$\delta d \log(p)_{t-4}$, Canada	−.429	.221	−1.93	.07

	Canada	France	Germany	Italy	UK
R^2	.68	.81	.82	.94	.57

Note: These are joint instrumental variables estimates of an equation like (6), except the dependent variable is the difference between the country's short-term nominal-interest rate and the U.S. three-month Treasury-bill rate, δ(nation, US, i).

percentage points at *annual* rates. So a coefficient of about four on the money-growth differential would indicate that a 1 percentage point rise in the money-growth differential raises the nominal-interest differential by 1 percentage point. In fact, the sum of the first four lagged coefficients is only about 1.5, and the coefficient on contemporaneous money is negative. So, besides the positive effect of lagged money differentials, there is weak evidence of a liquidity effect on nominal interest rates in the first quarter.[16]

The fact that an increase in the money-growth differential—which is associated with a lagged rise in the inflation differential—is accompanied by a fall in the expected real-interest differential (and perhaps a shorter-run fall in the nominal-interest differential) is some evidence in favor of the hypothesis that countries had (and used) some degree of monetary autonomy under the Bretton Woods system. Under the alternative (reserve-causation) hypothesis, which says that the rise in the nominal supply is an endogenous response to a real shock that (*a*) raises the demand for money and (*b*) raises the relative price of domestic in terms of foreign goods with a lag, one might expect a *rise* in the international real-interest differential. Additional evidence on this point comes from attempts to model the changes in money-supply differentials based on past changes in inflation differentials and other variables. There appears to have been little relation between changes in the money-supply growth differential and lagged changes in income, inflation, or nominal-interest differentials. Estimates of equations for money-growth differentials show *no* strong relation between lagged inflation differentials and the current money-growth differential (see table 6.5). In fact, the point estimates of the coefficients of lagged inflation differentials on the money-growth differential are mainly *negative*. When lagged differentials of the balance of payments or balance of trade are added to this equation, they have no additional predictive content for the differentials in money-supply growth rates. So this evidence supports the hypotheses that changes in money-growth differentials were responsible for subsequent changes in inflation differentials, that variables that normally affect money-demand-growth differentials had little effect on short-run differentials in money-supply growth, and that *short-run* international differentials in money-supply growth were not strongly related to inflation or money growth in other countries. In other words, there was *little* international transmission of inflation in the short run under Bretton Woods.

6.8 Conclusions

International transmission of real and nominal disturbances occurs through many channels. Some are independent of the exchange-rate system, while others depend on that system. Some create positive international transmission, while others create negative transmission across countries. The data available for the Bretton Woods system after the establishment of convertible currencies are sufficiently short that little evidence can be obtained about most of the main issues regarding these channels of international transmission. Distinguishing common shocks to real variables from their international transmis-

16. Leeper and Gordon (1991) find no liquidity effects in the U.S. data for this period when changes in the money stock are treated as endogenous as in these estimates.

Table 6.5 Money-Growth Differentials

	Coeff.	SE	t-Stat.	Two-Tail p-Value
$\delta d \log (M1)_t$	−.027	.023	−1.16	.26
$\delta d \log (M1)_{t-1}$	.007	.018	.37	.71
$\delta d \log (M1)_{t-2}$	.040	.019	2.04	.06
$\delta d \log (M1)_{t-3}$	.044	.019	2.32	.03
$\delta d \log (M1)_{t-4}$	.065	.028	2.32	.03
$\delta d \log (p)_{t-1}$	.013	.076	.16	.87
$\delta d \log (p)_{t-2}$	−.069	.069	−1.00	.33
$\delta d \log (p)_{t-3}$	−.185	.073	−2.51	.02
$\delta d \log (p)_{t-4}$, others	−.030	.071	−.41	.68
$\delta d \log (p)_{t-4}$, Canada	−.429	.221	−1.93	.07

