The Interest Rate-Exchange Rate Link in the Mexican Float

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Abstract: This paper examines empirically the interest rate-exchange rate link in the context of the Mexican experience with a floating exchange regime. The impulse response function derived from an ECM estimated by GMM reveals a lasting positive effect of a currency depreciation on the peso-dollar interest rate differential. Some of the macroeconomic consequences from this pattern are discussed, together with a possible explanation based on the incorporation of the central bank reaction function into private expectations.
Keywords: interest rate-exchange rate link, floating exchange rate regimes.

Resumen: Este artículo examina empíricamente el nexo tasa de interés-tipo de cambio en el contexto de la experiencia de México con un régimen de flotación cambiaria. La función de impulso respuesta derivada de un modelo de corrección de errores (ECM) estimado por GMM revela la existencia de un efecto positivo persistente de una depreciación cambiaria sobre el diferencial peso-dólar de tasas de interés. Se discuten algunas de las consecuencias macroeconómicas de este patrón, y se presenta una posible explicación basada en la incorporación de la función de reacción del banco central en las expectativas del sector privado.
Palabras clave: nexo tasa de interés-tipo de cambio, regímenes cambiarios de flotación.

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Introduction

In an early example of what would later become a trend, Mexico abandoned its official exchange rate band against the U.S. dollar in December of 1994. Preserving the system had become increasingly difficult on account of both a steady process of real currency appreciation and the impact of major political shocks. Eventually, these developments led authorities to devalue the band ceiling in about 20%, but, as is well known, the policy decision backfired and a major financial crisis ensued. Different interpretations for this seemingly perverse market reaction exist, including the possibility that the initial devaluation was to small to correct for the inherited real appreciation (see Dornbusch *et al*., 1995), and that the realignment acted as a focal point for expectations of an imminent default on dollar-indexed Tesobonos (see Ros 2001, Ibarra 1999).

The loss of international reserves intensified in the wake of devaluation and as a result the Banco de Mexico rapidly came to a situation in which it was no longer able to defend a target level for the exchange rate. This fact precipitated a forced shift into a floating regime. Initially, floatation was adopted as a strictly transitory arrangement, under the premise that it was the only viable option in a situation characterized by very unstable exchange rate expectations and depleted international reserves. Contrary to the early official statements, though, the floating regime has evolved into a rather solid component of the country's overall monetary framework (for a detailed account, see Carstens and Werner 1999).

So far, the flexible exchange rate regime has survived a number of major shocks, including the Russian debt default of 1998, the currency crises in Asia (1997), and in Brazil (1999), wide fluctuations in oil prices, and the country's political transition in 2000. At the same time, the inflation rate has fallen from a 52% peak in December of 1995 to about 5% in 2002, while the output growth rate remained moderately high until the recent world deceleration. This record has certainly been a plus for the system. Demonstrating that disinflation is possible under a fluctuating exchange rate regime has, in particular, been a major achievement for this developing country.

Furthermore, given the recent world economic experience, the discouragement of major speculative attacks against the currency may be, in practical terms, a good enough reason to keep the float.[1] But it is also possible to judge the regime's performance according to other conventional criteria. For instance, it is interesting to note that the current system has not eliminated the phenomenon of recurring periods of real currency appreciation.[2] It can also be noted that the volatility of both the exchange rate and the interest rate increased after the regime shift, in contrast to the prediction of traditional theory.[3] In a sense, this is not surprising: as recent empirical research has shown, actual floats tend to diverge from the textbook model in ways that make it difficult to distinguish between de jure floats and heavily managed exchange rate regimes (see Calvo 2000, Calvo and Reinhart 2002, and Hausmann *et al*. 1999 and 2000).

In terms of macroeconomic management, one of the potential benefits of a floating exchange regime is that it may allow a country to have an autonomous monetary policy despite being in an environment of high international mobility of capital; this stands in contrast to the case of a fixed exchange rate system, in which the international equalization of returns forced by arbitrage entails the equalization of local and foreign currency interest rates (up to some risk premium). The possibility of having an autonomous monetary policy depends crucially, however, on the way interest rate differentials respond to exchange rate changes. In this regard, it is conventionally assumed that an exogenous rise in the exchange rate (a decline in the value of the local currency) should lead to a fall in the expected depreciation rate, and thus, through arbitrage, a fall in local interest rates. This opens the possibility of a trade-off between the levels of the exchange rate and the interest rate that can be exploited by monetary policy. This kind of link has also the implication that a float may exhibit

[1] This idea underlies much of the recent debate on the so-called "two corners" approach to the choice of exchange rate regime in developing countries. See Edwards (2001) for an overview.

[2] As shown by the 33% increase in the National Institute of Statistics (INEGI) moving-average index of dollar unit labor cost in the manufactures, between January 1998 and December 2002. On the other hand, the most recent record (as of early 2003) indicates that, with the float, the eventually necessary upward adjustment in the exchange rate has been much less disrupting than what was observed in previous episodes featuring a fixed or predetermined rate (although the overall macroeconomic setting has also been more favorable).

[3] The exchange rate's average monthly change (in absolute terms) moved from 1.02% during January 1992-December 1994, to 1.51% during January 1996-October 2001. At the same time, the average change for the real interest rate increased from 1.2 percentage points to 2.15 points (see Ibarra 2002). Martínez *et al*., (2001) show that, although the volatility of the peso's exchange rate has been similar to that of other major floaters, interest rate volatility has been much higher, even after excluding 1995 data from calculation. The same conclusion emerges from Calvo and Reinhart (2002) data.

automatic output stabilizing properties in the presence of capital account shocks, as explained below.

The purpose of this paper is to analyze the actual way interest rate differentials have reacted to variations in the exchange rate during the floating regime currently in operation in Mexico. This is done by means of an Error Correction Model (ECM) for the interest rate gap between Mexican and US Treasury bills. The model is estimated by the Generalized Method of Moments (GMM) to allow for the possible endogeneity of regressors. As it turns out, the estimation results show a positive correlation between current exchange rate changes and future variations in the interest rate differential.

