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11 Capital Mobility and the Scope for Sterilization: Mexico in the 1970s

Robert E. Cumby and Maurice Obstfeld

This paper studies the interaction between Mexico's capital account and domestic credit policy during the decade 1970–1980. It seeks in particular to measure the offset to monetary policy caused by interest-sensitive capital flows, and, in doing so, is careful to account for the potential estimation bias introduced by central bank sterilization activities. The empirical record suggests that the instantaneous capital account offset to monetary policy, while substantial, was less than complete in the 1970s. The Banco de México's short-run control of the monetary base allowed it to sterilize international reserve movements, at least over part of the decade.

Empirical studies of offsetting capital flows have concentrated almost exclusively on the industrialized, North Atlantic economies.[1] But the impact of capital mobility on domestic monetary management is of great importance for Mexico, which until August 1982 had allowed relatively unrestricted external asset trading, and for other industrializing economies which have only recently removed impediments to capital account

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1. An exception is Miller and Askin (1976), which studies Brazil and Chile and reaches conclusions similar to those reached below for the Mexican case.

transactions. Argentina, for example, experienced substantial capital inflows and real exchange rate appreciation as a result of the disinflation policy it pursued in the late 1970s. Sterilization might mitigate these problems during the transition to lower inflation rates in countries (such as Uruguay) following strategies similar to Argentina's.

Broadly speaking, the econometric approaches taken in the industrialized country studies of the capital account offset may be classified either as "reduced form" (Porter 1972; Kouri and Porter 1974; Girton and Roper 1977) or "structural" (Herring and Marston 1977; Obstfeld 1980*a*).[2] In this paper, we apply the structural approach to the recent Mexican experience in order to avoid the simultaneous equations bias that may distort reduced-form offset estimates in the presence of a sterilization rule. The structural model estimated is a partial equilibrium model of financial markets, however. As such, it can yield at best a partial picture of the channels through which monetary policy was offset over the longer run.

An additional feature of our econometric technique deserves mention. Along with the standard two-stage least squares estimates of the Mexican structural equations, we present estimates based on the two-step, two-stage least squares procedure proposed by Cumby, Huizinga and Obstfeld (1981). The theoretical advantages of the latter estimator are discussed in context below.

The plan of the paper is as follows: Section 11.1 distinguishes between offsetting capital movements and systematic sterilization as possible causes of an empirical negative correlation between capital inflows and increases in the domestic source component of the monetary base. We briefly review the reduced-form approach to the offset in the light of possible contemporaneous feedback from the balance of payments to the central bank's domestic assets.

Section 11.2 describes our empirical measure of domestic credit expansion and estimates a quarterly Banco de México reaction function relating changes in the domestic source component of the high-powered money stock to the balance of payments and the public sector borrowing requirement. We find that reserve flows were a significant determinant of domestic credit movements in the 1970s and are unable to reject the hypothesis that sterilization of reserve flows was complete, at least over the second half of the decade.

Section 11.3 estimates the parameters of a small, aggregative model of Mexico's money market and capital account. The underlying portfolio balance model of the capital account assumes that peso-denominated, nonmoney assets and covered foreign assets are imperfect substitutes in

2. The paper of Argy and Kouri (1974) does not fall easily into either of these categories. See note 8 below for further discussion.

portfolios and allows for the gradual adjustment of portfolio shares to their desired values. The empirical results imply that, depending on how the increase in the money supply was effected, anywhere between 30 and 50 percent of an expansion in domestic credit was offset by capital outflow in the same quarter. The offset would have been higher had asset markets adjusted fully within one quarter.

Section 11.4 briefly discusses the extent to which a systematic relationship between domestic credit movements and the futures premium on foreign exchange might alter the results of section 11.3. The data reveal a pronounced relation between the futures premium and lagged deviations from purchasing power parity. We argue that expectations concerning possible peso devaluation were the major determinant of the premium.[3] The implication is that the external offset to monetary policy was probably exacerbated through channels not captured in our partial-equilibrium, financial-sector model.

Section 11.5 contains some concluding remarks. An appendix describes the construction of the data series employed in this study.

11.1 Sterilization and the Capital Account Offset

When the exchange rate is pegged and international capital movements are sensitive to interest rate differentials between countries, the capital account response to domestic monetary measures diminishes their effect on the monetary base. An expansion of domestic credit, say, exerts downward pressure on domestic borrowing costs, inducing a reduction in net private foreign indebtedness and a central bank reserve loss that offsets some fraction of the intended increase in the base. When domestic and foreign securities are perfectly substitutable and portfolios adjust instantaneously, this offset is complete and immediate: the central bank possesses no control over the domestic money stock.[4]

Both imperfect *substitutability* between interest-bearing assets of different currency denomination and imperfect *mobility* of capital between financial centers may afford a central bank some short-run monetary independence. Neither necessarily enables the central bank to peg the price level or money supply indefinitely (see Obstfeld 1980*b*). Imperfect

3. The peso was devalued on August 31, 1976. A second devaluation occurred on February 18, 1982; and a third, on August 5, 1982, was accompanied by capital controls and the establishment of a two-tier foreign exchange market.

4. See Keynes (1930, vol. 2, p. 309) and Mundell (1963). A key assumption in deriving this result is that the central bank expands domestic credit through an open-market operation that leaves private wealth unchanged. If domestic credit creation augments private wealth and the public's demand for money is a function of its wealth, the capital account offset will not be complete, even under perfect capital mobility and unlimited asset substitutability. Below, we compute the empirical offset coefficients associated with both types of domestic credit creation.

substitutability can arise if various risks render stochastic the perceived returns on domestic and foreign assets. When this is so, the desired portfolio share of domestic bonds in domestic wealth is an increasing function of the home interest rate; and the central bank can influence this rate (and so, the demand for money) by varying the stock of outside domestic currency debt available to private wealth owners.[5] Costs associated with rapid portfolio adjustment may allow international interest rate arbitrage to occur only over time. Thus, imperfect capital mobility affords the monetary authority a second means of temporarily influencing domestic credit conditions. The model of Mexico estimated below allows for both possible sources of short-run interest rate independence in the presence of international asset trade.

The offset to monetary policy gives rise, empirically, to a negative correlation between the capital account surplus and increases in the domestic component of the base. Figure 11.1 plots the change in Banco de México's reserves against the seasonally adjusted change in domestic credit and is suggestive of such a negative correlation in the Mexican case.[6] But the absolute magnitude of this correlation, by itself, is not evidence of a powerful capital account offset. Central banks frequently take advantage of any short-run monetary control they possess to sterilize reserve flows. Their attempts to divorce the balance of payments from the high-powered money supply introduce an additional source of systematic negative correlation between domestic credit and capital inflows. A sterilization rule increases reserve volatility, but can successfully counteract balance of payment influences on the money supply in the short run when the capital account offset is incomplete. Under sterilization, there is a systematic contemporaneous feedback from the balance of payments to the domestic assets of the central bank. These two variables are jointly, endogenously determined by the preferences of private asset holders and the monetary policy reaction function of the central bank.

Attempts to measure the offset coefficient—the fraction of any domestic credit increase offset by capital outflow over the relevant time horizon—have often failed to account for sterilization, and instead view the domestic source component of the base as a predetermined variable for purposes of estimation. Studies adopting this assumption produce estimates of the offset which reflect the central bank's policy as well as the true capital account response to domestic credit expansion; but they erroneously ascribe the computed correlation exclusively to the latter. This is true in particular of the "reduced-form" approaches to the offset

5. Even when foreign and home bonds are imperfect substitutes, the central bank may be unable to control the monetary base if government debt is not outside debt; see Obstfeld (1982*a*) and Stockman (1979). We ignore below the problems that can arise when the public internalizes the government and central bank budget constraints.

