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Volume Title: The International Transmission of Inflation

Volume Author/Editor: Michael R. Darby, James R. Lothian and Arthur E. Gandolfi, Anna J. Schwartz, Alan C. Stockman

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-13641-8

Volume URL: http://www.nber.org/books/darb83-1

Publication Date: 1983

Chapter Title: The Timing of Monetary and Price Changes and the International Transmission of Inflation

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Chapter URL: http://www.nber.org/chapters/c6124

Chapter pages in book: (p. 58 - 82)

4 The Timing of Monetary and Price Changes and the International Transmission of Inflation

Anthony Cassese and James R. Lothian

4.1 Introduction

Our aim in this chapter is to present evidence on two issues: the relative contributions to inflation in each of these countries of domestic and of international factors, and the relative importance of the channels through which the international factors have operated.

The difficulty that arises in investigating these issues is that most, if not all, of the foreign countries we consider seem to have been neither fully open nor fully closed. Exchange rates in a number of notable instances during the Bretton Woods era underwent substantial changes; the various domestic monetary authorities often seemed to pursue policies different from those of the world at large, and the propensity of government of some of these countries to tinker with markets for international goods and capital ran high. Nevertheless, all seven foreign countries experienced the same general pattern of inflation as the United States, the reserve-currency country, for close to half the sample period.

One solution to the problem would be to estimate more general models that relax some of the simplifying assumptions of the polar-case open- and closed-economy models.[1] Darby and Stockman in chapter 5 and Gandolfi and Lothian in chapter 14 adopt that approach. Our approach, in contrast, is to conduct a series of tests of Granger-causality for each country for a number of relations, some between domestic variables alone, others between domestic and foreign variables.

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An earlier version of this chapter appeared in the *Journal of Monetary Economics* 10 (August 1982): 1–23.

1. Blejer (1977), Cross and Laidler (1976), Jonson (1976), and Laidler (1978) are all examples of earlier work in this area.

The merit in this approach is that it avoids the problem of the structure of the model limiting the range of investigation. Indeed, the tests we apply are intended to provide evidence that will permit us to rule out some previous model-identifying restrictions. It therefore not only serves as a convenient point of departure for constructing and estimating more general models but provides a way of reevaluating some of the models that have been already estimated. The drawback, of course, is that the simple bivariate relations underlying our tests may themselves give rise to specification bias caused by the omission of other important variables.

4.2 Theoretical Consideration

To derive a set of testable hypotheses about the international transmission of inflation based on timing relations among variables, we first review the model underlying the simple monetary approach to the balance of payments (MABP).[2] We present expressions for the rates of inflation and of monetary growth in a small open economy and point out the model's implications for both. In so doing, we point out what we believe is a popular misconception surrounding the MABP: the view that, in the context of the most basic model, changes in monetary growth will follow rather than precede changes in inflation.[3] We then relax some of the simplifying assumptions of the model and state the timing implications of these modifications for questions of international transmission.

4.2.1 The Monetary Approach

The simplest expositions of the MABP start with a money demand function of the standard form, a purchasing power parity relation, and a money market equilibrium condition. Ignoring interest rates, we can write the first as

(4.1) $$\log (M/P)_t^d = k \log y_{pt},$$

where M is the nominal stock of domestic money, P the domestic price level, y_p permanent income, and k the income elasticity of demand. The purchasing power parity or, if the exchange rate is assumed perfectly rigid, price arbitrage relation is simply

(4.2) $$P_t = \pi P'_t,$$

where P' is the rest-of-world price level and π the (constant) exchange

2. Johnson (1976) is the classic statement of the monetary approach.
3. Swoboda (1977), in discussing the monetary approach to the transmission of inflation, states that the monetary approach may be distinguished from others in that "causation for a small open economy runs from income to the stock of money" (p. 15). For a contrasting view, see Branson (1977).

rate. The equilibrium condition relates the nominal stock of money supplied to the nominal stock demanded,

$$M_t = M_t^d. \tag{4.3}$$

Taking logarithms of (4.2) and (4.3), differencing the results along with equation (4.1), and making the appropriate substitutions, we arrive at the standard expressions for the domestic rate of inflation

$$\dot{P}_t = \dot{P}_t' \tag{4.4}$$

and monetary growth

$$\dot{M}_t = \dot{P}_t' + k\dot{y}_{pt}, \tag{4.5}$$

where a dot over a variable indicates a logarithmic first difference.

Equations (4.4) and (4.5) are equilibrium relations that describe the long-run growth paths of domestic money and domestic prices. This is readily apparent from the assumption of instantaneous adjustment of money demand to supply. In much of the literature, however, these dynamic relations are thought to do more: to have implications also for the time path of the adjustment to equilibrium. As the authors of one recent study using the simple MABP model have put it, "there is a clear presumption to [the] existence and direction" of the leads and lags between domestic money, prices, and nominal income in a small open economy under a fixed exchange-rate regime (Putnam and Wilford 1978).

4.2.2 Extensions of the Basic Model

What the authors of the statement seem to have in mind is something like the following. Consider a position of dynamic equilibrium in which the reserve-currency country's money stock and prices and the domestic money stock and prices are growing at constant rates, for simplicity all assumed to be equal. Now let monetary growth in the reserve-currency country increase. Its rate of inflation will eventually follow suit. The increase in inflation will, via arbitrage, be transmitted as an instantaneous and equal increase in inflation in non-reserve-currency countries. The new rate of inflation, in turn, will mean that domestic real cash balances are now growing more slowly than desired. The rate of hoarding, the inflow of foreign reserves, will increase as a result. Therefore, after the fact, so will the rate of growth of the domestic money supply.