The rest of the paper is structured as follows. The first section considers in more detail the macroeconomic implications of the interest rate-exchange rate link, providing motivation for the empirical analysis, and also an analytical framework to appreciate the main implications from the econometric results. The estimation results from the ECM for the peso-dollar interest rate differential are presented in section II together with the estimated impulse response function that describes the differential's dynamic response to a permanent change in the peso-dollar exchange rate. Section III considers a possible explanation for the findings, while section IV concludes with a summary of results.

I. Macro effects of the interest rate-exchange rate link

Consider the textbook case of an individual deciding whether to buy a peso- or alternatively a dollar-denominated bond with the same maturity. The return (in local currency) for the first option would be the current peso interest rate: i, while in the latter it would correspond to the sum of the dollar interest rate and the peso's expected depreciation rate against the dollar: $i^* + e$. In this context, the expected depreciation rate is equal to the proportional change in the present exchange rate expected for the length of the bond holding period.

Under conditions of high capital mobility, arbitrage ensures the existence of a strong link between the return on the two assets. Thus, it is possible to write an equilibrium condition of the form:

(1) $i = i^* + e + d,$

where d is by definition an equilibrium return differential or risk premium. With perfect capital mobility, d will be zero and (1) will simplify to the (uncovered) interest parity condition.

A floating exchange regime will allow a country to have an autonomous monetary policy, despite the equalization of returns forced by the international mobility of capital and for a given level of the risk premium, by adjustments in the expected depreciation rate. Assume the authorities adopt an expansionary policy stance, say through an open market purchase of peso bonds. The peso interest rate will tend to fall, thus creating an excess demand for dollars; if the authorities do not intervene in the exchange market, this excess demand will result in a weakened currency (an exchange rate rise).

The key point is how this currency depreciation would restore equilibrium condition (1). A standard assumption in the analytical literature is that the exchange rate rise reduces the gap between the current rate and the level of the exchange rate expected for some future period, thus bringing about the required fall in the expected depreciation rate. The reasoning implicitly assumes that the expected exchange rate is independent of the current rate (or that, if it moves, it does so less than proportionally). This is, for instance, the mechanism in Dornbusch's classic 1976 model: a permanent monetary expansion increases the expected exchange rate in the same proportion, and thus the exchange rate has to overshoot in the short run to restore asset market equilibrium.[4]

Thus, for a given level of the risk premium, an autonomous monetary policy is possible because the rise in the exchange rate reduces depreciation expectations and this tends to lower the local currency interest rates. The prediction is that there should be a negative relationship between the exchange rate and the interest rate. To further appreciate the macroeconomic role of this link, consider the case of a capital account shock. In particular, assume that there is an exogenous fall in the world demand for local bonds. The ensuing capital outflow in the balance of payments will tend to depress domestic output, while the reduced demand for local assets will weaken the

[4] If there is a high degree of capital mobility, but domestic and foreign assets are imperfect substitutes, then in general d will be different from zero, and its size will be positively affected by the relative supply of peso assets. This creates the possibility of a second adjustment mechanism. The central bank's purchase of bonds will reduce the stock of peso bonds available to the private sector, exerting in this way downward pressure on the risk premium.

currency.[5] Note, however, that if today's currency depreciation leads to a lower expected depreciation rate, then interest rates (except perhaps those for very short-term instruments) will fall, tending to offset the contractionary output effect of the capital account shock.

The automatic output stabilizing mechanism will not work, of course, if after a currency depreciation the interest rate differential fails to decline (e.g., because of an adjustment in risk assessments or expectations of future public policies —as explored in Section 4); it may even increase, in which case the output effect of the capital account shock would be reinforced.[6] In such case, the conduct of monetary policy would also be made more complicated. In particular, if a currency depreciation is not able to restore asset market equilibrium (Equation 1) at a lower peso interest rate, then a counter-cyclical policy response to the capital account shock could destabilize financial markets.

II. Empirical analysis

Having briefly discussed the macroeconomic role of the interest rate-exchange rate link in financially open economies, this section turns to an empirical analysis of the recent Mexican experience. In particular, it presents estimation results for the dynamic response of peso-dollar interest rate differentials to a permanent variation in the peso-dollar exchange rate. The analysis uses weekly interest rate data on Mexican and US Treasury bills since June of 1996. The impulse response function is derived from an error correction model estimated by GMM.

a) Description

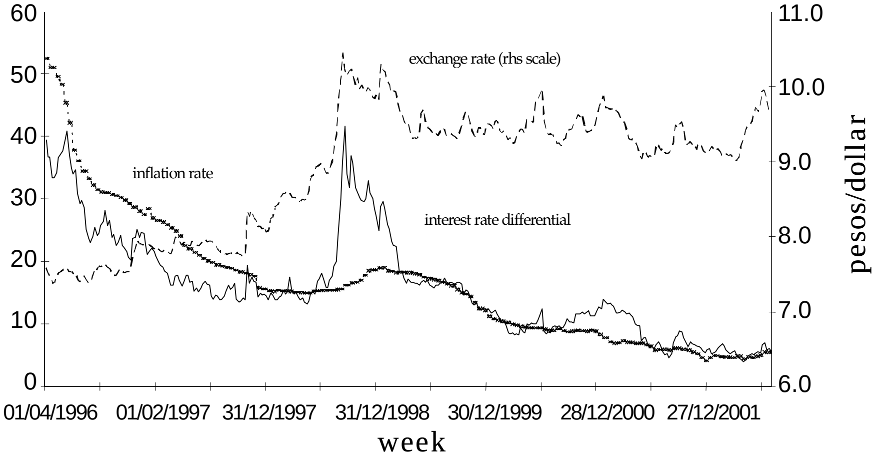
Figure 1 shows the evolution of the interest rate differential between Mexican and US Treasury bills from January 1996 through July 2002,

[5] Current work on the conduct of monetary policy and the choice of exchange rate regime in developing countries is giving increasing attention to this type of shock, prompted by the substantial increase in the volume and volatility of private international capital flows witnessed recently. See, for instance, Hausmann and Rojas-Suárez (1996) and Eichengreen (2001).