6. The series are adjusted for reserve requirements as described in section 11.2.

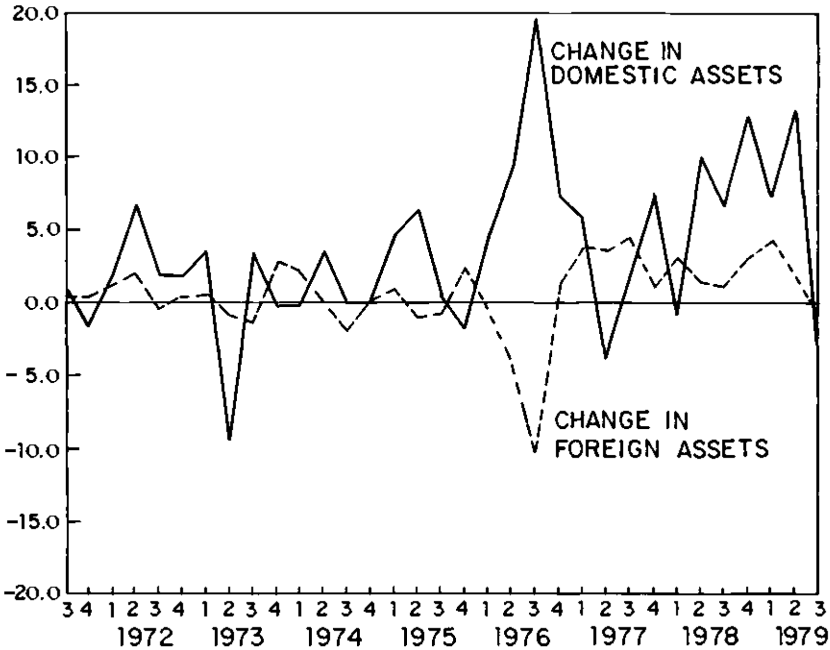

Fig. 11.1 Banco de México: changes in domestic and foreign assets (billions of pesos).

coefficient, which use ordinary least squares to regress the capital account surplus on the contemporaneous increase in domestic credit, the current account surplus, and the exogenous determinants of changes in the external asset position and the domestic interest rate (usually the contemporaneous change in the foreign interest rate and home income).[7] When the monetary authority pursues a sterilization policy, the resulting least

7. The reduced-form capital flow equation, as estimated by Kouri and Porter (1974), is derived in two steps. First, one writes the change in net external lending over a quarter as a function of the changes in the foreign and home interest rates and the changes in income and other determinants of the capital account. Second, one eliminates the change in the domestic interest rate from this equation using the (first-differenced) money-market equilibrium condition, which relates the quarterly change in (base) money demand to the sum of the capital account, the current account, and the increase in central bank domestic assets. It is of course possible that the change in home income is *not* a predetermined variable; and if income is not predetermined, ordinary least squares estimates of the reduced-form capital flow equation are inconsistent even if domestic credit policy is unrelated to the balance of payments. However, the assumption that income is predetermined is traditional in the empirical literature on offset coefficients. A similar problem arises if the current account is falsely taken to be a predetermined regressor. That problem can be avoided by moving the current account variable to the left-hand side of the capital flow equation and estimating an offset equation in which the change in international reserves is the dependent variable. Such an equation captures the current account as well as the capital account offset to domestic credit creation.

squares estimate of the domestic credit variable's coefficient is not a consistent estimate of the offset coefficient, for that variable is correlated with the capital-flow equation's disturbance term. The bias this correlation imparts to the estimated offset is discussed by a number of authors, including Argy and Kouri (1974), Magee (1976), Girton and Roper (1977), Murray (1978) and Obstfeld (1980*a*, 1982*b*).

Empirical equations which express changes in foreign reserves as a function of changes in domestic credit, changes in income, and changes in the *home* interest rate (e.g., Cardoso and Dornbusch 1980) are clearly money-demand equations, and thus can give no information regarding the effect of credit expansion on the capital account. (See Frenkel, Gylfason, and Helliwell 1980, among others, for discussion of this point.) Balance of payment equations such as the one estimated by Connolly and Dantas da Silveira (1979), which assume that income is predetermined and that money demand and the money supply multiplier are interest inelastic, assume implicitly that the external offset to domestic credit expansion is complete.[8]

In section 11.2 we estimate a Banco de México monetary policy reaction function. The results provide strong evidence that the Mexican authorities pursued a systematic policy of full sterilization during at least the second half of the 1970s. To avoid the bias this might introduce into reduced-form results, we then estimate a small structural model of Mexico's financial markets. This allows us to calculate estimates of the offset coefficient by tracing the effect on the stock of net external claims of increases in the domestic credit component of the monetary base. The structural model allows for gradual asset-market adjustment, and thus allows us to distinguish empirically between the consequences of imperfect substitutability and imperfect mobility of capital. Accordingly, we report estimates of both the short-run or one-quarter offset coefficient and the long-run offset coefficient. The former gives the fraction of a monetary expansion reversed by capital outflow in the same quarter on the assumption that output, the price level, and the futures premium are predetermined; the latter is a hypothetical construct measuring what the

8. If current real income were instead allowed to be endogenous, responding positively to a fall in the home interest rate, the offset could be incomplete even in this interest-inelastic case. It is worth noting that when money demand and money supply are both interest inelastic, the Kouri-Porter capital flow equation is underidentified. Identification is lost also when no variables other than the balance of payments enter the monetary policy reaction function. (The last statement assumes that no prior information is available concerning the degree of correlation between the disturbances of various equations.) If domestic credit responds systematically to variables other than the balance of payments, these variables, if predetermined, may be used as instruments in estimating the reduced-form capital flow equation by two-stage least squares. An instrumental-variable approach, which in principle yields consistent parameter estimates, was suggested by Argy and Kouri (1974). Their estimated offset coefficients were generally similar to those obtained by Kouri and Porter using ordinary least squares.

short-run offset would be if asset holdings could adjust immediately to their long-run desired levels.

11.2 The Banco de México's Reaction Function

In this section we examine the extent to which the Banco de México systematically neutralized the monetary effects of its foreign exchange intervention. To begin, we describe the construction of a domestic credit policy variable which summarizes the effects of a variety of instruments available to the central bank. We next estimate a central bank reaction function relating the level of this policy variable to a number of macroeconomic targets. The central finding is that a policy of systematic sterilization appears to have been followed at least during the second half of the 1970s. Not surprisingly, we find also that credit policy is influenced strongly by the need to finance the public sector's deficit, and that seasonal variation in liquidity preference is accommodated by the monetary authority.

To construct a comprehensive measure of monetary policy suited to the recent Mexican experience, two important adjustments of the published domestic credit series are required. The first involves the treatment of decisions to monetize changes in the peso value of the Banco de México's international reserves. The second incorporates the effects of variations in the reserve requirements imposed on private banks.

The peso value of the Banco de México's foreign reserves may change for two reasons other than actual foreign exchange intervention. The first of these is fluctuations in the market price of gold. Since the second quarter of 1976, the Banco de México has revalued its gold holdings daily to reflect prevailing market prices. As a result, the *dollar* value of gold holdings increased by more than 500 percent between 1975 and 1979, while physical gold holdings declined by 45 percent over the same period.[9] A second source of reserve change in the absence of balance of payments disequilibrium is exchange rate variation. When the peso-dollar rate was altered abruptly in 1976, Banco de México experienced a substantial capital gain, in peso terms, on its holdings of foreign currency denominated assets. Devaluation, like the gold price increases, inflates the book value of reserves.

The decision to monetize such capital gains as a means of government finance is entirely discretionary. The alternative is the creation of a fictitious accounting liability that offsets the increase in the peso value of central bank foreign assets without directly increasing the high-powered money stock. Monetization is thus completely analogous to an increase in

9. Calculations are based on year-end data published in the International Monetary Fund's *International Financial Statistics*, lines 1ad and 1and.

the domestic assets of the central bank, even though it presupposes a rise in the peso value of the bank's foreign assets. It should be included in any measure of domestic credit change and excluded when calculating foreign reserve changes.[10]

Minimum reserve requirements for private banks were varied several times during the 1970s, and these changes, too, should enter into a summary measure of domestic credit policy. We incorporate them by assuming that policymakers think in terms of an *adjusted monetary base*, that is, a base adjusted to reflect the effect of average reserve ratio changes on the volume of demand deposits it supports. (We abstract from currency in circulation.) The adjusted base at time t, BA_t, is given by

$$BA_t = \frac{q_0}{q_t} B_t,$$

where q_0 is the base-period (1971:1) average reserve ratio, q_t the current reserve ratio, and B_t the unadjusted base, measured in pesos.[11] BA_t is just the base that would support a money supply equal to B_t/q_t were the average reserve ratio at its base level q_0.