	Canada	Germany	Italy	UK
R^2	.29	.50	.94	.36

Note: These are joint instrumental variables estimates of an equation like (6), except the dependent variable is the difference between the country's nominal money-supply growth rate and that of the United States, δ(nation, US, M1)).

sion and isolating the various channels through which transmission occurs require longer time series than the Bretton Woods system made available to us. But it is possible to obtain some evidence about the *short-run* international transmission of inflation under the Bretton Woods system. This paper has presented evidence that there was little short-run international transmission of inflation under Bretton Woods and that countries exercised some control over their own short-run inflation rates through monetary policy, despite pegged exchange rates. The evidence indicates that a country with a money-growth rate 1 percent above another country's subsequently experienced higher inflation of between one-fourth and one-half percent. This paper has argued that it is reasonable to interpret this as a causal relation from money-growth differentials to inflation differentials, rather than reverse causation. The reverse-causation hypothesis, that real shocks affecting the demand for money *also* affected international inflation differentials with a lag, raises the question of precisely what these disturbances were. In addition, the evidence indicates that increases in the money-growth differential and subsequent increases in the inflation differential were associated with decreases in ex ante real interest-rate differentials, which might be expected from liquidity effects if the causality ran from money growth to inflation. The reverse-causation hypothesis might suggest the opposite reaction for real interest rates if increases in the money supply occur in response to higher demands for credit. And the reverse-causation hypothesis cannot explain why money-growth differentials do not appear to be positively related to lagged inflation differentials. So the natural interpretation of the evidence is that countries had some scope for monetary-policy independence under Bretton Woods and exercised it in ways that limited international transmission.

This conclusion raises new puzzles with both theoretical and empirical components. Obviously, the international transmission of monetary disturbances and inflation under the Bretton Woods system was more complicated than simple models suggest. How were countries able to conduct independent monetary policies under the Bretton Woods system of pegged exchange rates? The simplest version of the monetary approach to the balance of payments implies that independent monetary policy is impossible in a country that pegs its exchange rate because the one instrument of monetary policy, the supply of the monetary base, must be used to peg the exchange rate. Other models suggest a possible role for independent monetary policy. Some (portfolio balance) models explicitly introduce two instruments: the monetary base and the currency denomination of the assets that the central bank buys and sells when it conducts open-market operations. By buying assets in one currency and selling them in another, the central bank can in principle affect relative rates of return on the assets, and the exchange rate, without altering the money supply. This permits, in principle, separation of the pegged exchange-rate policy from money-supply policy. Was this the main operative channel that limited short-run international transmission of inflation under Bretton Woods? Alternatively, there may be other channels through which central banks can conduct independent monetary policies under pegged exchange rates, perhaps involving distribution effects and the choices of markets and instruments used for open-market operations. Were these the main channels? If the United States was a reserve-currency country, did it control the *long-run* inflation rates of Bretton Woods nations, as Darby et al. (1983) argue? Did barriers to international trade in goods limit arbitrage and allow each country some short-run control over its own nominal variables? If so, would these barriers have allowed *long-run* control, as long as price levels did not diverge too much? If this is the key channel that limited international transmission of inflation under Bretton Woods, what are its implications for flexible exchange rates? Does it imply that countries could use monetary policies to affect international relative prices under floating exchange rates? To what extent does this alter the international transmission of *real* disturbances under either exchange-rate system? These and other related questions call for future research.

Data Appendix

Data are from *OECD Main Economic Indicators,* Citibase (all U.S. series), and Darby et al. (1983) (French real income).

Canada. Data cover the entire period from 1960:1 through 1971:2.

France. Inflation, money-growth, and interest-rate data cover the entire period from 1960:1 through 1971:2. French real income data are from Darby et al., and I excluded the quarter of the general strike in May 1968. Because the data analysis employs lags, this reduces the sample period in France to 1961:1–1968:1 and 1969:4–1971:2.

Germany. Data cover the entire period from 1960:1 through 1971:2.