[6] Casual observation of this type of relationship led Calvo (1997), for instance, to conclude that the conduct of monetary policy in Mexico suffered from lack of credibility. Eichengreen and Hausmann (1999) argue that the positive contemporaneous correlation between interest rates and the exchange rate in Mexico can be explained by the reluctance of authorities to follow anti-cyclical policies in a context of currency and maturity mismatches in the banking sector.

together with the rates of inflation and currency exchange (pesos per dollar; the series are precisely defined below, in Subsection IIc). There are two important observations to make: the first is that the interest rate differential is strongly trended, and that the trend appears to be determined by the inflation rate (with transitory departures caused by phenomena such as the Russian crisis of August 1998). In terms of Equation (1), this observation suggests that, in the long run, the expected depreciation rate is determined by the domestic inflation rate, perhaps because expected inflation is, to an important extent, determined by current inflation.

Figure 1. Interest rate differential, and inflation and exchange rates.



A second feature to note is the strong positive *contemporaneous* correlation between the interest differential and the exchange rate, presumably as a reflection of the presence of capital account shocks.[7] In this case, an exogenous rise in the world demand for peso assets, for instance, would simultaneously strengthen the currency and push local interest rates down. This observation implies that any possibility of finding a negative relationship will depend on including a long lag

[7] It may be important to note that during this period the domestic interest rate under study was not a direct instrument in the Banco de Mexico's policy rule, but a market-determined variable (subject, of course, to influence from central bank actions).

structure in the regression analysis (an aspect that Equation 1 does not explicitly capture). It could very well be that in the very short run a rise in the exchange rate leads to higher interest rates, but that over time this bandwagon effect loses strength, and eventually a fall in expected depreciation lowers interest rates.

b) Specification

As could be expected, for most of the series under analysis it is not possible to reject the hypothesis that they contain a unit root. Thus, the econometric analysis will proceed in two steps, the first being the estimation of a cointegration equation from an autoregressive distributive lag (ADL) model for the level of the interest rate differential; the second step involves the estimation of an ECM in differences, from which an impulse response function for the interest differential can be derived.

Our purpose is to estimate the dynamic response of private expectations and risk assessments,[8] as reflected in the evolution of the peso-dollar interest rate differential, following a permanent rise in the exchange rate. This differential may of course also reflect monetary policy actions that affect asset supplies and local liquidity conditions. Thus, the regression equation includes, as a control variable, an index of the real money supply divided by a measure of economic activity; it also includes the inflation rate as the main determinant of the trend interest differential, and the Federal funds rate as an indicator of the US monetary policy stance.

The starting point for the estimation of the cointegration equation was the following ADL model for the interest rate differential:

(2) $$\mathrm{ird}_t = a_0 + \Sigma\, a_j\, \mathrm{ird}_{t-j} + \Sigma\, b_i\, \mathrm{lns}_{t-i} + \Sigma\, c_i\, \mathrm{lnm}_{t-i} + \Sigma\, f_i\, \pi_{t-i} + \Sigma\, g_i\, \mathrm{fed}_{t-i} + v_t,$$

where j = 1, 2, …, L, i = 0, 1, …, L, L is the number of lags included in the equation, t denotes the week, ird_{t-j} the interest rate differential, lns_{t-i} the log exchange rate, lnm_{t-i} the log adjusted real money base, π_{t-i} the annual inflation rate, fed_{t-i} the Fed funds rate, and v_t an error

[8] Berg and Borensztein (2000) discuss why a country's political risk premium may be positively correlated with expected depreciation, and illustrate with data from Argentina. See also Edwards (2001), Figure 4.

term.[9] The long-run equilibrium, or cointegration, version of Equation (2) is obtained by imposing the condition that each variable has converged to a constant value, i. e., $ird_t = ird_{t-j}$ for all j, etc.

Equation (2) was estimated in the following transformed, fully-equivalent version:

$$(3)\ ird_t = a_0 + \alpha\, ird_{t-1} - \Sigma\, a_k\, (ird_{t-1} - ird_{t-k}) + \beta\, lns_t - \Sigma\, b_j\, (lns_t - lns_{t-j}) + \chi\, lnm_t$$

$$- \Sigma\, c_j\, (lnm_t - lnm_{t-j}) + \phi\, \pi_t - \Sigma\, f_j\, (\pi_t - \pi_{t-j}) + \gamma\, fed_t - \Sigma\, g_j\, (fed_t - fed_{t-j}) + v_t,$$

where k = 2, …, L. It is easy to verify that estimation of this transformed version necessarily satisfies: $\alpha = \Sigma a_j$, $\beta = \Sigma b_i$, $\chi = \Sigma c_i$, $\phi = \Sigma f_i$, and $\gamma = \Sigma g_i$. One advantage of estimating Equation (3) instead of the original version is that it immediately yields the coefficients forming the long-run relationship (another is that it generates the p-values for the long-run coefficients; see Davidson and McKinnon 1993, chapter 19). In particular, the cointegration equation will be given by:

$$(4)\quad ird_t^c = a_0/\omega + (\beta/\omega)\, lns_t + (\chi/\omega)\, lnm_t + (\phi/\omega)\, \pi_t + (\gamma/\omega)\, fed_t,$$

where $\omega = 1-\alpha$. In any given period, the deviation from long-run equilibrium will simply be: $\upsilon_t = ird_t - ird_t^c$. According to the so-called residual-based test, if Equation (4) is indeed a cointegration equation, then we should be able to reject the null hypothesis of a unit root in the υ_t series (see Enders 1995, chapter 6).