Letting ΔFACB_t denote the change in central bank foreign assets over period t (excluding valuation changes) and ΔDACB_t the change in central bank domestic assets over period t (including monetized capital gains on foreign reserves), we may write

$$(1) \qquad BA_t = BA_{t-1} + \frac{q_0}{q_{t-1}} (\Delta\text{FACB}_t + \Delta\text{DACB}_t + \Delta B_t^*),$$

where $\Delta B_t^* = [(q_{t-1} - q_t)/q_t]B_t$. Because

$$(B_t + \Delta B_t^*)/q_{t-1} = B_t/q_t,$$

ΔB_t^* is the increase in the unadjusted base that would, at reserve ratio q_{t-1}, bring about the same rise in the volume of demand deposits supported by B_t as a reduction of the reserve ratio from q_{t-1} to q_t. The quantity $(q_0/q_{t-1})\Delta B_t^*$ appearing on the right-hand side of (1) thus measures the impact of the reserve ratio change on the adjusted base.

Identity (1) suggests a natural measure of overall domestic credit policy:

$$(2) \qquad \Delta\text{MP}_t = \frac{q_0}{q_{t-1}} \Delta\text{DACB}_t + \frac{q_0}{q_{t-1}} \Delta B_t^*.$$

We take ΔMP to be the dependent variable in the Banco de México's

10. The data appendix provides details on the construction of our central bank domestic asset series. See also Girton and Roper (1977) on the appropriate treatment of capital-gains monetization.

11. Details on the calculation of the average reserve ratio series used in this study appear in the appendix.

monetary reaction function, and turn next to a discussion of the appropriate independent variables.

A central bank reaction function should allow for response to a number of factors in addition to the balance of payments. Monetary policy, as defined by (2), may respond also to real output fluctuations, to changes in Mexico's international competitiveness as measured by the real exchange rate, and to seasonal fluctuations in money demand, for example. Further, in the Mexican case, the public sector's borrowing requirement is a major determinant of domestic credit creation. We therefore specified a reaction function of the form:

$$\Delta \mathrm{MP}_t = a_0 + a_1(q_0/q_{t-1})\Delta \mathrm{FACB}_t + a_2(q_0/q_{t-1})\mathrm{GOVBOR}_t$$

$$+ a_3 p_{t-1} + a_4 \ln(y_{t-1}/y_{t-2}) + \sum_{i=1}^{3} a_{4+i} Di + u_{1t}. \tag{3}$$

In (3), GOVBOR is the consolidated public sector deficit, $p \equiv \ln(e\mathrm{PUS}/\mathrm{PMex})$ the log of the real exchange rate, y the index of real industrial production, and Di a seasonal dummy for the ith quarter. PUS and PMex are the U.S. and Mexican price levels, while e is the peso price of U.S. dollars.[12]

When the central bank pursues a systematic sterilization policy, a_1 is negative. If $a_1 = -1$, the monetary authority seeks to neutralize all reserve flows through offsetting movements in domestic credit: sterilization is complete. A positive value of a_1 indicates that monetary policy is aimed at external balance.

The role of government deficit financing is particularly important in Mexico.[13] The consolidated public-sector borrowing requirement consists almost entirely of the central government's borrowing requirement and the borrowing requirements of "controlled" public enterprises. In general, that part of the public sector deficit not financed through external borrowing must be financed through the domestic banking system. (The Banco de México, since 1955, has induced private banks to hold a large portion of the public sector's debt by allowing certain debt holdings to serve as required reserves.) Because the domestic banking system plays an important role in deficit financing, we expect the coefficient a_2 in (3) to be positive and significant. However, because public external borrowing is important as well, we expect a_2 to be smaller than 1.

If the monetary authority adopts a competitiveness target, the coefficient a_3 of the lagged real exchange rate should be positive. Thus, when domestic prices rise more quickly than exchange rate adjusted foreign

12. All variables are defined in detail in the appendix. Financial aggregates are measured in billions of pesos.

13. We draw on the discussions of government deficit financing in Brothers and Solís (1966) and Ortiz and Solís (1979).

prices, credit policy becomes more restrictive. If monetary policy is used to lean against cyclical activity fluctuations, a_4 is negative.

Finally, as the major seasonal influence on money demand is the fourth-quarter increase, the coefficients of the seasonal dummies should be negative.

The results of estimating the reaction function with quarterly data appear in table 11.1. The endogeneity of the balance of payments makes an instrumental variables estimation technique necessary, and two different ones were employed. The first of these was Fair's (1970) version of two-stage least squares (2SLS), which incorporates a correction for first order serial dependence in the equation's disturbance. The second was the two-step, two-stage least squares (2S2SLS) procedure proposed by Cumby, Huizinga, and Obstfeld (1981). An advantage of 2S2SLS is that the asymptotic distribution theory it uses to calculate parameter estimates' standard errors is valid under assumptions less restrictive than those adopted by Fair.[14] But both estimation methods should yield consistent parameter estimates in the present setting.

Initially, the specification (3) was used; the results are reported as equations (A) and (C) in table 11.1. Both estimates give the competitiveness term the expected positive sign, but they provide no evidence that countercyclical considerations influence domestic credit policy. Equations (B) and (D) present estimates of a reaction function from which the statistically insignificant competitiveness and cyclical variables have been excluded. The remaining coefficients exhibited relatively little sensitivity to this exclusion restriction.

The accommodation of seasonal money demand shifts is apparent in the estimates, with a strong seasonal expansion in the fourth quarter.[15] The public sector borrowing requirement is highly significant in all the regressions. These indicate that roughly 70 to 85 percent of the overall public sector deficit is financed through domestic credit creation.

Most importantly, the balance of payments coefficient $\hat{a}_1$ is negative and has a marginal significance level lower than .05 in all versions of the reaction function. Although $\hat{a}_1$ is usually smaller than -1, it is more than one standard error away from -1 only in equation (D). Thus, one cannot strongly reject the hypothesis $a_1 = -1$. The data suggest that the Banco de México attempted to control the money stock through full neutralization of reserve flows.

14. The standard error estimates produced by 2S2SLS allow for a nonzero covariance between the estimates of the structural parameters and the estimate of the autoregressive parameter (denoted by ρ in table 11.1). In addition, 2S2SLS does not require the absence of conditional heteroscedasticity, an important problem in standard error estimation when lagged endogenous variables are used as instruments. Conditional heteroscedasticity is discussed by Dhrymes (1974, pp. 183–184), Engle (1982), and Hansen (1979), and, in a cross-sectional context, by White (1980, 1982).

15. This seasonality is reflected in the money demand equation estimated below.

Table 11.1 **Mexico: Reaction Function (1971:3–1979:4)[a]**

Method	Constant	$(q_0/q_{-t}) \times$ ΔFACB	$(q_0/q_{-t}) \times$ GOVBOR	p_{-1}	$\ln(y-1/y-2)$	$D1$	$D2$	$D3$	$\hat{\rho}$	SE	R^2
(A) Fair	20.8	−1.266	0.760	22.7	67.7	−40.0	−18.1	−41.2	−0.82	10.6	0.747
	(10.9)	(0.595)	(0.172)	(22.4)	(73.6)	(20.7)	(5.0)	(21.5)	(0.13)		
(B) Fair	16.8	−1.453	0.834	—	—	−32.9	−17.1	−31.6	−0.73	10.6	0.729
	(7.8)	(0.655)	(0.181)			(14.2)	(4.5)	(14.2)	(0.17)		
(C) 2S2SLS[b]	21.2	−1.153	0.691	21.3	39.7	−40.3	−17.0	−38.2	−0.86	9.4	0.738
	(25.5)	(0.223)	(0.121)	(13.0)	(51.9)	(50.8)	(3.4)	(48.3)	(0.26)		
(D) 2S2SLS	13.0	−1.315	0.737	—	—	−25.4	−14.8	−21.8	−0.69	9.7	0.721
	(3.1)	(0.127)	(0.102)			(4.6)	(2.6)	(3.7)	(0.09)		

[a]Standard errors are in parentheses. Mean of dependent variable is 5.8 billion Mexican pesos. Instruments used were a constant, three seasonal dummies, lagged monetary policy, lagged reserve changes, lagged government deficit, once- and twice-lagged competitiveness and real income changes, foreign income, and the foreign interest rate. When the lagged competitiveness and cyclical terms were dropped in (B) and (D), those variables were also removed from the instrument list. The choice of instruments allows the government deficit to be endogenously determined.