Italy. Inflation, money-growth, and real income data cover the entire period from 1960:1 through 1971:2. The short-term interest rate is the auction rate on six-month Treasury bills, from *OECD Main Economic Indicators: Historical Statistics,* and is available from 1960:1 through 1969:2.

United Kingdom. Data cover the entire sample, except M1 begins in 1963:1.

United States. Data from Citibase.

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Comment Toru Iwami

Alan C. Stockman's paper consists of two parts. The former (secs. 6.1–6.6) considers various forms of disturbances (shocks) and possible ways in which they are transmitted internationally. The latter (sec. 6.7) is devoted to testing the possibility that independent monetary policies cause inflation differentials, at least in the short run, contrary to the widely accepted view of the pegged exchange-rate system.

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The logical relation between the former and the latter parts is difficult to understand. In the former, Stockman mainly discusses the effects of real disturbances, while his argument in the latter is not about the transmission of inflation but about differential inflation rates and about how these differentials are caused by monetary rather than real factors.

In considering theoretical models, Stockman mentions actual settings of the period and compares the logical consequences of each model with the results of empirical research to date. Undoubtedly, this is the correct procedure. However, I am skeptical that the various models in the former part are relevant to the realities of the Bretton Woods era.

Let us take examples of "disturbances to preference," "technology shock," and the "presence of nontraded goods." The extent of "preference" effects is dubious, while technology must have been strongly related to the high-growth performance of the period and hence to economic fluctuations as well. But the relevance of Stockman's discussion is limited because a productivity shock is assumed to take place in the nontradable goods industry. I will discuss below the productivity shock mainly to tradables.

The reader would also like to know what kind of fluctuations in real variables the author deduces from the previous research. Stockman refers to the findings of, for example, Baxter and Stockman that changes in real macroeconomic quantities were not so much affected by the type of an exchange-rate system, on the one hand, and that the cross-country correlation of industrial production was higher under the Bretton Woods system than in the later period, on the other.[1] Then I wonder how these two statements are consistent with each other.

While Stockman concludes that inflation differentials resulted from autonomy in monetary policy, differences in productivity growth and in prices of nontradables among countries would also lead to inflation differentials. The best example of this is the fact that, of the countries represented in his figure 6.3, Japan has the highest average inflation rate; such a high inflation rate is caused by the higher inflation rate of nontradables, whereas import price is determined internationally. The greater price increase of nontradables reflects the ever growing demand for labor force and real estate, a demand associated with rapid economic growth.

In order to assess relative inflation, an econometric model based on the CPI is misleading. Table 6C.1 shows that the EPI (export price index) inflation rate of Japan is the lowest among the seven developed countries in the period 1960–70, despite the highest average inflation rate for the CPI. If the inflation rates in Japan had been quite low for every price index, the major cause would have been anti-inflationary management of the money supply. The higher inflation rate of the GDP deflator rejects such a possibility.

1. See Marianne Baxter and Alan C. Stockman, "Business Cycles and the Exchange Rate Regime: Some International Evidence," *Journal of Monetary Economics* 23, no. 3 (1989): 377–400.

Table 6C.1 International Divergence of Inflation Rates (yearly average, %)

	1950–60	1960–70	1950–70	1970–80
CPI:				
United States	2.09	2.75	2.42	7.82
Japan	4.01	5.74	4.87	8.97
Germany	1.88	2.59	2.23	5.08
France	5.58	4.04	4.81	9.63
Britain	3.33	4.05	3.69	13.09
Italy	3.15	3.64	3.39	13.97
Canada	2.20	2.72	2.46	8.04
GDP deflator:				
United States	2.61	3.10	2.86	7.39
Japan	3.67[a]	4.30	4.09[b]	7.62
Germany	2.84	3.71	3.27	5.31
France	6.03	4.35	5.18	9.49
Britain	4.08	4.23	4.16	13.95
Italy	3.19	4.50	3.84	16.40
Canada	3.43	3.01	3.22	8.76
WPI:				
United States	1.50	1.52	1.51	9.31
Japan	2.21	1.28	1.75	7.53
Germany	2.03	1.32	1.68	5.10
France	5.00	2.86	3.92	8.07
Britain	2.87	3.08	2.98	13.57
Italy	.54	2.49	1.51	15.42
Canada	. . .	1.77	. . .	9.68
EPI:				
United States	1.26	1.52	1.39	14.55
Japan	.29	.28	.28	3.69
Germany	3.89	.76	2.31	5.15
France	4.80	2.49	3.64	9.14
Britain	2.60	3.11	2.85	14.51
Italy	−.55	.55	.00	16.14
Canada	1.28	2.16	1.72	11.29