The problem is, however, that this sequence of events does not follow directly from the model presented above. In the model everything takes place within a single period. For the reserve inflow to follow the equalization of inflation rates, the growth rates of the actual and desired nominal stocks of money would have to differ. That can be effected within the model fairly simply, but it requires replacing equation (4.3) with some form of stock adjustment relation like

(4.6a) $$\log M_t - \log M_{t-1} = \beta(\log M_t^d - \log M_{t-1}),$$

or, equivalently,

(4.6b) $$\log M_t = \beta(\log M_t^d) + (1 - \beta) \log M_{t-1}.$$

Using (4.1), substituting successively for the lagged actual stock of money and differencing the result, we would then arrive at a new equation in which the current period's monetary growth would be a distributed lag, with geometrically declining weights of inflation in the reserve-currency country and of growth in permanent income:

(4.7) $$\dot{M}_t = \beta \sum_{i=0}^{\infty} (1 - \beta)^i (k\dot{y}_{pt-i} + \dot{P}'_{t-i}).$$

Extending the model in this way also seems reasonable from an empirical standpoint since most demand-for-money studies have uncovered lags of several quarters or more in the adjustment process linking actual and desired money balances. To derive alternative testable hypotheses about the international transmission mechanism, one might also want to relax some of the other strong assumptions of the simple MABP model. Three possible modifications of the simple model are to relax the assumptions of instantaneous price arbitrage, equilibrium in the money market of the reserve-currency country, and full employment. Later we consider the implications of permitting short-run sterilization policies.

First, let us consider the question of price arbitrage. Here the empirical evidence to date is inconsistent with convergence of overall rates of inflation within a quarter and perhaps even within a period of several years.[4] One reason often given is the existence of sizable nontradable goods sectors. In this instance, even if prices of tradable goods adjust quickly, prices of nontradable goods may adjust only with a substantial lag. If that is the case, then the domestic inflation equation, (4.4), and the domestic money growth equation, (4.5) or (4.7), would have to be rewritten to take account of the differences in speeds of adjustment of prices between tradable and nontradable goods across countries.[5] The end result is that the timing relation between domestic monetary growth and overall inflation becomes less easy to determine. Given a sufficiently slow adjustment of prices of nontradable goods, domestic inflation might not be observed to lead domestic monetary growth.

The next logical step would be to relax the implicit assumption that prices in the reserve-currency country adjust fully and instantaneously to monetary changes. For example, consider the monetary transmission mechanism Friedman and Schwartz (1963*a*) outline for a closed econ-

4. Kravis and Lipsey (1978), among others, present evidence counter to the arbitrage hypothesis.

5. See Blejer (1977) for a model in which the slower adjustment of prices of nontradable than of tradable goods plays a crucial role.

omy. The key element in their view is the series of portfolio adjustments that an unanticipated change in monetary growth engenders.[6]

To illustrate, suppose monetary growth in a closed economy suddenly increases. Initially, market yields on financial assets and equities, and then a whole host of implicit yields on consumer goods of every degree of durability, temporarily fall as money holders desire to rid themselves of excess cash balances and as the adjustment proceeds from one sector to another. Spending in all of these areas therefore increases, and output and prices begin to rise more rapidly. Eventually stock equilibrium is reestablished; holdings of real cash balances are lower, and inflation is higher than before the increase in money growth.

Suppose we now open that model to the international realm. Consider, for instance, what happens to the small country in a world of fixed exchange rates when monetary growth in the reserve-currency country undergoes an unanticipated increase.[7] Initially, this excess supply of money in the reserve-currency country reflects itself in an excess demand for alternative assets denominated in both the reserve currency and foreign currencies. The prices of those assets rise, and their yields fall. The fall in interest rates produces an excess demand for money in the small country which, in part, is satisfied by the inflow of reserves as residents of the reserve-currency country reduce their excess holdings of money and then increase their expenditures on bonds and equities. Eventually the process spreads to the markets for consumption and investment goods in both the reserve- and non-reserve-currency countries. As expenditures on these goods increase, their prices and the overall price levels in both countries begin to rise more rapidly. At the same time, interest rates on bonds and on equities begin to rise and approach their initial levels.

The final equilibrium position is one in which monetary growth, inflation, and the nominal interest rate on bonds, both in the reserve- and non-reserve-currency countries, are all higher; holdings of real cash balances are lower; and international payments positions are altered. The reserve-currency country now has a greater balance-of-payments deficit, and foreign countries have greater balance-of-payments surpluses or smaller deficits. If the asset approach is a reasonable expression of the adjustment mechanism, then we have a further reason to suppose that domestic monetary changes in a small open economy would *not* lag price-level changes.

6. If the monetary change were fully anticipated, the price-level response would be immediate. The information set used to form anticipations therefore has a crucial bearing on the exact timing relation.

7. The papers by Frenkel and Rodriguez (1975) and by Girton and Henderson (1976) describe models of this general sort. In both, however, the authors confine their analysis to organized asset markets.

We could also relax the implicit assumption in the MABP of full employment; then the transmission mechanism operating through portfolio adjustment provides a further rationale for small-country monetary growth actually leading its rate of inflation. For example, suppose an unanticipated increase in monetary growth in the reserve-currency country induced the portfolio adjustments described above. This would be followed by increased expenditures by residents of the reserve-currency country on foreign goods, which would lead to a balance-of-payments surplus and expansion of aggregate demand and output in the small economy. At the same time, the accumulation of reserves by the small economy's central bank would lead to an expansion of its high-powered money and overall money supply. Initially the bulk of the increase in the nominal income of the small economy would be reflected in output. Only after some time had elapsed would the effect be manifest upon the price level alone.

In conclusion, the lead or lag of money over prices, in what appears to be an open economy, is an uncertain guide to settling questions of causation and more importantly the international transmission of inflation. We would view a lead of prices over money and to a lesser extent a coincidence in movements as prima facie evidence of the importance of foreign influences. But a lag of prices behind money is consistent with either domestic or foreign monetary forces being the causative factor.

4.2.3 Other Implications of the Alternative Models

Fortunately these modifications of the simple model have other empirical implications that can help us differentiate among alternative hypotheses about the international inflation process. One testable hypothesis, of course, is derived from the presumed operation of price arbitrage. For a small open economy, if arbitrage were not instantaneous, we would expect prices in the rest of the world to lead domestic prices.

Similarly, if assets markets provide another linkage among countries we would expect there to be a relation among interest rates in one country and those in the rest of the world during periods of fixed exchange rates. Again, assuming that the effects are not instantaneously felt, we would expect changes in interest rates in the rest of the world, or in the reserve-currency country, to precede those in a small open economy.

Analyzing the timing relations between high-powered money and its counterparts on the asset side of the central bank's balance sheet—foreign reserves and domestic assets (domestic credit)—and between those two asset components themselves can also help to clear up some of the ambiguities that surround the timing relation between money and prices. Let us consider three cases: the reserve-currency country, a completely open small economy, and an intermediate case.