[b]Equation (C) reports two-stage least squares estimates that use a heteroscedasticity-consistent estimate of the parameter estimates' variance-covariance matrix. These results, rather than the more efficient second-step estimates, are reported here because the algorithm for computing the latter failed to converge after 200 iterations. The parameter estimates obtained after 200 iterations were virtually identical to those reported in (C), however. For example, the sterilization coefficient was −1.158 and the government deficit coefficient was 0.692.

To investigate the stability of the reaction function, we split our sample into two subperiods, 1971:3–1975:4 and 1976:1–1979:4. In the first subperiod there appeared to be no significant relationship between domestic credit policy and any of the explanatory variables (other than dummies). The relationship estimated (by Fair's method) over the second subperiod is similar to those reported in table 11.1:

$$\Delta MP = \underset{(48.7)}{64.6} - \underset{(0.584)}{1.362}\,(q_0/q_{-1})\Delta FACB + \underset{(.174)}{.441}\,(q_0/q_{-1})GOVBOR$$
$$- \underset{(95.6)}{122.9}\,D_1 - \underset{(6.8)}{29.7}\,D_2 - \underset{(94.8)}{114.6}\,D_3,$$

$$\hat{\rho} = \underset{(0.05)}{-0.94}, \qquad SE = 10.4, \qquad R^2 = 0.904.$$

These results suggest that sterilization was a more important factor in monetary policy during the second half of the 1970s than during the first half.[16] The finding is consistent with the fact that the range of monetary tools available to the Banco de México broadened considerably after 1975.[17]

We conclude that part of the observed negative correlation between changes in the domestic and foreign source components of the base is likely to be the result of official sterilization policy. An implication is that domestic credit policy responds to the contemporaneous balance of payments and should not be treated as a predetermined factor in estimating the capital account offset coefficient.

11.3 A Structural Model of Asset Markets

In this section we estimate a small, aggregative portfolio-balance model of Mexican financial markets. The model allows the calculation of both the short-run and long-run offset coefficients. It consists of three equations: a demand equation for the net external liabilities of the Mexican private sector, a money demand equation, and a money supply equation. All equations are based on quarterly data and were estimated by 2SLS (with Fair's autoregressive correction when necessary) and by the 2S2SLS procedure. A list of the instruments used is provided in a note to table 11.2.

16. Bhalla (1981) computes a positive correlation between the balance of payments and the change in the money stock using annual data for the period 1956–1972. This evidence also suggests that sterilization was of limited importance before the mid-1970s.

17. Business International (1979) reports that Banco de México has used *Certificados de Tesorería de la Federación* since 1978 and petrobonds since 1977 to conduct open-market operations. In addition, the move to market valuation of gold reserves in 1976 allowed greater flexibility in choosing the rate of domestic credit expansion. Prior to these innovations, the monetary authority relied on reserve-requirement changes, special deposits, and operations in government securities within the banking system (see Brothers and Solís 1966). Only the last of these was employed with any frequency.

Both the money and external liability demand equations relate desired asset holdings to the expected return on foreign assets. An important component of this return is the expected depreciation of the peso relative to foreign currency. The presence of a large, discrete devaluation of the peso in 1976:3 poses a problem, for it is unlikely that the devaluation was completely unanticipated, or that anticipations of exchange rate movements were a minor determinant of capital flows in 1976–1977. Indeed, figure 11.1 presents striking evidence that the devaluation of 1976 was preceded by a sizable anticipatory outflow of capital.

To capture the impact of exchange rate expectations, we used the premium on three-month peso futures as an explanatory variable in our empirical equations.[18] This premium does reflect the anticipation of a devaluation for several quarters preceding 1976:3, but was always substantially smaller than the realized parity change. This is not surprising in view of the uncertain date of the peso's devaluation.[19]

Each equation is now discussed in turn. At the end of the section, the implied offset coefficients are calculated.

11.3.1 Net Foreign Liabilities

We assume that the real peso value of the desired stock of net external liabilities, eF^d/PMex, may be written as a function of domestic and foreign interest rates, domestic real income, and domestic real wealth:

$$\frac{eF^d}{\text{PMex}} = \Phi(r, r^* + f, y, W/\text{PMex}) + u_2. \tag{4}$$

In (4), r is the domestic interest rate, r^* the foreign rate, f the premium on peso futures, and W nominal Mexican wealth.[20] We assume that Mexican participants comprise a sufficiently small share of the world financial market that the foreign interest rate may be taken as exogenous.

18. The futures rate is expressed in pesos per dollar; and the futures premium is the percent excess of the futures rate over the spot rate e (on an annualized basis). The futures premium can be interpreted as an indicator of exchange rate expectations or as the cost of forward cover. The two interpretations, of course, need not conflict. We use the futures premium rather than the forward premium used by Lizondo (chapter 10 of this volume) because there is a longer series of observations available for the former variable. Jacob Frenkel has suggested that the futures premium may measure exchange rate expectations with error. The two-step, two-stage least squares estimates (but *not* Fair's method estimates) reported below yield consistent parameter estimates even when all asset returns are measured with random, serially uncorrelated error. See Cumby, Huizinga, and Obstfeld (1981) on the procedure to employ when an equation with errors in variables is corrected for autoregressive dependence of its structural disturbance.

19. Lizondo (1983) shows how the futures premium may underpredict an anticipated future devaluation if agents have rational expectations and are uncertain about the timing (but not the magnitude) of the devaluation.

20. All rate-of-return variables are measured in units of percent per annum. We are assuming here that domestic and covered foreign bonds are imperfect substitutes because of political risk. See Aliber (1973) and Dooley and Isard (1980). After the August 1982 devaluation, the Mexican government did in fact take measures penalizing holders of U.S. dollar denominated assets within its jurisdiction.

In addition, we assume that foreign holdings of peso-denominated assets are negligible, so that we may ignore the effects of foreign income and wealth. To incorporate the possibility of imperfect capital mobility, we suppose that agents need not adjust portfolio shares instantaneously to their full optimum level, but instead succeed in making a fraction λ of the adjustment each period. Thus,

$$(5) \quad eF/\text{PMex} - e_{-1}F_{-1}/\text{PMex}_{-1} = \lambda(eF^d/\text{PMex} - e_{-1}F_{-1}/\text{PMex}_{-1}),$$

where F is the *actual* stock of net foreign liabilities, measured in dollars.

Combining equations (4) and (5) and linearizing, we obtain the equation to be estimated,

$$(6) \quad \begin{aligned} \frac{e_tF_t}{\text{PMex}_t} &= b_0 + b_1\frac{e_{t-1}F_{t-1}}{\text{PMex}_{t-1}} + b_2r_t + b_3(r_t^* + f_t) + b_4y_t \\ &\quad + b_5W_t/\text{PMex}_t + \epsilon_{2t}, \end{aligned}$$

where $b_1 = 1 - \lambda$, and $\epsilon_{2t} = \lambda u_{2t}$. A rise in the home interest rate induces an inflow of capital or an increase in net external liabilities, so $b_2 > 0$. Similarly, $b_3 < 0$. An increase in domestic real income augments the transactions demand for money and causes a decline in desired holdings of foreign assets, so $b_4 > 0$. Finally, an increase in domestic wealth leads to a reduction in external liabilities, and thus, $b_5 < 0$.