Source: Toru Iwami, "Japan's Experiences under the Bretton Woods System" (Discussion Paper no. 92-F-1, University of Tokyo, Faculty of Economics, 1992). Original data from *International Financial Statistics: Supplement* (1987).

Note: The figure marked [a] stands for 1955–60 only and [b] for 1955–70 only. Inflation rates are calculated as $\log(1 + p) = (\log Pt - \log Po)/t$, where p is the average rate of inflation, Pt is the price index of the tth year, and Po is the price index of the benchmark year.

The lower WPI inflation rate is the result of higher-productivity growth specific to large-scale firms, while the cause of the still lower inflation rate of the EPI is twofold: first, the composition of exports shifted to goods of higher-productivity growth; second, exporters may have cut export prices further, to get a larger market share abroad at the lower margins. The real exchange rate of the CPI is rising, while that of the EPI is falling (see fig. 6C.1).[2] It would be more fruitful to interpret the inflation differentials in terms of the dynamic aspect of postwar economic development. Unfortunately, Stockman's argument is confined to the short-run effects because of the limited time-series data.

Another important question is how far his argument goes and what the implications are of his econometric models. The independence of monetary policy, if any, does not imply that the balance of payments does not constitute a restraint on macroeconomic policy. The developed countries seem to have obeyed the "rules of the game" in general under the Bretton Woods system, with the exception of the United States.[3] This asymmetry enabled the developed countries to expand their money supply despite the pegged exchange rates. The fact that the key-currency country, the United States, did not respond to the balance of payments deficits by contracting the money supply is a main characteristic that distinguishes the Bretton Woods system from the classical gold standard.[4] Both the success in solving the international liquidity shortage and the consequent breakdown of the whole system resulted from U.S. macroeconomic policy preferring internal rather than external balances.

The remarkable differences in inflation rates between the two periods before and after the closing of the gold window suggest that the pegged exchange rate was the factor that imposed discipline on excessive monetary expansion, even in the United States. One might argue that the inflation of the 1970s was due mainly to the oil crisis. However, without the dollar devaluation, OPEC countries would not have raised oil prices so dramatically. The oil crisis was one of the side effects generated by the dollar devaluation. It was no coincidence that the so-called golden age of capitalism (i.e., greater economic growth and a lower inflation rate) and Bretton Woods co-occurred.[5]

Admittedly, the era of fixed exchange rates with full convertibility of the major currencies is too short to provide us with enough data to analyze empirically the long-term effects of real as well as monetary shocks. Partly because of such limitations, Stockman must content himself on the whole with raising questions rather than answering them.

2. The preceding discussion is based on Toru Iwami, "Japan's Experiences under the Bretton Woods System" (Discussion Paper no. 92-F-1, University of Tokyo, Faculty of Economics, 1992). The classic statement of productivity effects on the real exchange rate is Bela Balassa, "The Purchasing-Power Doctrine: A Reappraisal," *Journal of Political Economy* 72 (1964): 584–96.

3. Ronald I. McKinnon stresses that the asymmetry between the United States and the rest of the world continued to exist regardless of the exchange-rate system (see his comments in chap. 13 in this volume).

4. See Toru Iwami, "The Bretton Woods System as a Gold-Exchange Standard" (Discussion Paper no. 91-F-11, University of Tokyo, Faculty of Economics, 1991).