In the reserve-currency country, the U.S., the increase in monetary expansion underlying an increase in its inflation and ultimately that of the rest of the world is the result of credit expansion by the reserve-currency country's central bank. Accordingly, its domestic assets will be positively related to, and either lead or be coincident with, its high-powered money. Indeed, the foreign component of the reserve-currency country's high-powered money is of minor importance for that country. Changes in its balance of payments will be a result rather than a cause of variations in the growth of the reserve-currency country's high-powered money. High-powered money therefore will be negatively related, and either lead or be coincident with, the balance of payments of a reserve-currency country.

In a completely open small economy, movements in its domestic assets are unimportant as an effective source of monetary change. An overexpansion of domestic assets of the central bank ultimately will be nullified by reserve outflows, underexpansion by reserve inflows. Changes in foreign reserve holdings of the central bank are the channel through which monetary expansion occurs. Therefore foreign reserves will bear a positive and either coincident or leading relation to high-powered money. Changes in domestic assets will be unrelated to high-powered money growth but bear a negative and either coincident or leading relation to foreign reserve changes for a non-reserve-currency country.

The intermediate case is the most difficult to handle. Changes in domestic assets and foreign reserves are both potential sources of monetary changes. Some sterilization of balance-of-payments movements is likely, and at the same time some feedback of domestic credit expansion on foreign reserves flows will be observed. We would expect therefore to see changes in both foreign reserves and domestic assets to bear a leading, or perhaps coincident, positive relation to high-powered money growth and a negative and bidirectional relation to each other. Both foreign reserves and domestic asset movements can influence high-powered money growth in the intermediate case.

4.3 Testing Timing Relations

In this section we describe the technique we use to test timing relations. We define such relations as relations that exhibit a temporal precedence of one or more variables over another. In this paper we concentrate on bivariate timing relations. We believe these tests are useful for discriminating between relations which are postulated to be fundamentally different in various versions of the monetary model of transmission discussed in the previous section.

To examine timing relations, we use the incremental prediction criterion introduced by Granger (1969) and developed further by Sims (1977). Granger defines a causal relation, e.g. between X and Y, on the basis of the usefulness of information on the characterization (probability laws) of one stochastic process, say X_t, for the description of the joint stochastic process, $\{Y_t, X_s\}$. This is usually stated as: series X (Granger) causes series Y if we can better predict Y by utilizing past values of Y *and* X than by using merely past Y alone. The criterion Granger suggests for making this assessment is a comparison of conditional mean squared errors contingent upon the information sets inclusive and exclusive of series X. Thus, if X helps to predict Y, in the sense of reducing the mean squared prediction error for Y, then X Granger-causes Y.

Sims proves two theorems on (stationary) stochastic processes which are relevant in this context. Sims's analysis begins by recognizing that the stationary processes Y and X can be represented as

$$Y_t = A(L)u_t + B(L)\epsilon_t, \tag{4.8}$$

$$X_t = C(L)u_t + D(L)\epsilon_t, \tag{4.9}$$

where u_t and ϵ_t are uncorrelated stationary processes and $A(L)$, $B(L)$, $C(L)$, and $D(L)$ are polynomials in the lag operator L. According to Sims's first theorem, a necessary and sufficient condition for Y *not* causing X is that either $C(L)$ or $D(L)$ be identically zero. For example, Y would not cause X if, and only if, equation (4.9) could be written as

$$X_t = D(L)\epsilon_t. \tag{4.10}$$

His second theorem states that the failure of Y to Granger-cause X is a necessary and sufficient condition for treating X as strictly econometrically exogenous with respect to Y.

The import of these two theorems is that once we establish the existence of a particular representation between two variables (or, more accurately, once we establish that we cannot refute the existence of one) we have good reason to treat one variable as exogenous. Of course, one variable, which may be exogenous with respect to another variable in the framework of a bivariate system, may be endogenous with respect to a third variable. Nevertheless, the treatment of certain variables as exogenous lends structure to our economic models. The implied structure permits us to choose a better model from among classes of models each of which has a structure with a particular set of exogenous variables.

To conduct the causality tests, we ran regressions of the general form[8]

$$Y_t = \alpha_0 + \sum_{i=1}^{m} \beta_i Y_{t-i} + \sum_{j=1}^{n} \gamma_j X_{t-j} + U_t, \tag{4.11}$$

as well as the corollary regressions in which we constrained the γ_j to be identically zero,

$$Y_t = \alpha_0 + \sum_{i=1}^{m} \beta_i Y_{t-i} + U_t. \tag{4.12}$$

8. Sargent (1976) contains a discussion of this form of the test.

By comparing the improvement in the explanation of Y obtained from (4.11) with that derived from the companion regression (4.12), we can determine whether series X contains information useful in explaining series Y. Then, by reversing the roles of X and Y in regressions (4.11) and (4.12), we can establish whether an empirical representation of Y and X implies that one of the series is exogenous. Thus, if we can demonstrate within reasonable statistical limits that the following representation is plausible,

$$(4.13) \qquad Y_t = a_1 + \sum_{i=1}^{m} b_i Y_{t-i} + \sum_{j=1}^{n} c_i X_{t-i}$$

and

$$(4.14) \qquad X_t = a_2 + \sum_{i=1}^{m} d_i X_{t-i},$$

then, according to Sims's theorems, Y does not cause X or, alternatively, X is exogenous.

This is the regression test suggested by Granger; our interpretation of it is, however, somewhat looser than the conventional one. For the most part, we eschew using the word "cause" and instead speak in terms of timing. The reason, which should be clear from the theoretical presentation in section 4.2, is that in at least one of the areas in which we deal—the money-price relations—leads and lags are a poor guide to the question of causation in economies that have an unknown degree of openness. In terms of the debate over "measurement versus theory" that has recently been rekindled (see Sims 1977) our approach can perhaps best be described as "measurement with some theory."

A related point about methodology that bears mentioning is the potential bias inherent in this type of testing procedure. Commonality of movements in the series being analyzed may be captured in the autoregressive terms; this is implicitly disregarded by the method we use. As several others have pointed out (e.g. Zellner 1977), this can lead to accepting the null hypothesis of no relations between the two series when, in fact, one actually exists. In defense of the methodology, we should point out that this bias can also be a blessing. The simple fact of the matter is that in most industrial contries inflation and monetary growth over our sample period rose dramatically and at much the same time. Analyzing innovations in the time series may be the only way to separate the influence of one factor from another.