The dynamic response of the interest rate differential to an exchange rate change was obtained by means of an impulse response function. The starting point was again an ADL model for the interest differential, but this time specified in differences and including the

[9] Equation (1) is mainly a theoretical relationship stating that under free capital mobility similar assets must offer similar rates of return, up to a risk premium. Equation (2), in contrast, is a specification intended for empirical examination. In moving from Equation (1) to (2), there are two features that must be considered: first, in time series analysis it is common practice to include lagged values of both the dependent variable and the regressors, in order to account for the purely statistical properties of the data (so as to avoid, for instance, a potential problem of serial correlation in the residuals) and the probable protracted impact of the regressors on the variable under study. The second feature is that it surely would be an unrealistic assumption to posit that there is perfect capital mobility between the US and Mexico; under imperfect mobility, the interest parity condition does not hold exactly, and there can be a risk premium affected by variables such as those included in the right side of Equation (2), namely, the local money supply, the inflation rate, and the foreign interest rate.

short-term deviation from equilibrium as a regressor.[10] The resulting ECM is:

$$(5)\quad \Delta ird_t = D\,\upsilon_t + h_0 + \Sigma\, h_j\, \Delta ird_{t-j} + \Sigma\, n_i\, \Delta lns_{t-i} + \Sigma\, p_i\, \Delta lnm_{t-i} + \Sigma\, w_i\, \Delta fed_{t-i} + u_t,$$

where *D* is the coefficient of the short-run deviation from equilibrium. The dynamic response of the interest differential to a permanent rise in the log exchange rate was derived from the estimated coefficients of Equation (5). In particular, the points on the impulse response function correspond to the (total) derivative of Δird_{t+r} with respect to Δlns_t, for $r = 1, 2, \ldots$ (see Enders 1995, chapter 1). For instance, the first three points were calculated as:

$$d\Delta ird_t / d\Delta lns_t = n_0$$
$$d\Delta ird_{t+1} / d\Delta lns_t = n_0 + n_1 + h_1\,(d\Delta ird_t / d\Delta lns_t)$$
$$d\Delta ird_{t+2} / d\Delta lns_t = n_0 + n_1 + n_2 + h_1\,(d\Delta ird_{t+1} / d\Delta lns_t) + h_2\,(d\Delta ird_t / d\Delta lns_t)$$

where it is assumed that the variation in the exchange rate is permanent (i.e., $d\Delta lns_{t+r} = d\Delta lns_t$, for $r = 1, 2, \ldots$).

c) Estimation results

The interest rate differential used in the analysis was calculated from the weekly auctions of 91-day Mexican Cetes and 3-month US Treasury bills. As noted before, these rates are particularly suitable for our purposes, because during the sample period they were not central bank policy instruments, but market-determined variables. The exchange rate is the weekly average of closing, interbank bid and ask rates. The inflation rate is the 24 half-month variation in the consumer price index (CPI) published by Banco de Mexico. Since interest rate observations are weekly, but the CPI is available only twice a month, it was necessary to roughly assign one inflation observation to two interest rate observations. Given that the inflation rate appears to determine mainly the differential's long-run level, this does not seem to pose a serious problem. The real money base index equals the

[10] The inflation rate was excluded under the assumption that it does not affect variations in interest rate differentials in the very short run. This intuition was confirmed in statistical terms: inclusion of inflation in the estimated ECM yielded very poor results for the entire model.

nominal base divided by the product of the consumer price index and the monthly industrial production index calculated by the National Institute of Statistics (INEGI).

The sample runs from the last week of June 1996 to the last week of July 2002. The initial specification had a long lag structure (24 lags), with the purpose of capturing the protracted effects of exchange rate variations on the interest differential. This initial structure was simplified according to variations in the Schwarz and Akaike criteria. In the end, 22 lags were included for each variable.

During the period under analysis, monetary policy in Mexico was conducted under a system of zero average (over 28-day periods) reserve requirements for commercial banks (see Yacamán 1999 for a detailed description). The Banco de Mexico is committed to satisfy whatever level of reserve demand comes from commercial banks. But the *conditions* under which such reserves are created are indicative of the central bank's policy stance. In particular, if the Banco de Mexico announces a so-called "corto", or shortage of some amount, it means that such volume of commercial bank reserves will be supplied at penalty rates. A rise in the "corto" has the purpose of pushing up market interest rates since it induces banks to compete for funds so as to avoid the penalization. In fact, it has been documented that such action does have a very short-run, transitory impact on the Cete interest rate (see Díaz de León and Greenham, 2000).

Our regression equations include two variables intended to capture this effect; in particular, *tight* is a dummy that equals one in the three weeks following a rise in the short, and zero in the rest, while *loose* is equal to one if the observation falls within three weeks after a reduction in the short, and zero otherwise.[11] There is also a dummy that captures the (immediate) impact of the fall of 1998 financial market turbulence linked to the Russian debt default; thus, *russia* equals one during the first three weeks of September 1998, and zero in the remaining of the sample.

It can be reasonably assumed that the interest rate differential, the exchange rate, and the real money supply are affected by common shocks. Thus, both the cointegration equation and the ECM were estimated by GMM to allow for the possible endogeneity of the

[11] The rationale for introducing these dummies is as in the inclusion of real money: to isolate the effect of exchange rate variations on interest rate differentials, keeping constant conditions in the money market.

regressors. The presentation of results includes p-values for the J test of adequacy of instruments and the Q test for serial autocorrelation.