5. On the golden age of capitalism, see Stephen A. Marglin and Juliet B. Schor, eds., *The Golden Age of Capitalism: Reinterpreting the Postwar Experience* (Oxford: Oxford University Press, 1990).

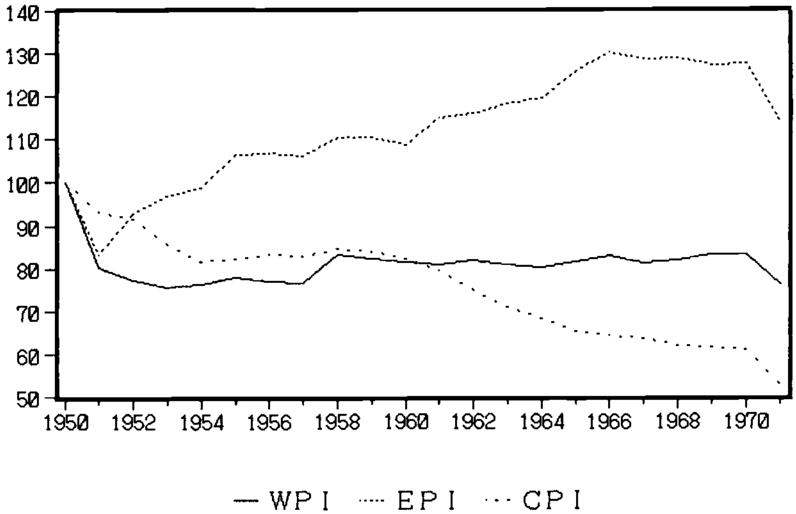

Fig. 6C.1 Yen/dollar real exchange rate based on WPI, CPI, and EPI (1950–71) (1950 = 100)
Source: Toru Iwami, "Japan's Experiences under the Bretton Woods System" (Discussion Paper no. 92-F-1, University of Tokyo, Faculty of Economics, 1992). Original data from *International Financial Statistics: Supplement* (1987).
Note: Exchange rate is expressed in terms of yen/dollar.

Comment Bennett T. McCallum

Alan Stockman's useful paper consists of two distinct parts. The first of these is the exposition in sections 6.1–6.6 of a theoretical framework for the analysis of the transmission, from one nation to another, of the effects of macroeconomic shocks. Although a form of nominal price stickiness is introduced in section 6.6, for the most part the shocks considered are real (as opposed to monetary) in nature—shocks to technology and preferences. Stockman's development of this theoretical framework is expertly crafted, just as one would anticipate in light of his role as a major contributor to the subject.[1]

The second part of the paper, by contrast, consists of an empirical exploration (presented in sec. 6.7) of the proposition—implied by some popular

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1. Among those contributions are Alan C. Stockman, "Real Exchange Rates under Alternative Nominal Exchange Rate Systems," *Journal of International Money and Finance* 2 (1983): 147–66, "The Equilibrium Approach to Exchange Rates," *Federal Reserve Bank of Richmond Economic Review* 73, no. 2 (1987): 12–31, and "Real Exchange Rate Variability under Pegged and Floating Nominal Exchange-Rate Systems: An Equilibrium Theory," *Carnegie-Rochester Conference Series on Public Policy* 29 (1988): 259–94.

models—that nations had no scope for monetary autonomy under the Bretton Woods arrangements. This exploration is not tightly linked to the framework developed in the first part of the paper but concerns the transmission of inflation. The following comments will, like Stockman's presentation at the conference, focus on the second of these two distinct subjects.

I enjoyed studying Stockman's empirical work and would certainly agree with his main conclusion, namely, that the evidence from the period 1958–71 is inconsistent with the proposition mentioned above. This empirical work is rather ingenious in its design; by focusing on differentials across countries and imposing equality restrictions on distributed-lag coefficients where permitted by the data, Stockman was able to get some estimates that are statistically significant and come close to being economically intelligible. In my opinion, the results fall somewhat short of full intelligibility, however, since interest-rate differentials are not first-differenced as the other variables are. Except for that, Stockman's equation (6) would be a distributed-lag money demand equation of conventional specification (solved for the price level and first-differenced). It might also be noted that Stockman has been careful to report exactly what he is doing in his econometric work.