In almost all instances, we transform the data for the purpose of rendering the series stationary. In general, we use natural logs of the levels to reduce the problem of heteroscedasticity. We then difference the log levels, usually once but in some experiments twice. This procedure is intended to eliminate the trend in the mean of a series which is often encountered in aggregate economic time series. This procedure has the advantage of simply and symmetrically "prefiltering" the data without the substantial time costs and lost degrees of freedom one typically incurs when applying Box-Jenkins techniques. Moreover, it is not subject to the criticism that too much has been removed since nearly all aggregate economic time series regression analysis must consider the transformation we apply in order to come to terms with the estimation-efficiency question. The one exception to the general transformation procedure was the (net) domestic asset versus (net) foreign asset relations for certain of the countries for which the net positions took on a negative value. In these exceptional instances, we used arithmetic values of the levels and arithmetic first differences scaled by high-powered money.

4.4 Empirical Results

Our discussion of empirical results is divided into several parts: domestic money and prices, price and interest-rate arbitrage, asset components of high-powered money, and sources of monetary change. In our analysis, we cover periods beginning in 1958II and experiment with a variety of lag structures.

4.4.1 Domestic Money and Prices

We summarize the money-price results in tables 4.1 and 4.2. There we report the F statistics for the Granger tests of the relations between three monetary aggregates, high-powered money, M1 and M2, and two measures of prices, the GNP or GDP deflator (table 4.1) and the consumer or other similar retail price index (table 4.2), for the eight countries in our sample.[9]

Except for France and Italy, a significant effect of lagged money on prices exists for at least one domestic monetary aggregate and both price variables for all three periods. In the case of France, the only significant effects for all periods were for high-powered money growth on consumer price inflation. In the case of Italy, the significance of the money-price relation varies among the combinations of monetary and price variables from period to period. In most countries, however, we find a more pervasive influence than appears in either the French or Italian case; the majority of the relations prove significant for both definitions of the price level.

The reverse influence (prices on money) is considerably less visible. A significant effect of prices on money without feedback only appears in Italy and the U.K. in two instances, each with high-powered money, and in France in two instances with M2. Significant bidirectional influences appear in relatively few instances. Moreover, only in the case of the U.K.

9. The data we use were compiled from individual country sources by the NBER Project on the International Transmission of Inflation.

Table 4.1 **Money and Price Deflator**

$$Y_t = \alpha_0 + \sum_{i=1}^{m} \beta_i Y_{t-i} + \sum_{j=1}^{n} \gamma_j X_{t-j}$$

	Variable[†]		F Statistics for Lags (m, n) and Period Ending:[§]					
			1971III		1973IV		1976IV	
Country	Y	X	$m = 6$, $n = 3$	$m = 8$, $n = 8$	$m = 6$, $n = 3$	$m = 8$, $n = 8$	$m = 6$, $n = 3$	$m = 8$, $n = 8$
CA	PD	H	5.0857[##]	2.8006[#]	4.2300[##]	2.2937[#]	2.3145[‡]	2.3198[#]
	PD	M1	1.2176	1.0800	1.9479	1.9383[‡]	3.3748[#]	3.2819[##]
	PD	M2	2.6210[‡]	3.3309[##]	3.3975[#]	2.9488[##]	1.6940	2.1065
	H	PD	0.9001	0.9920	0.3877	0.7326	0.7274	0.8209
	M1	PD	0.9338	1.2448	0.5172	0.8475	0.8610	1.4687
	M2	PD	1.2395	1.5719	2.7234[#]	1.9840[‡]	2.3919[‡]	1.2493
FR	PD	H	4.7019[##]	1.7986	4.6467[##]	1.7584	0.8354	0.7941
	PD	M1	0.5858	0.9226	0.3987	1.0925	0.1559	0.4114
	PD	M2	0.1516	0.6431	0.3631	0.2317	0.6683	0.5199
	H	PD	1.0110	2.6440[#]	1.0153	1.5907	0.7415	1.2736
	M1	PD	1.1399	0.8372	1.1634	1.0560	0.5488	0.8831
	M2	PD	2.4164[‡]	1.6700	2.4090[‡]	1.2625	0.4447	0.4643
GE	PD	H	3.5186[#]	1.0623	2.4042[‡]	1.0295	0.6435	2.4534[#]
	PD	M1	0.4479	0.3952	0.4683	0.2100	1.1187	1.3269
	PD	M2	1.7745	1.2036	2.0504[‡]	1.2604	0.9762	0.6737
	H	PD	1.5316	1.0373	1.1161	0.4482	0.2838	0.1091
	M1	PD	0.7794	0.7514	0.9441	0.6567	2.1476[‡]	1.2652
	M2	PD	0.0693	0.2920	0.2636	0.6659	0.4931	1.0815

IT	PD	H	1.1682	1.1094	1.3511	0.8454	0.9918	0.7573
	PD	M1	1.9426	1.2206	3.0492#	2.0289‡	1.7427	1.3796
	PD	M2	0.6455	0.7834	2.2500‡	2.3987#	1.0636	1.3427
	H	PD	1.8111	0.7057	2.7941#	1.2006	8.7666##	3.4494##
	M1	PD	0.9739	0.5882	0.5743	0.4037	1.2931	0.8135
	M2	PD	0.5978	0.2149	0.4895	0.2453	2.6562‡	1.1188
JA	PD	H	3.8405#	1.9646‡	6.0414##	2.4172#	3.2189#	1.3024
	PD	M1	2.2473‡	1.6163	2.2842‡	1.8310‡	0.9347	1.7369‡
	PD	M2	1.1656	1.5835	2.2754‡	1.8709‡	1.6225	1.4317
	H	PD	1.5237	1.0461	1.3528	0.8219	0.6845	1.0836
	M1	PD	3.0488#	1.2816	1.0183	0.9410	1.8314	1.5997
	M2	PD	1.3220	0.9918	1.4421	0.7172	4.2628##	1.4727
NE	PD	H	0.7663	0.6710	0.1439	0.5099	0.2313	0.7476
	PD	M1	2.8542#	2.8115#	3.4698#	2.2073#	1.1498	0.7352
	PD	M2	2.9346#	2.1987#	2.8755#	2.0128‡	3.2533#	1.4874
	H	PD	0.1041	0.7291	0.3436	1.1746	0.4657	1.3963
	M1	PD	0.9419	1.0318	0.8451	1.3412	1.7868	1.3853
	M2	PD	0.1341	0.9253	0.8393	1.6698	0.7360	0.9330