Table 1 shows the main estimation results for Equation 3. All the coefficients are statistically significant, with the exception of the intercept and *fed*; these variables were kept, however, because without them the model's statistical performance was negatively affected. The model passes the tests for absence of serial correlation (up to 36 lags) and adequacy of instruments. Solving for the cointegration equation, as in (4), yields:

$$\text{(6)} \quad \text{ird}_t^c = -48.6077 + 34.0508 \text{ russia} + 2.2697 \text{ tight} - 3.6137 \text{ loose} + 42.9631 \text{ lns} - 13.4167 \text{ lnm}_t + 0.9093\, \pi_t + 0.3292 \text{ fed}_t.$$

Leaving aside the exchange rate, it can be seen that all the coefficients have the expected sign. Thus, a tighter monetary policy stance leads to wider interest rate differentials, and the same happens with a rise in inflation. The size of the coefficients seems plausible. For example, the long-run effect (i.e., after the dynamic effects have been worked out) of a 10% rise in the real money base is a 1.3 point fall in the interest differential; in the same way, a 1 point rise in the inflation rate leads to a 0.9 rise in the interest rate gap.[12]

For our purposes, the most important result concerns the exchange rate coefficient. Its estimated value implies that, holding everything else constant, a 10% permanent depreciation eventually leads to a 4.3 point rise in the interest rate differential. Thus, we do not find the negative relationship between the exchange rate and interest rates frequently assumed in traditional models of monetary policy under a float.[13]

As noted above, the short-run deviation from equilibrium is simply $\upsilon_t = \text{ird}_t - \text{ird}_t^c$. The Phillips-Perron test statistic for this series (at the Newey-West suggested truncation lag of 5) is –5.9123 with intercept and –5.3042 without it, for sample size 319. The augmented Dickey-Fuller test statistic (including 3 lags, as suggested by the Schwarz

[12] The equation intercept implies that when the exchange rate, the real money supply, the inflation rate and the Federal funds rate are at their mean values (2.1924, 3.5574, 14.3233 and 4.8634, respectively), the interest rate differential's predicted value (setting all dummies at zero) is 12.5; its actual sample mean value was 14.7.

[13] It should be recalled that this result does not reflect exclusively the very short-run interest rate-exchange rate nexus, but that it captures the dynamic response incorporating almost six months of lagged impacts.

Table 1. GMM-estimated, long-run coefficients for the ird model

	Coefficient	p-value
a_0	–8.6376	0.2156
russia	6.0509	0.0000
tight	0.4033	0.0889
loose	–0.6422	0.0527
α	0.8223	0.0000
β	7.6346	0.0050
χ	–2.3842	0.0617
ϕ	0.1616	0.0003
γ	0.0585	0.2600
Adjusted R^2	0.9823	
J p-value	0.2651	
Q p-values	All above 0.10 up to lag 36	

Instruments: constant, russia, tight (–1 to –3), loose (–1 to –3), ird (–1 to –23), lns (–1 to –23), lnm (–1 to –23), inflation (to –23), fed (to –23)
Sample: Last week of June 1996-Last week of July 2002
Sample size: 319.

criterion) is –4.9475 with intercept and –4.3463 without it. In both cases, the MacKinnon critical values reject the unit root hypothesis at 1%. Thus, the residual-based test suggests that (6) is indeed a cointegration relation.

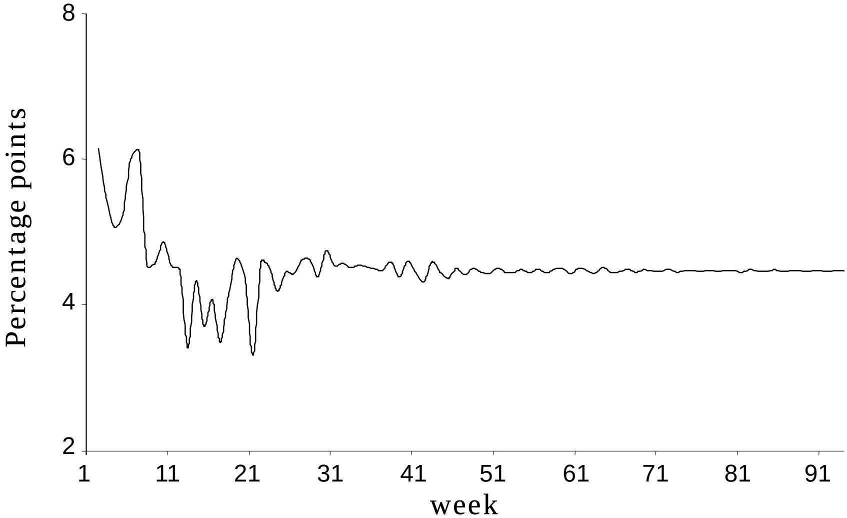
The next step was the estimation of the ECM (5), from which to derive an impulse response function. This was carried out by GMM, for the same sample running from the last week of June 1996 to the last week of July 2002. The estimated equation passed the tests for serial error correlation and instruments adequacy; as must be the case in the presence of cointegration, the error correction coefficient (lagged five weeks) was negative and statistically significant.

Figure 2 shows the dynamic response of the interest differential to a permanent depreciation of the exchange rate. As expected, the figure shows that in the long run the interest rate differential converges to a rise of about 4.4 points after a 10% exchange rate rise. Moreover, it shows that the differential overshoots in the initial months.[14] The

[14] To check the statistical significance of this response, the ECM was also estimated in a transformed version similar to equation (3). This made it possible to test for the significance of the "long-run" or cumulative effects. The p-value for the sum of the auto-regressive coefficients was 0.0020, and 0.0381 for the sum of exchange rate coefficients.

implications from these results were discussed in Section I: the observed reaction of the interest rate differential to a rise in the exchange rate may represent a stumbling block for the adoption of an anti-cyclical monetary policy, and it may also compromise the output stabilizing properties of the floating regime in the presence of capital account shocks.

Figure 2. Interest rate differential dynamic response to a 10% currency depreciation.



