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ABSTRACT

This paper attempts to make the case that a 2-sector model using the familiar traded non-traded distinction offers a reasonably successful empirical account of why Mexico needed to devalue its exchange rate in 1994. This model provides a way to define and measure disequilibrium in the exchange rate, and thus may be useful in assessing the likelihood of an exchange rate crisis in other developing countries. The results suggest that Mexico's exchange rate was about 25 percent overvalued on the eve of its 1994 crisis, but was much closer to equilibrium by the end of 1996. The approach in this paper is compared with other ways of assessing disequilibrium in the exchange rate, based on purchasing power parity or monetary models of the exchange rate.

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1 Introduction

When can a nominal exchange rate be said to be under-valued or over-valued? Broadly speaking, the approaches economists have used to answer this question include purchasing power parity calculations, calculations which look at the change in a real exchange rate measure from a base year, and calculations based on monetary exchange rate models. What this paper tries to do is to make the case that an approach based explicitly on a two-sector model with the familiar traded-non-traded distinction can be successfully applied to Mexico's 1994 exchange rate crisis.

The basic ideas in this paper are familiar but have not been applied to the Mexican crisis. The essential idea is that the crucial equilibrium relationship concerns the ratio of non-traded goods prices to traded goods prices within a country. More specifically, the model in this paper yields a reduced-form where, in equilibrium, the relative price of non-traded goods is a function of exogenous variables. We may write this equilibrium relationship as $p^n/E * p^t = g(Z)$, for example, where the superscripts "n" and "t" stand for "non-traded" and "traded", (with traded prices measured in foreign currency), E is the nominal exchange rate, and Z is a vector of exogenous variables. To provide a contrast, the analogous equilibrium condition in the purchasing power parity approach would be $P = EP^*$, where P and P^* are domestic and foreign price indexes. We may also write the purchasing power parity equation as $P/E^*P^* = k$ (a constant), to emphasize the fact that the price ratio is assumed to be constant in equilibrium, rather than depend on variables in Z.

The next hypothesis is quite standard. Either E or p^n , or both, can change to establish equilibrium. With flexible exchange rates E can jump quickly to restore equilibrium. But when E is fixed p^n must adjust, and does so with a finite adjustment speed, so that the observed value of p^n/E can deviate from equilibrium for a while. Therefore under fixed exchange rates it is possible to think of the shadow or equilibrium exchange rate as being potentially different from the actual observed exchange rate.

To demonstrate that the data from Mexico support this approach, this paper offers the following list of results. First, p^n/E and the variables in Z appear cointegrated, which supports the idea that they are linked by a long run equilibrium. In particular, the results suggest that two of the variables in Z are important: the oil price and capital flows to Mexico. Second, with this first result providing motivation, the paper presents estimates of the parameters of the long run equilibrium. Third, these estimated parameters are used to compute a shadow equilibrium exchange rate. Fourth, this is compared with the actual exchange rate in late 1994 to estimate the size of Mexico's overvaluation. Fifth, the paper argues that measures of disequilibrium from the forward exchange market agree with a key feature of the model in this paper.

This paper is related to the previous literature in the following ways. There is a large literature attempting to explain real exchange rates. This includes all of the studies of purchasing power parity, recently surveyed in Froot and Rogoff (1995). It also includes recent attempts to formulate and test structural models of deviations from PPP, Asea and Mendoza (1994), Edison and Klovland (1987), Marston (1987), Froot and Rogoff (1991a,b), De Gregorio, Giovannini and Wolf (1994), Edwards (1989), Devarajan, Lewis and Robinson (1993). Some of these papers use the traded-non-traded model used here. I have tried to ensure that the list of explanatory variables considered here is a larger set than that considered in these studies, data permitting. The main purpose of this literature is to explain levels of real exchange rates across countries or within countries, rather than to see whether equilibrium real exchange rate models can be used to understand exchange rate crises such as Mexico-1994.