The results of estimating (6) are reported in table 11.2.[21] They provide evidence that capital flows are quite sensitive to the domestic interest rate even in the short run. The two techniques yield very similar parameter estimates, although those obtained by 2S2SLS appear to be more precise. All interest rate coefficients have the expected sign and are significant at the 5 percent level. Equation (B), for example, suggests that a 100 basis point rise in the home interest rate, all else equal, induces a capital inflow of 1.2 billion real pesos in the same quarter, while an equal increase in the covered foreign rate induces a 0.25 billion real peso outflow. Both estimates of the adjustment parameter λ are near 0.35. Again using equation (B), the long-run capital inflow occasioned by a 100 basis point rise in r is 3.9 billion real pesos, while the outflow following an equal increase in $r^* + f$ is 0.83 billion real pesos.

The wealth variable has the anticipated sign and is significant at the 5 percent level in both equations. Equation (B) suggests that approximately 15 percent of an increase in wealth is allocated to foreign assets within one quarter. The long-run portfolio share is 50 percent.

11.3.2 Money Demand

The demand for narrowly defined real money ($M1$) balances is assumed to depend on the domestic and foreign covered interest rates,

21. The domestic income variable had a small and very insignificant coefficient. It was therefore omitted from the equation reported in table 11.2.

Table 11.2 Mexico: Net Foreign Liabilities (1971:3–1979:4)[a]

Method	Constant	r	$(r^* + f)$	W/PMex	$\frac{e_{-1}F_{-1}}{\text{PMex}_{-1}}$	$\hat{\rho}$	SE	R^2
(A) Fair	4.64	1.46	−0.265	−0.207	0.605	−0.457	3.263	0.935
	(3.14)	(0.29)	(0.103)	(0.064)	(0.073)	(0.158)		
(B) 2S2SLS	3.22	1.161	−0.252	−0.150	0.696	−0.866	3.425	0.916
	(1.08)	(0.146)	(0.066)	(0.032)	(0.025)	(0.131)		

[a]Standard errors are in parentheses. Mean of dependent variable is 6.73 billion 1975 Mexican pesos. As in the regressions reported in tables 11.3 and 11.4, the instruments used here are a constant, three seasonal dummies, the contemporaneous foreign interest rate and real income level, the lagged government deficit, lagged domestic real income, the lagged futures premium, and the lagged dependent variable. This choice of instruments allows the domestic interest rate, the futures premium, domestic real income, and the budget deficit to be endogenous. The use of contemporaneous foreign variables as exogenous instruments is justified if Mexico can be regarded as a small country in world markets for goods and assets. When necessary, the instrument list was augmented to satisfy Fair's minimum criterion (see Fair 1970).

real income, and real wealth. Thus, long-run desired money holdings may be written as

$$\frac{M^d}{\text{PMex}} = \Lambda(r, r^* + f, y, W/\text{PMex}) + u_3.$$

Invoking the partial adjustment mechanism and linearizing as before, we obtain the empirical specification,

$$(7)\qquad \frac{M_t}{\text{PMex}_t} = c_0 + c_1\frac{M_{t-1}}{\text{PMex}_{t-1}} + c_2 r_t + c_3(r_t^* + f_t) + c_4 y_t$$
$$+ c_5 W_t/\text{PMex}_t + \epsilon_{3t},$$

where $1 - c_1$ is again the adjustment parameter. As usual, we expect c_2, $c_3 < 0$, and c_4, $c_5 > 0$.

The results of estimating (7) appear in table 11.3.[22] As before, the 2SLS and the 2S2SLS estimates are quite similar. Table 11.3 reports two versions of the money demand equation. In (A) and (B) we estimate the money demand equation without imposing coefficient constraints, while in (C) and (D) the two rate-of-return coefficients are constrained to be equal. In neither of the latter two equations is the constraint rejected by the data. When the constraint is imposed, the coefficient on the interest rates is significant at the 5 percent level. In the unconstrained equation only the coefficient on the covered foreign interest rate is significant.

The adjustment of real balances to long-run desired levels is estimated to be approximately 20 percent per quarter. Equation (D), for example, suggests that a 100 basis point increase in either rate of return leads to a 0.3 billion peso decrease in real money demand in the same quarter and a 1.4 billion peso decrease in real money demand in the long run.

As expected, an increase in real income raises real money demand. At the sample means of y and M/PMex, the income elasticity of money demand derived from equation (D) is 0.42 in the short run and 1.94 in the long run. The empirical equation also contains seasonal dummies, which reveal a marked seasonality in money demand. It is this seasonal variation that gives rise to the significant seasonal dummies in the Banco de México's domestic credit policy function.

11.3.3 Money Supply

The model's monetary sector includes a money supply function relating the supply of real $M1$ to the real monetary base. We assume that the supply of money by the private banking system may be written as a function of the monetary base (adjusted for reserve requirements as

22. Domestic wealth has been dropped from the equation, as its coefficient was small and insignificant. No evidence of serial correlation was found.

Table 11.3 **Mexico: Money Demand (1971:3–1979:4)**[a]

Method	Constant	r	$r^* + f$	y	$\frac{M_{-1}}{PMex_{-1}}$	$D1$	$D2$	$D3$	SE	R^2
(A) 2SLS	5.877	−0.560	−0.324	0.426	0.828	−28.7	−21.3	−22.1	4.04	0.962
	(6.100)	(1.002)	(0.170)	(0.193)	(0.228)	(5.0)	(2.6)	(2.2)		
(B) 2S2SLS	5.498	−0.723	−0.347	0.446	0.838	−29.5	−21.7	−22.0	3.65	0.961
	(3.279)	(0.952)	(0.121)	(0.050)	(0.134)	(2.8)	(1.6)	(1.8)		
(C) 2SLS	6.201	−0.312	−0.312	0.418	0.801	−28.1	−20.9	−21.9	3.86	0.964
	(5.689)	(0.156)		(0.182)	(0.192)	(4.0)	(2.1)	(1.9)		
(D) 2S2SLS	6.464	−0.306	−0.306	0.440	0.782	−28.5	−21.4	−22.0	3.47	0.965
	(2.383)	(0.086)		(0.056)	(0.050)	(1.9)	(1.5)	(1.7)		

[a]Standard errors in parentheses. Mean of dependent variable is 104.8 billion 1975 Mexican pesos. See the footnote to table 11.2 for the list of instrumental variables.

Table 11.4 Mexico: Money Supply (1971:3–1979:4)[a]

Method	Constant	r	BA/PMex	$\hat{\rho}$	SE	R^2
(A) Fair	10.8	2.249	1.016	0.717	5.620	0.907
	(12.9)	(1.166)	(0.111)	(0.128)		
(B) 2S2SLS	2.7	2.392	1.042	0.829	5.558	0.909
	(11.0)	(0.943)	(0.054)	(0.101)		

[a]Standard errors are in parentheses. Mean of dependent variable is 104.8 billion 1975 pesos. See footnote to table 11.2 for instruments.

described in section 11.2) and of the opportunity cost of holding excess reserves. When linearized, the money supply function takes the form,

$$\frac{M_t^s}{\text{PMex}_t} = d_0 + d_1 r_t + d_2 \frac{BA_t}{\text{PMex}_t} + u_{4t}. \tag{8}$$

Estimates of the parameters of (8) are reported in table 11.4.[23] The coefficient of the real, adjusted base is quite small, reflecting both high marginal reserve requirements on demand deposits (in place throughout the estimation period) and banks' practice of holding sizable excess reserves.[24] The high interest sensitivity of money supply is also consistent with the existence of significant excess reserves.

11.3.4 The Offset Coefficient

The estimated coefficients of the structural equations may be used to calculate the capital account offset to domestic credit expansion. Two types of monetary expansion are considered. The first is an increase in domestic credit accomplished through an open-market-type asset swap that leaves private financial wealth unchanged. The second is a helicopter-type increase in credit that is accompanied by an equal increase in private financial wealth. Because our empirical money demand function does not include domestic wealth as an argument, we would expect the offset associated with the latter type of operation to be the greater one. Indeed, were b_5 equal to -1, the offset to a helicopter increase in domestic credit would be complete, even with limited asset substitutability.