There is one interpretive quibble that I will mention, nevertheless, before going on to more important matters. It concerns the statement that "a sustained 1 percent rise in domestic money growth relative to foreign money growth leads to a .28 percent rise in the inflation differential," .28 being the sum of the coefficients on the d $\log(M1)_t$ variables in table 6.1. But since lagged values of the dependent variable are included as regressors, we need to divide by 1.0 minus the sum of their coefficients (i.e., by $1.0 - .27 = .73$) to ge the steady-state effect. That would give a value of .38, for countries other than Canada, which is still rather low in relation to 1.0. (For Canada, the number is $.28/[1 - .799] = 1.39$.)

Let us now consider Stockman's main conclusion. It is that, in his words, "there was little short-run international transmission of inflation under Bretton Woods and that countries exercised some control over their own short-run inflation rates through monetary policy, despite pegged exchange rates." With regard to this conclusion, it is important that the two "short-run" qualifications are included. If they were excluded, this conclusion would suggest that it is wrong to tell one's students that the adoption of fixed exchange rates precludes a nation from choosing its own inflation rate. But, when I tell my students that, what I am referring to is a nation's *average* inflation rate over a number of years—perhaps even a decade. Now Stockman's results indicate that, over short spans of time, nations can chose their money growth rates and that these influence their inflation rates. But these results do not deny that, if a nation maintains a 20% inflation rate for ten years, then it will be unable to keep its exchange rates fixed if, for example, most other nations are inflating at only 2% per year. Consequently, Stockman is right to state his conclusion in terms of there being some short-term or *temporary* scope for monetary autonomy under Bretton Woods.

Having said that, I must go on to admit that, at first glance, Stockman's data seem rather inconsistent even with the longer-run version of the no-autonomy proposition. Specifically, the series plotted in his figure 6.1 and 6.3 appears inconsistent with the usual no-autonomy notion because Japan, Italy, and the Netherlands are three nations in his sample with high average inflation rates (according to fig. 6.3), yet figure 6.1 indicates that all three of these had currencies that appreciated relative to the dollar over the years of convertibility under Bretton Woods.

Reflection suggests that it would be more appropriate to base average inflation rates for the comparison on a somewhat longer span of time than 1962–67. Not having access to Bordo's paper (chap. 1 in this volume) at the time, I calculated my own averages and decided to base them on the period 1957–70, using annual CPI data from the IMF's *International Financial Statistics Yearbook*. The chosen span drops off 1971 because by then the system was breaking down, and it includes 1957 and 1958 because the inflation experience of those years would seem to be relevant for the 1959–70 period of convertibility. These choices may appear rather ad hoc but nevertheless seem appropriate.

Be that as it may, table 6C.2 shows that the average inflation rates over 1957–70 all fall within 1.25 points of the U.S. rate (2.58%) except for France and Japan—which are about 4.5%, just over two points greater than the U.S. value. And these two exceptions are *not* troublesome from the perspective of the usual notion because France was in fact forced to devalue in 1958 and again in 1969 whereas Japan's inflation rate was offset over these years by its spectacular rate of productivity growth—something that a country cannot achieve by macroeconomic policy measures. So the data are actually consistent with the longer-term version of the no-autonomy proposition.