There is also a large literature attempting to explain nominal exchange rate determination across countries. This literature would include all of the models and related literature surveyed in Frankel and Rose (1994) for example. Included within this literature is the monetary model of exchange rates as in Frenkel (1976) or Mussa (1976, 1979). Since the monetary model expresses the nominal exchange rate as a function of fundamentals (output levels, interest rate differentials), it can also be used to assess nominal exchange rate misalignment. To contrast the non-traded model with this literature, I also examine the performance of a simple monetary model applied to the Mexican case.

Finally, there is a literature offering analysis of the Mexican crisis itself. This includes Dornbusch and Werner (1994), and Sachs, Tornell and Velasco (1995). While these papers discuss the exchange rate issue, they are not explicitly focussed on testing a model of exchange rate misalignment.

The paper is organized as follows. Section 2 describes the model to define equilibrium in the real exchange rate. Section 3 describes the data. Section 4 presents the main empirical results, including cointegration tests and estimates of the parameters of the cointegrating vector. These parameters are then used to calculate a time series for the shadow equilibrium real exchange rate, with the difference between this and the actual real exchange rate providing a measure of exchange rate misalignment. These measures are used to quantify the extent of misalignment.

Section 4 interprets the Mexican exchange rate crisis of December 1994 in light of the estimates from the model. Section 5 considers a further test of the model provided by data on future exchange rates in the early 1980s. The question is whether these markets behaved as though a terms of trade model was driving equilibrium in the exchange rate market. Section 6 reviews two purchasing power parity approaches applied to Mexico, one based on price indices, the other based on wages, and argues that these approaches either imply implausibly large and protracted periods of disequilibrium, or are too imprecise to serve as practical guides for this question. Section 7 then presents evidence on how a monetary model performs in accounting for the Mexican crisis. It is argued that while the monetary model fits the data, the monetary fundamentals all moved in lock-step with the exchange rate, so that this model would not have been useful in providing advance warning of a crisis. Section 8 concludes with a summary of the argument and the evidence.

2 The non-traded model

This section describes the model for the equilibrium nominal exchange rate. The model is in the tradition of the traded/non-traded models, and thus owes a debt to the classic papers of Meade (1956), Salter (1959), Swan (1960) and Corden (1960). In addition, some of the formal features of the model borrow from Matsuyama (1992).

On the production side there are three sectors: a non-traded sector, a sector producing a traded good that sells at an exogenous world price, which will be set equal to 1 as the numeraire, and a sector producing a natural resource. Since employment in natural resource sectors are typically a small fraction of the labor force, we make the assumption that this sector uses no labor. The natural resource sector produces a constant flow of output, normalized to unity, that is sold at an exogenous relative price, p^r. Real revenue from the natural resource sector then takes the simple form:

$$R = p^r \tag{1}$$

The size of the labor force is normalized to unity, with a fraction, n, employed in the traded sector and the rest, $1 - n$, employed in the non-traded sector. The production functions, given below for the non-traded and traded sectors respectively, have the usual properties:

$$Q^n = H(1-n) \tag{2}$$

$$Q^m = F(n) \tag{3}$$

The notation for the prices in this model is as follows. The price of the traded manufacturing good is p^m, expressed in units of foreign currency. The price of the natural resource, also in units of foreign currency is p^r. The price of the non-traded good, expressed in units of the domestic currency is p^n. Let E represent the exchange rate giving the quantity of domestic currency that can be purchased with one unit of the foreign currency, and let p^m be the numeraire. Then the relative prices of the natural resource and the non-traded good, expressed in terms of the traded manufacturing good are, respectively, p^r and $\frac{p^n}{E}$.