Table 4.1 (continued)

	Variable[†]		*F* Statistics for Lags (*m*, *n*) and Period Ending:[§]					
			1971III		1973IV		1976IV	
Country	*Y*	*X*	$m = 6$ $n = 3$	$m = 8$ $n = 8$	$m = 6$ $n = 3$	$m = 8$ $n = 8$	$m = 6$ $n = 3$	$m = 8$ $n = 8$
UK	PD	H	1.1017	0.9244	1.3687	1.0933	0.2929	1.9991[‡]
	PD	M1	3.5272[#]	3.6844[##]	4.2292[##]	4.1970[##]	2.1304[‡]	3.9948[##]
	PD	M2	3.3290[#]	4.0148[##]	3.4599[#]	4.8635[##]	1.0124	2.3725[#]
	H	PD	5.9046[##]	2.3159[##]	4.2821[##]	2.8633[##]	0.6952	1.4133
	M1	PD	0.4415	1.2775	1.5263	1.6117	2.8020[#]	2.0691[#]
	M2	PD	0.2520	1.6050	2.2744[‡]	4.1369[##]	3.3308[#]	1.4786
US	PD	H	3.0960[#]	1.2327	1.1244	0.8451	2.1612[‡]	0.7881
	PD	M1	7.1747[##]	3.2115[##]	3.9259[#]	2.3341[#]	3.6139[#]	2.6592[##]
	PD	M2	5.0927[##]	2.0143[‡]	2.2580[‡]	1.8163[‡]	2.5727[‡]	2.6491[##]
	H	PD	1.9995	2.1232[‡]	2.4702[‡]	2.5302[#]	1.6230	3.6927[##]
	M1	PD	0.6292	0.3813	0.7209	0.8829	1.0213	0.4108
	M2	PD	0.5870	0.2438	1.3583	0.6631	0.4676	0.5512

[†]All variables are first differences of the natural log; PD is the GNP or GDP deflator, H is high-powered money, M1 is currency plus demand deposits, and M2 is currency plus the sum of demand and time deposits.

[§]All regressions start in 1958II. The null hypothesis is that the γ_j are as a group equal to zero.

[‡]Reject null hypothesis at $\alpha = 0.10$.

[#]Reject null hypothesis at $\alpha = 0.05$.

[##]Reject null hypothesis at $\alpha = 0.01$.

Table 4.2 **Money and Consumer Price Index**

$$Y_t = \alpha_0 + \sum_{i=1}^{m} \beta_i Y_{t-i} + \sum_{j=1}^{n} \gamma_j X_{t-j}$$

	Variable[†]		F Statistics for Lags (m, n) and Period Ending:[§]					
			1971III		1973IV		1976IV	
Country	Y	X	$m = 6$, $n = 3$	$m = 8$, $n = 8$	$m = 6$, $n = 3$	$m = 8$, $n = 8$	$m = 6$, $n = 3$	$m = 8$, $n = 8$
CA	PC	H	1.7304	2.0398[‡]	2.8630[#]	3.4068[##]	2.4287[‡]	3.3497[##]
	PC	M1	0.9011	1.3335	2.3543[‡]	2.6750[#]	0.9549	1.8960[‡]
	PC	M2	1.8998	2.3211[#]	2.1980[‡]	2.4818[#]	1.7972	1.7089[‡]
	H	PC	0.4004	0.9647	0.7010	0.7435	1.8513	1.0520
	M1	PC	0.7429	1.2814	0.6568	0.7356	1.1255	0.9205
	M2	PC	1.9417	1.2898	4.0227[##]	2.0999[#]	3.1621[#]	1.6265
FR	PC	H	3.0838[#]	1.6784	5.9429[##]	2.1667[#]	2.1861[‡]	1.1267
	PC	M1	0.9035	0.4313	0.8488	0.9236	0.9707	0.7959
	PC	M2	0.9320	0.8640	1.5080	0.6122	1.2368	0.5168
	H	PC	1.0301	1.1479	0.6391	0.8123	1.1896	0.9482
	M1	PC	0.1366	0.7419	0.0794	0.8701	0.0667	1.0880
	M2	PC	0.0472	1.1412	0.4648	1.0315	0.4843	0.8597
GE	PC	H	0.3373	0.6452	0.7065	0.6828	0.6488	0.7574
	PC	M1	3.6700[#]	2.0091[‡]	2.2902[‡]	1.1840	0.8899	0.4544
	PC	M2	2.0487	0.9324	3.6316[#]	1.4334	2.0873[‡]	1.0248
	H	PC	1.3580	1.5144	0.7117	0.6157	0.1522	0.3870
	M1	PC	0.1615	0.5855	0.2980	0.2447	0.3265	0.1900
	M2	PC	0.0639	0.5631	0.1868	0.6004	0.2075	0.7861

Table 4.2 (continued)

	Variable[†]		F Statistics for Lags (m, n) and Period Ending:[§]					
			1971III		1973IV		1976IV	
Country	Y	X	$m = 6$ $n = 3$	$m = 8$ $n = 8$	$m = 6$ $n = 3$	$m = 8$ $n = 8$	$m = 6$ $n = 3$	$m = 8$ $n = 8$
IT	PC	H	2.0895	1.7326	2.2146[‡]	1.4969	0.4835	0.5277
	PC	M1	0.7485	1.1998	0.6685	1.2960	2.5815[‡]	1.4106
	PC	M2	0.0562	1.4058	0.5205	1.9588[‡]	2.6051[‡]	1.9020[‡]
	H	PC	1.6496	1.5617	2.3577[‡]	2.0966[‡]	6.1068**	2.6657**
	M1	PC	1.2290	0.9196	1.0196	0.9489	2.7236*	1.1030
	M2	PC	0.8907	0.4999	1.3936	0.9262	5.1792**	2.2908*
JA	PC	H	2.5529[‡]	2.2855*	5.5676**	2.7080*	3.8263**	2.8386**
	PC	M1	0.8923	1.3026	1.3859	2.6490*	0.1656	1.6207[‡]
	PC	M2	1.2829	0.4988	1.7822	0.1308	1.7505	0.5856
	H	PC	1.0003	0.5991	0.5468	0.3308	1.3736	0.9399
	M1	PC	1.2112	1.6718	0.8157	0.9009	1.6885	1.2710
	M2	PC	0.3674	0.5470	0.1371	0.7524	1.8995	1.7773[‡]
NE	PC	H	1.4213	0.7616	0.9301	0.6842	0.7642	0.5470
	PC	M1	5.4306**	3.5512**	6.8611**	3.6791**	1.8408	1.1385
	PC	M2	3.7966*	2.5407*	4.5943**	2.9069**	3.8946*	2.6756**
	H	PC	0.7038	0.6883	0.3858	0.6059	0.6452	0.7099
	M1	PC	1.9109	0.9570	1.8164	0.8057	1.8521[‡]	0.9979
	M2	PC	0.4137	0.8526	1.5806	1.5429	2.1967[‡]	1.5192