In conclusion, I would like to comment on the recently popular practice of testing the validity of the purchasing power parity (PPP) doctrine as a long-run proposition. This topic is not explicitly on Stockman's agenda but is in fact closely related because long-run validity of PPP is much the same as long-run incompatibility of fixed exchange rates with inflation rate discrepancies. Specifically, the recent practice I am concerned with is that of testing for the presence or absence of *cointegration* of nominal exchange rates with relative price levels. If these two series are not cointegrated, but instead the implied real exchange rates are nonstationary (in the sense that their ARMA representations have unit roots in the AR polynomial), then the PPP is said to fail even as a long-run proposition.[2]

2. Three references that come to hand are Mark P. Taylor, "An Empirical Examination of Long-Run Purchasing Power Parity Using Cointegration Techniques," *Applied Economics* 20 (1988): 1369–81; Cletus C. Coughlin and Kees Koedijk, "What Do We Know about the Long-Run Real Exchange Rate?" *Federal Reserve Bank of St. Louis Review* 72, no. 1 (1990): 36–48; and Robert McNown and Myles S. Wallace, "National Price Levels, Purchasing Power Parity, and Cointegration: A Test of Four High Inflation Economies," *Journal of International Money and Finance* 8 (1989): 533–45. But there are others that could be cited.

Table 6C.2 **CPI Inflation Rates, 1957–70**

Country	CPI, 1975 Base 1957	1970	Ratio, X	Average $X^{.07143} - 1$
Belgium	48.3	66.9	1.3851	.0254
Canada	51.0	70.2	1.3764	.0249
France	34.7	65.4	1.8847	.0499
Germany	55.0	74.2	1.3491	.0233
Italy	37.9	58.4	1.5409	.0338
Japan	31.8	58.0	1.8239	.0473
Netherlands	42.2	66.0	1.5640	.0350
United Kingdom	35.2	54.2	1.5398	.0338
United States	52.3	72.1	1.3786	.0250

Source: IMF, *International Financial Statistics Yearbook* (1980).

But I would argue that to draw such a conclusion is unwarranted. Suppose the relevant real exchange rate is a random walk with zero drift and small variance and that its evolution is independent of monetary policy actions in the relevant countries. Then it remains true that major differences in money growth rates over a decade would have major effects on the (nominal) exchange rate and tend to dominate its behavior. Indeed, the practical messages of the PPP doctrine would retain their validity, provided that the doctrine is interpreted as a long-run matter. That would remain true, furthermore, even if real exchange rates were dependent at high frequencies on money growth behavior, provided that there is independence at low frequencies. Note also that the logic of the cointegration test would imply that one should in principle reject PPP if any of the system's shock processes that affect the real exchange rate have even a small permanent component. As Stockman has emphasized in previous writings,[3] one would surely expect this to be the case. But, even if the process is entirely permanent, as in my example, one should not jump to the usual conclusion. Thus, in my opinion, the barrage of cointegration tests of PPP that we have seen in the literature serves primarily as another (unnecessary) indication of the profession's enthusiasm for the application of new and undigested statistical techniques.

General Discussion

Sebastian Edwards followed up on *Bennett McCallum's* comment that much of what Stockman's regressions are picking up is not nominal disturbances but structural disturbances that permanently altered the real exchange rate.

3. Especially in Stockman, "The Equilibrium Approach to Exchange Rates," and "Real Exchange Rate Variability under Pegged and Floating Nominal Exchange-Rate Systems."

The disturbances that are important include productivity differentials via the Balassa effect, where one would expect countries with more rapid productivity growth to exhibit equilibrium real appreciation; terms of trade shocks; and changes in tariffs and commercial policy.

Alexander Swoboda questioned Stockman's claim that there was no world inflation rate. He suggested that the approach taken in Bordo's table 1.1 (see chap. 1 in this volume) comparing the degree of convergence toward an average across regimes, would reveal a world inflation rate for the Bretton Woods period as well. He also suggested testing for the effects of aggregate money growth (across countries) on average inflation. He also did not agree with Stockman's interpretation of his findings of little influence of changes in international reserves on money growth as suggesting sterilization. The same results could follow if countries set money growth targets, which in turn induced changes in international reserves, yet without any causality running from reserves to money. *Hans Genberg* suggested that the author should test for feedback effects through interest rates and the price level. *Richard Marston* thought it was possible that, instead of the regressions identifying a money demand equation, as McCallum argued in his Comment, they were identifying an endogenous money supply.