On the demand side, consumption of both goods is chosen to maximize a time-separable utility function of the following form.

$$\text{Max } V(t) = \int_t^{\infty} e^{-\rho(s-t)} \left[Ln(C^m(s)) \; + \; \beta \; Ln(C^n(s)) \right] ds \tag{4}$$

subject to the solvency constraint that the present value of production must equal the present value of consumption plus the level of the foreign debt D(t).

$$\text{s.t.} \int_t^{\infty} e^{-r(s-t)} \left(C^m + \frac{p^n}{E} C^n \right) ds \; + \; D(t) \; = \; \int_t^{\infty} e^{-r(s-t)} \left(\frac{p^n}{E} Q^n + Q^m + p^r \right) ds \tag{5}$$

Setting up the Hamiltonian for this problem and maximizing yields two important first order conditions. The first establishes a fixed relation between spending on the two goods at any point in time.

$$\beta E C^m = C^n p^n \tag{6}$$

In equation 6, E is the nominal exchange rate giving the quantity of local currency that can be purchased with a unit of foreign currency. And β is a preference parameter: a higher value represents a shift in preferences in favor of the non-traded good.

To obtain a tractable solution, I will assume that the discount rate is equal to the real interest rate, $\delta = r$, so that the desired consumption profile is constant over time. To obey the external solvency constraint, this means that the consumer will spend an amount on the traded good equal to the real interest rate times national wealth.

$$C^m(t) = rW(t) \tag{7}$$

where W(t), national wealth in terms of traded goods, is simply the present discounted value of all future production of the traded good and the natural resource, net of the external debt.

$$W(t) = \int_t^{\infty} e^{-r(s-t)} \left(Q^m(s) + p^r(s) \right) ds - D(t) \tag{8}$$

The next issue is to state how expectations about the future path of the natural resource price are determined. Following the large body of research that establishes that one cannot improve on the random walk model in forecasting commodity prices, I will assume that the current natural resource price is the best forecast of future natural resource prices. This permits a simplification of the consumption side of the model. If the price of the natural resource is expected to remain constant at its current level, then the share of labor in traded manufacturing will be constant and so will real output of the traded good. In this case, real wealth simplifies to:

$$W(t) = \frac{1}{r}(Q^m + p^r) - D(t) \tag{9}$$

And, recalling that $C^m = rW(t)$, consumption of the traded good becomes:

$$C^m = Q^m + p^r - D(t) \tag{10}$$

Next, labor market equilibrium requires that the value marginal products are equated across the two sectors,

$$EF'(n) = p^n H'(1-n) \tag{11}$$

Finally, equilibrium in the non-traded market requires

$$C^n = H(1-n) \tag{12}$$

This completes the simple version of the model. There are six equations: 2, 3, 6, 10, 11, and 12. To solve for the equilibrium of p^n/E, it is convenient to solve first for n, the equilibrium share of labor in the traded sector. The model can be reduced to a single equation determining the share of employment in the traded sector as a function of preferences, the natural resource price and the inherited debt:

$$\frac{F'(n)H(1-n)}{H'(1-n)} - \beta F(n) = \beta(p^r - rD) \tag{13}$$

Where the expression on the left-hand side is decreasing in both n and β. This establishes that n, the share of employment in the traded sector, is decreasing in both p^r and β. The dependence of n on p^T is a Dutch Disease result: a natural resource boom raises income and demand for non-traded goods; this demand stimulus raises output in the non-traded sector and draws resources from the traded sector to the non-traded sector. The dependance of n on β comes from the fact that a rise in β means a shift in preferences towards non-traded products: this demand shift also draws resources away from the traded sector.

Having solved for n in terms of exogenous variables and parameters, the equilibrium relative price of non-traded products can be determined from the labor market equilibrium condition, equation 11, as follows:

$$\left(\frac{p^n}{E}\right)^* = \frac{F'(n)}{H'(1-n)} \tag{14}$$

Since in this equation p^n and n are inversely related, the effect of the exogenous variables on p^n is opposite to their effect on n. That is, a rise in the terms of trade raises the equilibrium price of non-traded products, and a shift in preferences for non-traded products also raises the equilibrium price of non-traded products.