UK	PC	H	4.9425##	2.2847#	5.6819##	2.6542#	3.2730#	4.0026##
	PC	M1	1.3392	0.9494	1.6227	1.1369	0.7719	1.8216‡
	PC	M2	0.4981	1.1294	2.3374‡	1.7292	1.6433	2.4200#
	H	PC	1.0225	0.7083	0.5323	1.1533	1.2367	2.1754#
	M1	PC	3.2914#	1.8360	4.4124##	2.9159##	5.7665##	2.5341#
	M2	PC	3.7181#	1.7491	5.1800##	2.8629##	1.0491	0.7693
US	PC	H	3.3590#	1.6969	1.3730	1.1135	2.3505‡	1.2689
	PC	M1	4.5219##	5.0305##	6.6044##	3.9097##	8.6231##	4.2129##
	PC	M2	0.5545	2.8073#	1.3136	3.1041##	2.4869‡	3.2708##
	H	PC	0.1369	0.3614	0.4343	0.3393	0.2956	0.4610
	M1	PC	2.4532‡	1.8937‡	2.6349‡	2.2025#	1.8309	1.5376
	M2	PC	0.9170	1.9163‡	1.2794	2.2896#	0.8068	1.9386‡

†All variables are first differences of the natural log; PC is the consumer price index, H is high-powered money, M1 is currency plus demand deposits, and M2 is currency plus the sum of demand and time deposits.

§All regressions start 1958II. The null hypothesis is that the γ_j are as a group equal to zero.

‡Reject null hypothesis at $\alpha = 0.10$.

#Reject null hypothesis at $\alpha = 0.05$.

##Reject null hypothesis at $\alpha = 0.01$.

do these reverse influences show any consistency with regard to the monetary aggregate employed.[10] These results therefore suggest that the rate of inflation is not necessarily exogenous in monetary models regardless of the degree to which prices are equalized via arbitrage.[11]

One problem with the results is that in several of the countries the relations differ markedly depending upon which price variable is used. Britain is the prime example. Using the GDP deflator, we find no influence from lagged high-powered money to prices in Britain and a significant influence, in two of the three periods, running the other way. Using the retail price index, we find almost exactly the opposite. A similar inconsistency exists using M1 and M2.[12] In the regressions with the GDP deflator, both monetary aggregates have a significant influence on prices with little relation the other way; in the regressions with the retail price index, prices more often influence money. For the other countries, the results are more consistent between price-level measures.

The data therefore establish a pattern that on the whole is consistent with monetary explanations of the inflation process. They fail, however, to corroborate the popular interpretation of the MABP, in which prices adjust instantaneously but money supply adjusts only with a lag. Either domestic monetary forces by themselves or international forces operating via some combination of a reserve-flow mechanism and central bank reaction function (or some combination of the two) were important.

4.4.2 Price and Interest-Rate Arbitrage

In table 4.3 we report test results derived from two sets of international price relations. In one we compare movements in the domestic price levels in each of the eight countries with movements in an index of price levels in the remaining seven countries. In the other we compare movements in the price level in each of the seven non-reserve-currency countries with movements in the price level in the U.S. Both sets of results are for the period through 1971III, since after that time most countries experienced substantial changes in their dollar exchange rate. In all instances we included six lagged values of the dependent variable in the equation and three of the independent variable.

For the comparisons of domestic and rest-of-world inflation, the results are mixed. We find some influence from lagged rest-of-world to domestic prices for the period ending 1971III in two countries, France and Japan. When we included the contemporaneous value of the world price index in

10. British results from much longer-term time series consistent with these findings are reported in Huffman and Lothian (1980) and for the postwar period in Williams, Goodhart, and Gowland (1976).

11. This same result was obtained for a broad range of Latin American countries in Cassese (1979, chapter 6).

12. In the U.K. what we call M2 is what the Bank of England calls sterling M3, but unlike their series it excludes government deposits and certificates of deposit.

Table 4.3 Price Arbitrage

$$Y_t = \alpha_0 + \sum_{i=1}^{m} \beta_i Y_{t-i} + \sum_{j=1}^{n} \gamma_j X_{t-j}$$

	Variable[†]		F Statistic[§]	Variable		F Statistic
Country	Y	X	$m = 6$, $n = 3$	Y	X	$m = 6$, $n = 3$
CA	PD	PDw	1.6741	PD	PDus	1.6765
	PDw	PD	3.4386#	PDus	PD	0.5394
FR	PD	PDw	3.0056#	PD	PDus	0.9744
	PDw	PD	3.9842##	PDus	PD	0.4912
GE	PD	PDw	0.2701	PD	PDus	3.9752#
	PDw	PD	0.8389	PDus	PD	1.1123
IT	PD	PDw	1.1179	PD	PDus	0.3129
	PDw	PD	1.3534	PDus	PD	1.1805
JA	PD	PDw	2.3618‡	PD	PDus	0.6907
	PDw	PD	0.6436	PDus	PD	1.4863
NE	PD	PDw	1.2523	PD	PDus	1.3365
	PDw	PD	0.9483	PDus	PD	0.3511
UK	PD	PDw	0.3151	PD	PDus	2.0759‡
	PDw	PD	0.3744	PDus	PD	0.4319
US	PD	PDw	1.4831			
	PDw	PD	2.4181‡			

†All variables are first differences of the natural log. PD is the GNP or GDP deflator, PDw is the rest-of-world deflator, and PDus is the GNP deflator for the United States.

§All regressions 1958II to 1971III. The null hypothesis is that the γ_j as a group are equal to zero.