III. Explaining the link

This section offers an interpretation of the observed pattern of interest rate-exchange rate correlations in the Mexican float; the interpretation focuses on how an inflation-averse central bank may react to an exogenous currency depreciation, and notes the implications for the behavior of local interest rates, if private agents incorporate the central bank reaction function into their expectations formation process.[15]

[15] The analysis assumes that the central bank reaction function is at least imperfectly known (and credible) within the private sector.

There is a large body of literature that studies the interest rate-exchange rate link, with particular emphasis on testing the validity of the uncovered interest parity condition. A stylized fact from much of this work is the existence of a negative correlation between current interest rate differentials and future exchange rate variations, against what the parity condition would predict.[16] Several explanations have been put forward, including the existence of a time-varying currency risk premium (for critical assessments, see Takagi 1991 and Svensson 1992), realignment risk in the context of exchange bands (see Bertola and Svensson 1993), and bandwagon effects in the formation of expectations (see Takagi 1991).

Related work has advanced the idea that governments typically show “fear of floating”, in the sense that they use monetary policy to stabilize exchange rates (see references to work by Calvo, Hausmann *et al*. in the introduction). This could produce a positive correlation between domestic interest rates and the *level* of the exchange rate. In fact, McCallum (1994) had argued that the frequently observed negative association between current interest rate differentials and next-period exchange rate variations can be rationalized by assuming the existence of a government policy reaction function, by which local interest rates are raised in response to a weakening in the currency’s international value. McCallum (1994) simply assumes that governments try to smooth exchange rate variations; in what follows, we will take for granted that there is some degree of pass-through from the exchange rate to domestic inflation, and that inflation-averse authorities may thus respond to a rise in the exchange rate by tightening monetary policy.[17]

A formal exposition of the problem is as follows. By definition, the proportional change in the real exchange rate (defined as the ratio of foreign to local prices, in local currency) is equal to the proportional change in the nominal exchange rate minus the domestic inflation rate (assuming for simplicity that foreign

[16] See Froot and Thaler (1990) and Sarno and Taylor (2001) for an overview. Nakagawa (2002) and Obstfeld and Taylor (2001) show that the so-called forward premium puzzle may reflect the presence of nonlinearities in the relationship between exchange and interest rates, while Bansal and Dahlquist (2000) argue that in fact no such puzzle can be detected in the data for developing countries.

[17] Clarida (2001) summarizes recent empirical work showing that the central bank, in a number of developed countries, incorporates the exchange rate in its policy reaction function. Eichengreen (2001) argues that inflation-targeting central banks will react by tightening policy after the local currency depreciates as a result of capital account shocks.

inflation is zero): $d\ln q / dt = d\ln s / dt - \pi$, where q is the real exchange rate, and as before *ln* denotes the natural logarithm. How the change in the nominal exchange rate is determined is a matter of dispute in the literature. For our purposes, it seems safe to posit that it is determined by a combination of fundamentals (represented by the inflation rate) and monetary factors (summarized by the interest rate): $d\ln s/dt = \sigma\pi - \mu i$, where σ and μ are positive coefficients. To the extent that the rate does not fully reflect fundamentals (or because for a country like Mexico there may be a Balassa-Samuelson effect), σ will be less than one. If the inflation rate depends negatively on the interest rate and positively on the real exchange rate, the change in the real exchange rate will be given by:

$$(7) \quad d\ln q/dt = -\mu i - (1 - \sigma)\, \underset{(+,\,-)}{\pi (q, i)}.$$

After equalizing to zero, Equation (7) defines a downward sloping schedule of stationary q values in the (q, i) space. It is easy to see that the real exchange rate has stable dynamics in the sense that, starting from stationarity, an exogenous rise in the interest rate and/or the exchange rate will lead to a negative rate of change of q.

We will conventionally assume that the central bank attempts to minimize a weighted sum of output and inflation deviations from target:

$$(8) \quad \min L = \tfrac{1}{2}\, [y^2 + \tau (\pi - \pi^T)^2]$$

where τ reflects the strength of inflation aversion and for notation simplicity the output target is set at zero (Martínez *et al.*, 2001, present evidence supporting this sort of reaction function for the Banco de Mexico, at least since November 1998).[18]

[18] This formulation is now standard in the analysis of monetary policy rules among developed countries (see Taylor 1999). For supporting evidence in the case of Latin America, see Corbo (2000). Recently, a difference has been made between countries following strict inflation targeting, where output (or the output gap, or unemployment) does not enter the central bank policy function, and in cases of flexible targeting, where it does. According to the results in Martínez *et al.* (2001), Mexico would belong to the latter category at least since late 1998. But it is important to note that the conclusions derived below regarding the interest rate-exchange rate link do not depend on including output in the government's loss function. Even if they were strict targeters, the authorities would react to a currency depreciation by tightening monetary policy, thus producing the positive correlation discussed in the text.

To solve the problem, let us postulate linear functions for output: $y = y_0 + y_q q + y_i i$, the real exchange rate: $q = q_0 + q_i i$, the interest rate: $i = i_0 + i_m m$, and the inflation rate: $\pi = \pi_0 + \pi_q q + \pi_i i$. Output is assumed to depend negatively on the interest rate, but the effect of variations in the real exchange rate is uncertain: a rise in *q* improves the trade balance, thus raising aggregate demand, but it also has income-distribution and balance-sheet effects operating in the opposite direction (see, e.g., Ocampo 2000). Following the previous discussion, the real exchange rate is taken to be a negative function of the interest rate; we leave aside considerations of dynamic adjustment for simplicity. The interest rate is posited to have a market component (i_0), reflecting portfolio preferences, expectations, etc., and a policy component. If, for instance, the central bank uses the money base as its instrument (m), then $i_m < 0$.