In both cases the offset coefficient is (minus) the total derivative of net foreign liabilities with respect to an increase in DACB. Table 11.5A contains the short-run offset coefficients for both types of credit expansion, computed from the two sets of parameter estimates using the

23. There was no evidence of a lag in the adjustment of the money supply to its long-run level. The Banco de México discount rate was constant at 5 percent over the sample period, and therefore is omitted from the money supply equation.

24. Business International (1979) attributes this practice to the extremely limited recourse of commercial banks to rediscounting at the central bank. Generally, only certain export bills are discountable.

Table 11.5 **Mexico: Offset Coefficients**[a]

	Estimation Method	
Credit Expansion	Fair	2S2SLS
A. Short Run		
Open-market type	0.37	0.31
Helicopter type	0.51	0.41
B. Long Run		
Open-market type	0.50	0.51
Helicopter type	0.76	0.75

[a]Offset coefficients are calculated at base period reserve requirements. The capital account offset to an open-market-type credit expansion is given by

(9) $$(q_0/q_t)b_2d_2/[(d_1 - c_2) + (q_0/q_t)b_2d_2].$$

The offset coefficient for the helicopter-type expansion is

(10) $$\frac{(q_0/q_t)b_2d_2 + b_5(c_2 - d_1)}{(q_0/q_t)b_2d_2 + (d_1 - c_2)}.$$

constrained money demand equations. The short-run offset coefficients imply that, while substantial, the capital account offset to a monetary expansion was considerably less than complete. At the initial reserve ratio, anywhere from 30 to 50 percent of an increase in domestic credit by the Banco de México was offset by capital outflow within a quarter, with the exact figure depending on the method through which the domestic credit increase was effected. For example, to achieve a 1 billion peso increase in the monetary base through helicopter money creation, a 1.7–2 billion peso expansion of domestic credit was required. As expected, the computed offsets to a helicopter-type expansion exceed those to an open-market-type expansion, in both cases by approximately 10 percentage points. The offset coefficients derived from the Fair's method estimates exceed those derived from the 2S2SLS estimates. This difference is the result of the greater domestic interest rate sensitivity of capital flows implied by the former set of estimates.

It is also of interest to calculate the offset in a hypothetical world in which portfolio adjustment occurs instantaneously. Replacing the parameters in (9) and (10) with their corresponding long-run values, we obtain "long-run" offset coefficients in all cases between 50 and 76 percent (see table 11.5B). The computed "long-run" offsets to open-market-type expansions are in the lower end of this range, and those corresponding to helicopter-type expansions are near 76 percent. It should be stressed that we are using the term "long run" in a limited sense to signify only the complete adjustment of asset stocks to their desired values.

The estimates indicate that the Banco de México could exercise considerable short-run control over the domestic money stock and domestic credit market conditions during the 1970s, but only at the cost of high reserve volatility.

11.4 Expectations and the Futures Premium

The preceding analysis, while recognizing the role of the futures price as an indicator of exchange rate expectations, has negelcted both the possible influence of the home interest rate on the futures premium and the endogeneity of expectations. The offset to monetary policy has been calculated on the assumption that a one-time expansion of domestic credit leaves the futures premium unchanged.

How might monetary expansion affect the futures premium? By lowering the domestic interest rate, monetary expansion would induce capital outflows and, at the initial forward rate, an excess demand for future pesos calling for a rise in their equilibrium price. As an appreciation of the peso on the futures market discourages capital outflow, the offset coefficient would be lower than calculated in the previous section if covered interest arbitrage were incorporated into the model.

Speculative transactions are also an important determinant of the futures price, however, and the activities of speculators would tend to raise the offset coefficient calculated in section 11.3. Monetary expansion raises the likelihood of devaluation by reducing the central bank's international reserves and encouraging domestic expenditure. Speculators would respond by selling the peso forward, thus enhancing the profitability of capital outflows.

Theoretically, the net effect on the futures price of these two types of activity—interest arbitrage and speculation—is indeterminate. But as an empirical matter, we could find no strong evidence that contemporaneous domestic interest rates affected the futures premium during the 1970s. Expectations regarding the future level of the exchange rate did seem to be an important determinant of the futures premium, however. In particular, lagged deviations from purchasing power parity exerted a persistent and strong effect on the futures premium, with lagged real exchange rate appreciation leading to forward depreciation of the peso.

Letting $p \equiv \ln(e\text{PUS}/\text{PMex})$ again denote the natural logarithm of the real exchange rate, we estimated the following relationship between the futures premium on dollars, f, and past changes in the real exchange rate between 1974:2 and 1979:4:

$$\begin{aligned} f_t = {} & \underset{(12.708)}{45.209} - \underset{(1.324)}{6.479}\,\Delta p_{t-1} - \underset{(4.608)}{14.803}\,\Delta p_{t-2} - \underset{(4.022)}{11.669}\,\Delta p_{t-3} \\ & - \underset{(3.250)}{6.288}\,\Delta p_{t-4} - \underset{(2.071)}{7.175}\,\Delta p_{t-5}, \end{aligned}$$

$$\hat{\rho} = \underset{(0.079)}{0.930}\,, \qquad SE = 0.927\,, \qquad R^2 = 0.740$$

(standard errors are in parentheses). The correlations between the futures premium and lagged values of the purchasing power parity gap are extremely high. They suggest that any decline in the competitiveness of Mexican exports occasioned forward speculation against the peso and a rise in the price of forward dollars.[25]

This strong evidence that expectational factors influenced the forward premium indicates that our offset estimates probably understate the true offset.

11.5 Conclusion

This paper has studied the capital account offset to monetary policy faced by the Banco de México during the decade 1970–1980. Using a small structural model of Mexican financial markets, we found that roughly 30–50 percent of a domestic credit increase leaked away through the capital account within a quarter, with the precise figure depending on the method of domestic credit expansion adopted. This incomplete offset was the result of imperfect mobility of capital as well as imperfect substitutability between peso-denominated assets and assets denominated in foreign currencies. The offset coefficient would have been substantially higher under instantaneous portfolio adjustment.

These findings suggest that the Mexican central bank possessed some degree of short-run control over the monetary base in spite of the fixity of the exchange rate. While short-run monetary control implies an ability to neutralize the liquidity effects of transitory reserve fluctuations, it does not imply an ability to resist the adjustments needed to eliminate sustained disequilibria in the balance of payments. Conclusions as to the scope for long-run monetary control cannot be drawn from our partial-equilibrium, financial-sector model, which neglects the current account effects of international wealth flows and changes in home borrowing costs. The sharp reserve losses preceding the 1976 and 1982 devaluations provide convincing evidence against the hypothesis that the Banco de México enjoyed any long-run independence from monetary developments abroad.

Estimates of a Banco de Mexico reaction function provided strong evidence of official sterilization activities during the 1970s. Although the reaction function exhibited instability when estimated over subperiods of the decade, the Banco de México seems to have pursued a policy of full neutralization of reserve movements, at least since early 1976. The pursuit of sterilization under conditions of substantial capital account

25. The contemporaneous real exchange rate exerted no significant effect on the futures premium. This is probably the result of lags in the reporting of price level figures.

sensitivity helped give rise to periods of considerable reserve volatility during the decade under study.

Appendix

The following data were employed in this study:

B: High-powered money in billions of pesos. The series is the sum of currency and the reserve deposits of deposit banks in the Banco de México, including securities held at the Banco de México in fulfillment of reserve requirements. Source: *Indicadores Económicos*, various issues, for data from 1974:1 to 1979:4. From 1970:4 to 1973:4, currency in circulation is taken from *Indicadores Económicos* and bank reserves from *Informe Anual*.

BA: Adjusted stock of high-powered money, equal to $(q_0/q_t)B_t$.