‡Reject null hypothesis at $\alpha = 0.10$.

#Reject null hypothesis at $\alpha = 0.05$.

##Reject null hypothesis at $\alpha = 0.01$.

the equations, there was a significant relation for Canada also. For the U.S., the relation ran in the opposite direction. Somewhat anomalously, we uncovered a statistically significant reverse influence for Canada and France.

The U.S. versus individual foreign country price comparisons showed significant effects of lagged U.S. prices on German and British prices only and a borderline relation for Canada, which again became significant when we included the contemporaneous value of U.S. prices. France and Japan, the countries that exhibited the strongest response to rest-of-world prices, showed no relation with the U.S.

We summarize the U.S. versus foreign interest rate relations in table 4.4. With the exception of Italy for which we could obtain only a long-term rate, these comparisons are for three-month U.S. Treasury bills and a similar short-term foreign rate. Of all of the arbitrage relations, these

Table 4.4 **Interest Arbitrage**

$$Y_t = \alpha_0 + \sum_{i=1}^{m} \beta_i Y_{t-i} + \sum_{j=1}^{n} \gamma_j X_{t-j}$$

Country	Variable[†] Y	X	F Statistic[§] m = 6 m = 3
CA	IS	ISus	3.3243[#]
	ISus	IS	1.6404
FR	IS	ISus	2.7322[#]
	ISus	IS	0.8850
GE	IS	ISus	3.6046[#]
	ISus	IS	4.9406[##]
IT	IL	ILus	3.9248[#]
	ILus	IL	1.4547
JA	IS	ISus	0.2948
	ISus	IS	1.4438
NE	IS	ISus	5.9041[##]
	ISus	IS	1.0401
UK	IS	ISus	3.8546[#]
	ISus	IS	0.8776

[†]The interest rates are in first difference form. IS is the short-term interest rate for each country except Italy, for which the long-term interest rate is used. ISus is the short-term interest rate for the United States.

[§]All regressions 1958II to 1971III. The null hypothesis is that the γ_j as a group are equal to zero.

[‡]Reject null hypothesis at $\alpha = 0.10$.

[#]Reject null hypothesis at $\alpha = 0.05$.

[##]Reject null hypothesis at $\alpha = 0.01$.

show the most consistency among countries. For all the foreign countries other than Japan, lagged U.S. interest rates have a significant effect. And in most instances—Canada especially—both the magnitude and significance of the effect increase when we include the contemporaneous value of the U.S. rate along with the lagged. For Germany, however, we also uncovered a reverse influence. For Japan, our failure to find any relation may be largely the result of the nature of the Japanese capital market over much of this period, the fact that the Japanese government exercised substantial direct control over interest rates.

4.4.3 Central Bank Behavior and the Balance of Payments

In table 4.5 we report the results of the Granger tests of the relations between changes in foreign reserves and in domestic assets of the monetary authorities of the seven foreign countries.[13] For the U.S., since it is

13. Blejer (1979) presents results of similar tests for four of the countries in our sample—France, Germany, Italy, and the U.K.—and for Sweden. He, however, finds considerably less evidence of sterilization.

Table 4.5 **Domestic Credit and the Balance of Payments**

$$Y_t = \alpha_0 + \sum_{i=1}^{m} \beta_i Y_{t-i} + \sum_{j=1}^{n} \gamma_j X_{t-j}$$

	Variable[†]		*F* Statistics for Lags (*m*, *n*) and Period Ending:[§]		
Country	*Y*	*X*	1971III $m = 3$ $n = 3$	1973IV $m = 3$ $n = 3$	1976IV $m = 3$ $n = 3$
CA	FH	DH	1.2185	1.4081	1.6945
	DH	FH	0.8582	1.0134	1.0938
FR	FH	DH	0.1140	0.4690	0.1017
	DH	FH	3.8398[##]	2.7887[#]	2.4045[‡]
GE	FH	DH	0.2463	0.6432	0.4089
	DH	FH	2.2295[‡]	3.3784[#]	3.9930[##]
IT	FH	DH	0.1142	0.4898	1.0168
	DH	FH	0.8010	1.0569	2.2833[‡]
JA	FH	DH	0.8563	1.9006[‡]	1.5299
	DH	FH	2.4706[‡]	2.9194[#]	1.9233[‡]
NE	FH	DH	0.9079	2.7864[#]	2.7909[#]
	DH	FH	4.6111[##]	4.3709[##]	6.0623[##]
UK	FH	DH	0.3949	0.8334	1.4041
	DH	FH	0.1568	2.4819[‡]	2.5390[‡]
US	BP	H	0.5770	2.0949[‡]	2.6524[‡]
	H	BP	1.2728	1.1110	1.0156

[†]The variables for Canada, Germany, Italy, and Japan are first differences of the natural log. The variables for France, the Netherlands, the U.K., and the U.S. are arithmetic first differences scaled by high-powered money. FH is official reserve assets, DH is domestic credit, BP is the U.S. official settlements balance, and H is high-powered money.

[§]All regressions start in 1958II. The null hypothesis is that the γ_j are as a group equal to zero.

[‡]Reject null hypothesis at $\alpha = 0.10$.

[#]Reject null hypothesis at $\alpha = 0.05$.

[##]Reject null hypothesis at $\alpha = 0.01$.

the reserve-currency country, we report results based on the relation between the balance of payments, on an official settlements basis and scaled by high-powered money, and changes in total high-powered money.

By far, the more consistent relation for the foreign countries is from changes in foreign reserves to changes in domestic credit. France, Germany, Japan, the Netherlands, the U.K., and, to a lesser extent, Italy all show a significant and negative effect of foreign reserves on domestic assets. In Canada, the sums of the coefficients are positive but not statistically significant at the lag lengths reported in the table. However, when we extended the lag to six periods for the independent variable, the coefficients became significant and their sum remained positive.

The relations running in the other direction, somewhat surprisingly, are less well defined. Among the foreign countries, Japan is the only country for which there is a significant and negative influence of domestic on foreign assets. In the Netherlands, the relation is significantly different from zero in two instances but the sum of the coefficients is positive.

In the U.S., in two of the periods we find a significant relation running from high-powered money to the official settlements balance and no effect in the opposite direction.