The inflation rate is assumed to depend negatively on the interest rate and positively on the real exchange rate. The former effect simply reflects the idea that a rise in the interest rate is disinflationary because it reduces aggregate demand and, thus, upward price pressures in the labor and goods markets; naturally, the inflation rate may in turn affect the interest rate through the market component i_0, but such complication is not further considered here. The second determinant of inflation may require some elaboration. Calvo (1997), among others, has called attention to the existence of a strong negative link between the inflation rate and the level of the real exchange rate in Mexico. This nexus is a critical factor in the present analysis. In particular, if an exogenous rise in the exchange rate only led to a higher price level, but without affecting the inflation rate, then inflation-averse authorities would not assume a tighter policy stance (except in the unlikely case that they were targeting the price level, and not the inflation rate).

Returning to the government's loss function, we can set dL/dm = 0 and find that the policy rule is:

$$(9) \quad m = \{ \tau (\pi^* - \Pi) \Pi^m - OY^m \} / \{(Y^m)^2 + \tau (\Pi^m)^2\}$$

where $\Pi = \pi_0 + \pi_q (q_0 + q_i i_0) + \pi_i i_0$, $\Pi^m = i_m (\pi_q q_i + \pi_i)$, $O = y_0 + y_q (q_0 + i_0 q_i) + i_0 y_i$, and $Y^m = i_m (y_q q_i + y_i)$. Y^m measures the output response to a monetary expansion; it will be positive, unless the possibly negative effect of the real exchange rate on output is very strong. Π^m measures the overall impact of a monetary expansion on the inflation rate and it is, of course, positive.

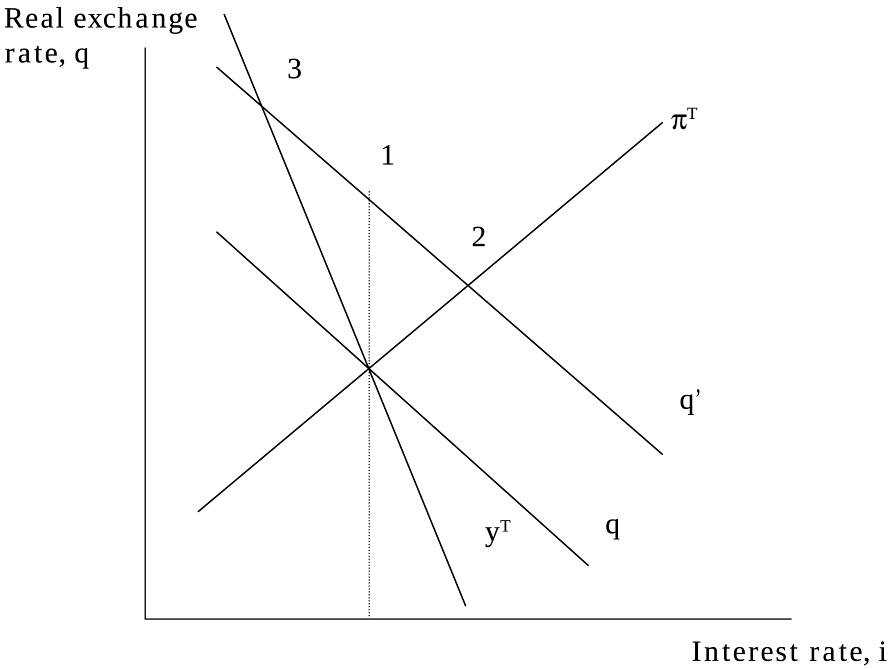
Consider now the effect of a capital account shock, for instance in an exogenous fall in the world demand for domestic assets. This will appear as an exogenous rise in the rates of interest and exchange. The rise in q_0 and i_0 will increase the inflation rate (unless there is a strong disinflationary effect from the higher interest rate, captured by the third element in Π). The output effect is likely to be contractionary, unless a currency depreciation is strongly expansionary. As Equation (9) shows, in this situation the central bank faces a dilemma arising from the simultaneous rise in Π (which calls for monetary contraction) and fall in O (which calls for the opposite response). A tightening will be the likely course of action to the extent that authorities are strongly anti-inflationary (high τ).

The policy dilemma can be better understood with the help of Figure 3. The figure shows a negatively sloped schedule for the determination of the real exchange rate in the (q, i) space. There is also a y^T schedule along which output is kept as a target; the schedule slopes downward under the assumption that a currency depreciation is contractionary: the fall in output associated with an interest rate rise has to be offset by a real exchange rate appreciation. The output schedule is steeper under the assumption that, after taking into account the effect of an interest rate rise on the real exchange rate, the net output effect is contractionary. The target inflation rate schedule is positively sloped as the inflationary impact of a real currency depreciation has to be offset by a tighter monetary policy stance.

The real exchange rate schedule shifts out as a consequence of the posited capital account shock. At the same time, the market interest rate rises. If, as seems plausible, the shock results in higher inflation and lower output, the economy will move to a position along the 1-2 segment of the q schedule. The authorities may respond with a monetary expansion, pushing the economy toward point 3, or they may instead adopt a more restrictive policy stance, moving toward point 2. In the first case, output is protected at the cost of higher inflation, whereas in the second the authorities are inclined to stick with the inflation target and are willing to sacrifice output. The actual choice will depend on policy preferences, as shown by the role of parameter τ in our previous discussion. But the policy response may also be conditioned by the behavior of private expectations.

To see this, first note that if the authorities choose to move toward point 3 by adopting a looser policy stance, and if they are successful in raising the real exchange rate, this implies that there will be a rise in

Figure 3. Output and inflation targets under contractionary depreciation.



the rate of nominal currency depreciation (given that the inflation rate will be increasing). But the higher depreciation rate will take place in a context of falling interest rates. Both factors tend to depress the return on peso investments, as shown by Equation (1). If private agents are able to foresee this path, they will reduce their demand for peso assets as they try to shift to dollar assets. This fall in the demand for peso assets will make it difficult to follow an anti-cyclical policy. In contrast, choosing a tighter policy stance after the capital account shock will yield a declining rate of currency depreciation together with higher interest rates. This combination will tend to stabilize the demand for peso assets, which may be particularly important in the aftermath of the shock (a point stressed by Carstens and Werner 1999, pp. 44, 47).