D_1, D_2, D_3: Seasonal dummies taking the value of 1 in the ith quarter ($i = 1, 2, 3$) and zero in other quarters.

ΔDACB: Change in central bank domestic assets. Calculated as $\Delta B - \Delta$FACB. Included are monetized capital gains on international reserves.

e: End-of-period exchange rate, in pesos per dollar. Source: *International Financial Statistics* (IFS), line ae.

f: End-of-quarter premium on peso futures for delivery three months forward, measured in percent per annum. The premium is set at zero prior to 1974:2. Source: *International Money Market Yearbook*, various issues.

F: Private Mexican net external liabilities, in billions of dollars, calculated as the cumulated STCF + LTCF.

ΔFACB: Change in reserves of the Banco de México, excluding valuation changes. Calculated as $e_t\Delta R_t$.

GOVBOR: Consolidated borrowing requirement of the Mexican public sector (defined as the central government plus "controlled" public enterprises), in billions of pesos. Source: Ministry of Finance.

LTCF: Surplus on long-term private capital account, excluding direct foreign investment, in billions of dollars. Source: *Indicadores Económicos*, various issues.

M: Narrowly defined money $M1$, in billions of pesos. Source: *Indicadores Económicos* and *Informe Anual*, various issues.

PMex: Mexican CPI, 1975 = 1.00. Source: IFS, line 64.

PUS: United States CPI, 1975 = 1.00. Source: IFS, line 64.

q: Weighted average reserve requirement. End-of-quarter stocks of various domestic and foreign liabilities of the Mexican financial system are used to weight the marginal reserve requirement for each type of deposit. When more than one reserve requirement is published for a given type of deposit (depending, e.g., on location of the issuing institution), some effort is made to choose the rate which is likely to apply to the majority of deposits in that category. In addition, the series is adjusted so that $q_t = q_{t-1}$ if no change is made in legislated reserve requirements. Source: *Indicadores Económicos* for 1972:4–1979:4; *Informe Anual* for 1971:1–1972:3.

r: Domestic interest rate, measured in percent per annum. The rate chosen is the gross yield on *financiera* bonds for 1971:1–1973:4 and the gross yield on three-month certificates of deposit from 1974:1–1979:4. Source: *Indicadores Económicos*.

r^*: Three-month London Eurodollar rate, measured in percent per annum. Source: IFS, line 60d.

ΔR: Change in foreign exchange reserves of the Banco de México, in billions of dollars. The reserve series is taken from the balance of payments data in *Indicadores Económicos* and is based on a constant valuation of gold.

STCF: Short-term private capital account surplus, in billions of dollars. The series includes the errors and omissions in the balance of payments until 1977:1, when short-term capital flows and errors and omissions were first published separately. Source: *Indicadores Económicos*.

y: Mexican index of industrial production. Source: IFS, line 66.

YUS: U.S. disposable income (nominal). Source: IFS, line 99a.

W: Mexican financial wealth, calculated as $B_t + (-e_t F_t)$.

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Comment Jacob A. Frenkel

The paper "Capital Mobility and the Scope for Sterilization: Mexico in the 1970s" by Robert Cumby and Maurice Obstfeld represents a significant contribution to the literature on the scope for an independent

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monetary policy under a pegged exchange rate regime. After pointing out the possible biases in earlier estimates of the offset coefficient (measuring the extent to which the effects of domestic credit policy on the money supply are being offset by losses of international reserves through the balance of payments), the authors develop and estimate a structural model for Mexico and compute the relevant offset coefficient for the decade of the 1970s. My own comments are divided into three parts. The first deals with econometric issues and with the sources of the bias in previous reduced-form estimates; the second deals with the structural model, and the third with the estimated offset coefficient.

Estimating the Offset Coefficient: Econometric Issues

A typical reduced-form equation used to estimate the offset coefficient is presented in equation (1).

$$\Delta R_t = a_0 + a_1 X_t + a_2 \Delta D_t + u_t, \tag{1}$$

where ΔR_t denotes changes in international reserves during period t, ΔD_t denotes changes in the domestic assets component of the monetary base, X_t denotes a vector of other factors that induce changes in international reserves, and u_t denotes an error term. In equation (1) the parameter a_2 is being referred to as the offset coefficient; it is a measure of the degree to which changes in the domestic asset component of the monetary base (ΔD) are offset by changes in the stock of international reserves (ΔR). A negative value of a_2 indicates that losses of reserves offset the effects of credit expansion, and when $a_2 = -1$, the offset is complete.

As emphasized by Cumby and Obstfeld, to the extent that domstic credit policy is influenced by the state of the balance of payments, ordinary-least-squares (OLS) estimates of a_2 will be biased. The dependence of domestic credit policy on the balance of payments is usually rationalized by noting that the monetary authority may wish to sterilize the consequences of the balance of payments. Such a sterilization function is described in equation (2):

$$\Delta D_t = b_0 + b_1 Y_t + b_2 \Delta R_t + v_t, \tag{2}$$

where Y_t denotes a vector of other factors determining credit policy, and v_t denotes an error term. In equation (2), b_2 is being referred to as the sterilization coefficient. A negative value of b_2 indicates that the monetary authority attempts to sterilize the monetary consequences of reserve flows, and when $b_2 = -1$, sterilization is complete. As is evident, when the behavior of the monetary authority is characterized by equation (2) with $b_2 < 0$, ΔD_t would be correlated with u_t, and the OLS estimate of the offset coefficient, a_2 in equation (1), would generally be biased downward (algebraically). This is the nature of the bias which has been frequently discussed in the literature (e.g., Magee 1976) and which is also reiterated by Cumby and Obstfeld.

If the monetary authority employs its domestic credit policy to attain a target level of international reserves rather than to sterilize the monetary consequences of the balance of payments, the direction of the bias is likely to be reversed. For example, consider the following reaction function:

$$\Delta D_t = c_0 + c_1 Z_t + c_2(R_t - R_t^*) + \epsilon_t, \tag{3}$$

where R_t and R_t^* denote actual and desired stocks of international reserves, Z_t denotes other factors determining credit policy, and ϵ_t denotes an error term. In equation (3) c_2 is likely to be positive, suggesting that when the holdings of reserves exceed the target level, the monetary authorities expend credit and thereby induce a decline in the stock of reserves toward the target level. As is evident, when the behavior of the monetary authorities is characterized by equation (3), with $c_2 > 0$, the OLS estimate of the offset coefficient, a_2 in equation (1), would generally be biased upward (algebraically). A reaction function of the type described by equation (3) was estimated by Ujiie (1978) and Lau (1980). These estimates showed that, for the cases studied, the parameter c_2 was significantly positive. In general, it seems that domestic credit policy is influenced by the considerations which underlie equation (2) as well as by those which underlie equation (3). Consequently, while the OLS estimate of equation (1) may yield biased estimates of a_2, the direction of the bias may not be stated on a priori grounds.

Independent of the detailed specification of the reaction function, the OLS estimate of equation (1) will be biased if the error term u_t is correlated with the error term in the reaction function. It is clear, therefore, that to obtain consistent estimates of the offset coefficient, the simultaneity of the various relationships has to be taken into account. There are, in principle, two ways to obtain consistent estimates. First, one could estimate equations (1) and (2), or (1) and (3), simultaneously as in Ujiie (1978) and Lau (1980); alternatively, one could proceed along the lines of Cumby and Obstfeld and estimate a structural model of the economy and then derive the implied offset coefficient. The choice between the two approaches reflects the usual trade-off between reduced form and structural estimates. On the one hand, estimates based on a structural model permit an interpretation of the results in terms of the structural parameters; on the other hand, however, confidence in these estimates depends on one's confidence in the detailed specifications of the structural model. It might be useful, therefore, to supplement the structural model estimate by an estimate of the reduced form as obtained from a simultaneous estimation of equations (1) and (2), or (1) and (3), or (1) and a combination of (2) and (3). If the two sets of estimates yielded similar results, then the interpretation in terms of the structural parameters would gain credibility. If, however, the two sets of estimates differed greatly from each other, then it seems that some more questions concerning the detailed specifications of the structural model will have to be answered.