In all of the foreign countries, therefore, some type of central bank reaction function seems to have existed over the sample period. The monetary authorities, in countries other than Canada, apparently tried to offset the effects of balance-of-payments movements on their domestic money stocks. The Bank of Canada, in contrast, seems to have done the opposite. Desirous perhaps of maintaining a stable exchange rate with the U.S. dollar, the Canadians appear to have reacted to balance-of-payments inflows by engaging in some monetary expansion of their own.

The Federal Reserve's actions—and the results are hardly at variance with what one could expect for the central bank of a reserve-currency country—appears to have paid little attention to the balance of payments in conducting policy. That policy, however, seems to have been the source of the sometimes sizable U.S. balance-of-payments deficits during this period.

4.4.4 Sources of Monetary Change

We ran two other series of regressions and performed the associated Granger tests to analyze the sources of monetary growth in the seven foreign countries in the sample from two slightly different perspectives.[14] In one, we compared movements in the three domestic monetary aggregates in each of the countries with the movements of their counterparts in the U.S. In the other, we compared the movements in each of the domestic aggregates with movements in foreign and domestic assets of that country's monetary authorities. For the sake of brevity, we do not report these results.

The first set of results was not terribly satisfactory. Only in the Canadian and German regressions were there significant positive relations between the lagged U.S. aggregate and the comparable domestic aggregate. In both countries, moreover, there were somewhat implausible significant reverse influences in several instances.

The foreign asset and domestic asset versus domestic monetary aggregate tests were slightly better. For all the non-reserve-currency countries except the U.K., movements in lagged foreign assets made a statistically

14. The results that we discuss in this section are for the period ending 1971III only. Results for the longer period during which exchange rates were more variable were considerably less satisfactory.

significant contribution to the explanation of movements in at least one of the monetary aggregates. The results for domestic assets were a mixed lot. For three of the countries—Canada, Italy, and the U.K.—domestic assets had no perceptible influence on any of the three monetary aggregates. For the others—France, Germany, Japan, and the Netherlands—domestic assets had a statistically significant, but negative, effect.

These latter results are difficult to rationalize as reflections of central bank behavior. They could arise because of either spurious correlation or the existence of a more intricate relation between foreign assets of the central banks of the reserve-currency and non-reserve-currency countries.

4.5 Summary and Conclusions

Our purpose in this chapter has been to investigate the channels through which inflation has been transmitted internationally. To do so we have focused upon five areas that featured prominently in our theoretical discussion: the relation between domestic money and prices, the influence of foreign prices on domestic prices, the influence of foreign interest rates on domestic interest rates, the behavior of the central bank, and the relation between the components of high-powered money and the monetary aggregates.

The results we have obtained have several major implications. Let us consider the money-price relation first. In all countries our tests showed a significant effect of lagged domestic money growth on domestic inflation, which appears to be fairly robust across the specifications we tried. The strength of these relations suggests that one-shot and transitory phenomena, such as shifts in money demand, are unlikely to have been the major causative factors behind inflation. Similarly, given the absence of a consistent reverse relation from inflation to money growth for most countries, an explanation of inflation that attributes it primarily to cost-push accommodated by domestic monetary growth appears doubtful for most, if not all, of the countries in the sample.

What at first glance appears surprising about these results is the similarity in the timing relations among countries. According to one somewhat popular notion, they ought to differ: changes in monetary growth occurring before changes in inflation in the United States, the reserve-currency country, and occurring afterward in the seven foreign countries. As we have pointed out, however, there is no necessary correspondence between openness and the direction of Granger-causation.

Our results are consistent with the seven foreign economies being independent of the U.S. or, alternatively, with a chain of transmission running from U.S. money via the balance of payments to foreign money and thence to foreign prices. They are inconsistent with an adjustment mechanism that operates exclusively via price arbitrage.

Further evidence on the question of price arbitrage comes from the two sets of price comparisons we have made. They provide no evidence of a strong price arbitrage relation and thus do not suggest that domestic money was purely passive or that foreign central banks were purely silent partners of the U.S. monetary authorities. They imply that some potential existed for a number of the non-reserve-currency countries to operate an independent monetary policy, at least in the short run.

To the extent that there was an international transmission process, it appears to have worked through asset markets. In all countries but Japan, some evidence of interest arbitrage was uncovered. Additionally, in all but the U.K., changes in foreign reserves had a statistically significant effect on at least one of the three monetary aggregates. Furthermore, in Canada and Germany—the countries that both had very similar inflation experiences to that of the U.S. in the period prior to 1972—U.S. monetary variables had a significant effect on the domestic monetary variables. Thus, when we combine the inflation comparison results with the interest arbitrage and the foreign reserve–domestic credit results, we obtain a picture of the operation of a self-regulating mechanism preventing long-run monetary independence but allowing some scope for short-term domestic monetary control.

Another set of implications stems from what we have learned from analyses of changes in the asset components of the central banks' portfolios and of their relations with changes in high-powered money and the two broader monetary aggregates. These are, however, somewhat tenuous. In a number of countries—France, Germany, Japan, the Netherlands, and to some extent Italy and the U.K.—we find evidence of some sterilization of reserve inflows. For Canada, we found a significant positive effect of reserve inflows on domestic assets.

On the whole, these are a priori appealing results that appear to explain some of the differences among countries: low- and moderate-inflation countries trying to avoid importing inflation from the U.S. and being at least partially successful; Canada seeking to stabilize its price level and exchange rate vis-à-vis the U.S. dollar; and Italy and the U.K.—the higher-inflation countries—acquiescing in the face of reserve inflows and perhaps, though the data are mostly moot on this point, going the U.S. one step better in the way of monetary expansion.[15]

15. The general thrust of these conclusions is similar to that of Connolly and Taylor (1979). Tullio (1979) contains a model of the U.S. balance of payments that is also consistent with our results. His finding of an initial overshooting in the U.S. balance of payments following an increase in U.S. domestic credit is suggestive of a chain of causation similar to the one we have outlined: from U.S. monetary policy via the balance of payments to foreign money and then to foreign prices.

Acknowledgments

The authors would like to acknowledge the able research assistance of Connie McCarthy and the helpful comments of the other members of the NBER Project on the International Transmission of Inflation, Anna J. Schwartz, Alan Stockman, and, in particular, Michael R. Darby and Arthur Gandolfi. The suggestions received from members of the Macroeconomics Workshop at New York University were also helpful, especially those of Michael Hamburger.

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