Perhaps it is important to clarify that this result does not depend on the assumption that a currency depreciation has a negative output effect, but only that output falls after a negative capital account shock (for instance, because of the effect on financial aggregates following a fall in foreign investment). Figure 4 illustrates the point. In the figure it is assumed that inflation is relatively more sensitive than output to variations in the real exchange rate, in the sense that after $\underline{q}$ rises, returning to target inflation requires a larger interest rate increase than returning to target output. If the capital account shock is contractionary, the economy will shift to a point along the 1-2 segment. There is thus again a policy dilemma.

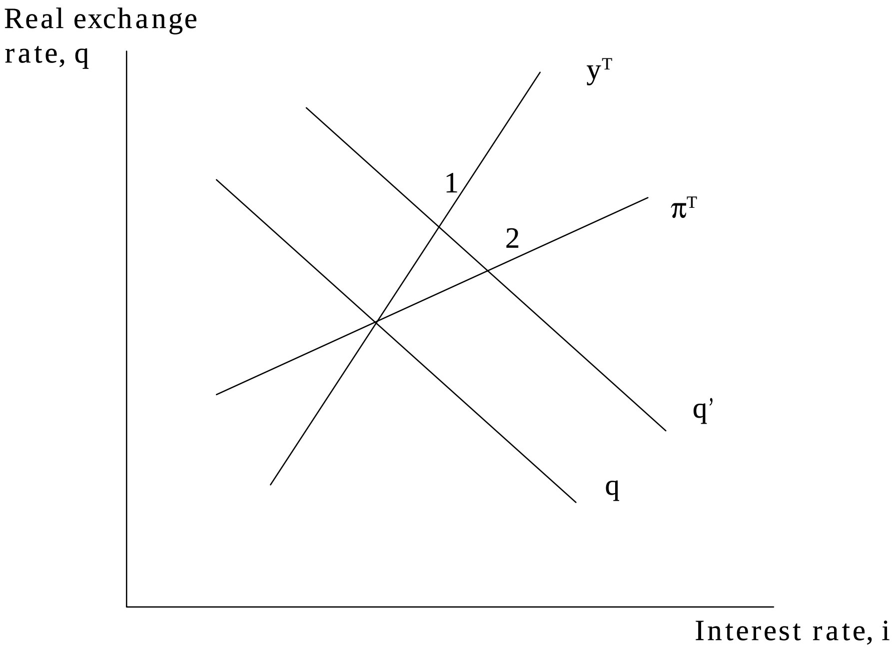
The preceding discussion stresses the point that, if the central bank behaves in anti-inflationary fashion after an exogenous decline in the currency's value, then interest rates will increase for some time. But in addition there may be a more immediate effect through variations in private expectations. In particular, if private agents believe that the central bank will adopt tighter policies in the near future, then standard term structure theory predicts that current interest rates (except those for very short-term instruments) will start moving upward (even if the uncovered interest parity condition holds; see Ibarra 2002). This is a channel that may be of importance in the Mexican case, given that the Cete rate has not been a central bank instrument during the float.

IV. Conclusions

The possibility of having an autonomous monetary policy under conditions of high international mobility of capital, and the output stabilizing properties of a floating currency regime, depend on the way interest rate differentials react to exogenous variations in the exchange rate. An adverse capital account shock, for instance an exogenous fall in the world demand for local assets, besides having a negative output effect, reduces the local currency's international value. If the latter leads to a decline in the expected depreciation rate for some future date, then current interest rates (aside from those on very short-term instruments) will tend to fall. This interest rate adjustment would be an automatic output stabilizer embedded in the floating regime. Even more, the negative correlation between the current exchange rate and the interest differential would give the central bank the leeway to assume a clear anti-cyclical policy stance.

In this paper we have estimated, from an ECM, the dynamic response of the interest rate gap between Mexican and US Treasury bills to a permanent variation in the exchange rate, using data from

Figure 4. Output and inflation targets under expansionary depreciation.



the current period of peso floating. The results indicate that, even considering a long lag structure, a weakening in today's exchange rate leads to a protracted increase in the interest rate differential. This stands in contrast to an assumption commonly found in policy-oriented macroeconomic models, and has potentially important implications. In particular, given the discussion summarized in the previous paragraph, the observed dynamic reaction of the peso interest rate represents a stumbling block for the conduct of an anti-cyclical monetary policy and compromises the output stabilizing properties of the floating currency regime in the presence of capital account shocks.

It could be considered whether the results obtained are biased by the single-equation estimation approach that has been followed. As is well known, VARs are widely used in the field. However, in the present context a VAR methodology was unattractive given the purpose of studying the dynamic response of the interest differential to an exchange rate change holding the rest as a constant, in particular holding the policy stance unchanged. The intention was not to study how the interest rate-exchange rate link evolves as a result of policy actions, but rather to analyze how private expectations (and perhaps risk assessments) change following an exchange rate variation.

The last section of the paper offers an initial formal exploration of the possibility that the dynamic response of the interest rate differential reflects private anticipations of future monetary policy actions, à la McCallum (1994). The basic idea is that if the central bank exhibits inflation aversion, and there is a positive relation between the exchange rate and the inflation rate, then agents may expect a policy tightening in the aftermath of an exogenous exchange rate depreciation. According to conventional term structure theory, this sole anticipation would tend to raise current and future interest rates, even if no central bank action actually takes place. Even more, it is also noted that if the central bank were to choose an alternative course of action, then there could be destabilizing effects on the assets market, given the concurrence of expectations of currency depreciation and falling interest rates.

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