The Structural Model

The structural model is composed of three building blocks: a demand equation for the net external liabilities, a money demand equation, and a money supply equation. The model is estimated using quarterly data over the period 1971:3–1979:4. Since, however, the authors provide some evidence indicating instability in the Banco de México's reaction function (evidence which is also documented by Porzecanski 1979), it would be useful to examine whether the structural model remained stable throughout the decade.

Net Foreign Liabilities

In specifying the demand for net foreign liabilities, Cumby and Obstfeld assume that asset holders adjust the *composition* of their portfolios to the desired composition only gradually. Specifically, for a given value of wealth, asset holders are assumed to make up each period a fraction λ of the disequilibrium. This fraction is estimated to be between 30 to 40 percent of the discrepancy between desired and actual composition. As a theoretical matter, it is not easy to envisage the precise nature of the cost which induces this type of adjustment to portfolio composition equilibrium. More importantly, as an empirical matter it is extremely difficult to separate out changes in asset holdings into those associated with the restoration of the desired *composition* and those associated with the attainment of the desired *size* of the portfolio, and theoretically, the former is likely to proceed at a much faster speed than the latter. It is not unlikely, therefore, that the estimated speed reflects both types of adjustment.

Throughout their study the authors provide the results of two estimation procedures. The first procedure is Fair's version of two-stage least squares; the second procedure is a two-step, two-stage least squares (2S2SLS) as proposed by Cumby, Huizinga, and Obstfeld. The two procedures have yielded similar parameter estimates. For the case at hand the similarity among the estimates is especially reassuring since one of the determinants of the demand for foreign liabilities is the futures premium on foreign exchange which is being used as a proxy for expectations. To the extent that this proxy measured expectations with an error, Fair's method would have resulted in inconsistent estimates. The 2S2SLS method yielding similar estimates suggests that in the present case the errors in variables problem is not severe.

One of the interesting results in table 11.2 concerns the different responses of capital flows to changes in the domestic rate of interest and to changes in the covered foreign rate of interest. Other things being equal, a 100 basis point rise in the domestic rate of interest is estimated to induce (using the 2S2SLS procedure) capital inflow of 1.16 billion (real) pesos in the same quarter, while an equivalent rise in the covered foreign rate of interest is estimated to induce an outflow of only 0.25 billion (real) pesos. This difference suggests that for the case of Mexico it would be inappropriate to follow the convention of specifying capital flows as a function of covered interest differential; rather it suggests that one needs to decompose the differential into its components. To gain some idea of the orders of magnitude, one may note by inspection of figure 11.1 that these flows are usually smaller than the typical quarterly changes in Banco de México's foreign assets.

Finally, it is noteworthy that the estimated value of the autocorrelation coefficient, ρ, (using the 2S2SLS procedure) is -0.866. This estimate is much more negative than the customary estimates. It may reflect the difficulties of estimating jointly a speed of adjustment λ and the autocorrelation coefficient ρ.

The Demand for Money

Analogously with the specification of the demand for foreign liabilities, the authors postulate a stock adjustment model of the demand for money. The speed of adjustment is estimated to be about 20 percent per quarter. Since the adjustments of both money and foreign assets are carried out by the same asset holders, it would be useful to provide a formal link between the two speeds. Once such a link is established, it would be useful to estimate the dynamic equations jointly subject to the implied cross-equation constraints. The desirability of this procedure is exemplified by noting that the long-run effects of a rise in the domestic interest rate on capital inflows is about 3.9 billion (real) pesos (based on equation [B] in table 11.2) while the corresponding decline in money holdings is only 1.4 billion (real) pesos (based on equation [D] in table 11.3). It would be useful to account for this long-run difference within the context of the model.

The specification of the demand for money states that money holdings depend on the expected holding cost. The authors stress two relevant costs corresponding to two margins of substitution. They include the domestic nominal rate of interest to capture the substitution between money and domestic bonds, while the inclusion of the covered foreign nominal rate of interest represents the substitution between money and foreign bonds. However, when various parity conditions are satisfied, these two rates of interest are not independent of each other. Specifically, when the requisite conditions for covered interest arbitrage hold, these rates are likely to be highly collinear. It is possible, therefore, that this collinearity might be responsible in part for the imprecise estimate of the domestic interest elasticity of the demand for money.

Finally, it may be noted that the various estimates in table 11.3 suggest that the long-run income elasticity of the demand for money exceeds 2. This value seems to be somewhat high in comparison with corresponding estimates for other countries as well as for Mexico (e.g., Blejer 1975). It is not unlikely that a joint estimation of the speeds of adjustment in the various markets could yield a higher estimated speed in the money market and, correspondingly, a lower value of the long-run income elasticity.

The Money Supply

In estimating the money supply function, the authors have imposed the constraint (which is not rejected by the data) that the supply is not subject to a lagged adjustment process and that the two primary factors governing the supply are the monetary base and the rate of interest. The estimates in table 11.4 reveal a high interest elasticity (exceeding 2.2) and a low elasticity with respect to the base (about unity). The estimated unit elasticity is, however, consistent with other findings (e.g., Blejer 1975).

Of special interest is the estimate of ρ, the autocorrelation coefficient. This is the only case in the study in which estimating the autocorrelation coefficient yielded a positive value of ρ. By the same token, the money supply function is the only building block of the structural model which does not include in the estimation a lagged dependent variable representing a stock adjustment process. I believe that these two facts might be intimately related. The difficulties in estimating a speed of adjustment along with an autocorrelation coefficient are well known, and it is possible that when the lagged dependent variable is included, it picks up "too much" of the serial correlation and thus yielding a negative estimate of ρ (as in table 11.2). On the other hand, when the lagged dependent variable is not included, the resulting positive estimate of ρ captures the "true" nature of the serial correlation (as in table 11.4). These considerations provide an additional reason for attempting a further examination of the estimated speeds of adjustment.

The Offset Coefficient

Having estimated the three building blocks of the structural model, the authors have computed the offset coefficient as (minus) the total derivative of net foreign liabilities with respect to a change in the domestic asset component of the monetary base. Intuitively, an expansion of domestic credit yields a new equilibrium rate of interest that clears the money market. This equilibrium rate of interest, which is found with the aid of the estimated money demand and money supply functions, is then substituted into the net foreign liabilities function from which the offset through capital flows is being determined. It is clear, therefore, that the computation of the offset coefficient, as in equations (9)–(10) of Cumby and Obstfeld's paper, involves all the estimates of the interest rate coefficients. Following this procedure, the "long-run" offset coefficient to open market policy is computed to be about 50 percent. Intuitively, this estimate seems to be somewhat low. The payoff to the authors' structural model estimation is that one can identify the sources of possible biases in the final estimate. Specifically, a given expansion of credit lowers the rate of interest in an inverse proportion to the interest elasticity of the supply of money and in an inverse proportion to the (absolute value of the) interest elasticity of the demand for money. The resultant capital flow, in turn, depends positively on the interest elasticity of the net foreign liabilities function. It follows that an overestimation of the sensitivity of the demand or of the supply of money to changes in the rate of interest, as well as an underestimation of the interest sensitivity of capital flows, will result in an underestimation of the offset coefficient. Since the authors' definition of capital flows includes the item measuring errors and omissions in the balance of payments, it is unlikely that the elasticity of capital flows is being significantly underestimated. My speculation is that to the extent that the offset coefficient is being underestimated, the source of the bias would be found in the overestimation of the interest elasticity of the demand for money. As indicated before, the high value of the estimated long-run elasticity may be attributed, in part, to the extremely low estimate of the speed of adjustment. Furthermore, as recognized by the authors, allowance for the endogeneity of the futures premium on foreign exchange is also likely to yield a higher value of the long-run offset coefficient.

In conclusion, I wish to reiterate my opening remarks. This paper represents a significant contribution to the study of the scope for sterilization. I have found the empirical research extremely well designed and professionally executed. As such, I believe that it could serve as a model for the proper way to study and estimate the offset coefficient.

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