2.1 Effects of trade liberalization and fiscal reform

Disputes about the impact of the economic liberalization on the equilibrium exchange rate has been central to the exchange rate debate in Mexico. Before December, 1994, defenders of the real exchange rate appreciation asserted that it was an equilibrium phenomena justified by the Mexican reforms. This section examines this question by extending the basic model in two ways.

Two main features of the Mexican liberalization have been budget cutting and the reduction in tariffs and quotas. The retreat of the public sector can be seen in the fact that the share of government spending in total spending has fallen from 38 percent in the second quarter of 1982 to about 19 percent in the second quarter of 1992. Trade liberalization began with Mexico joining the GATT in 1985 and accelerated a few years later as the average (production weighted) import tariff fell from 24.5 percent in December 1986 to 11 percent in June of 1988.

To analyze the impact of these reforms in the context of the model, we include a public sector budget equation where government spending, G, is financed trough lump-sum taxes, T, and tariffs levied on imports of the traded good, $t(C^m - Q^m)$. In the equilibrium below, the level of lump-sum taxes, T, adjusts endogenously to satisfy the government budget constraint at each point in time.

Since the import tariff alters the internal relative price of the traded good, the first order condition for private sector consumption, given above in equation 6, changes to

$$(1+t)\beta E C^m = C^n p^n \tag{15}$$

and for the same reason, the labor market equilibrium condition, equation 11, changes to

$$(1+t)EF'(n) = p^n H'(1-n) \tag{16}$$

To take into account the fact that the public sector has a higher propensity to spend on non-traded goods than the private sector, government spending is assumed to fall entirely on non-traded goods. Consequently, equation 12 becomes,

$$C^n + G = H(1-n) \tag{17}$$

Once again the model reduces to a single equation determining n as a function of exogenous variables and parameters, similar to equation 13,

$$\frac{1}{\beta}\left[\frac{F'(n)}{H'(1-n)}(H(1-n)-G)\right] - F(n) = \beta(p^r - rD) \tag{18}$$

It can be shown formally from this equation that a cut in government spending will increase the share of employment in the traded sector – because it reduces demand for the non-traded good.

Finally, to solve for the equilibrium price of non-traded products, rearrange equation 16 to obtain,

$$\left(\frac{p^n}{E}\right) = \frac{(1+t)F'(n)}{H'(1-n)} \tag{19}$$

We can now summarize the effects of liberalization in this model. First, budget cutting causes a net reduction in demand for non-traded products, which reduces both output and the price of the non-traded good. So the effect of this kind of liberalization is to depreciate the equilibrium real exchange rate. Second, a tariff cut also depreciates the equilibrium real exchange rate, because it reduces the value marginal product of labor in the traded sector, which reduces wages and reduces the equilibrium price of non-traded goods. Combining these results with the earlier analysis, the equation below summarizes all of the determinants of the equilibrium relative price of non-tradeables.

$$\left(\frac{p^n}{E}\right)^* = z(p^r, \beta, rD, G, t) \text{ where } z_1, z_2, z_4, z_5 > 0, z_3 < 0 \tag{20}$$

Finally, in equation 20, either p^n or E, or both, can adjust to achieve equilibrium. In our view, it is most reasonable to view the nominal exchange rate as more flexible than goods prices, so that during periods of floating exchange rates, most of the adjustment is achieved by discrete changes in E rather than p^n. When the exchange rate is fixed, the adjustment burden falls on non- traded prices, which are assumed to adjust to equilibrium according to the dynamic equation below, with the speed of adjustment given by the parameter ψ.

$$\frac{\dot{p^n}}{E} = -\psi\left(\frac{p^n}{E} - \left(\frac{p^n}{E}\right)^*\right) \tag{21}$$

3 Data

To measure p^r, the ratio of natural-resource export prices to import prices, I obtained data on the price of West Texas Intermediate crude oil, and divided this by a price index of imported goods to Mexico (both measured in U.S. dollars). Crude oil has long been the most important natural resource export from Mexico. In 1985 for example, at about the middle of the sample period, crude petroleum exports were about 83 percent of all natural resource exports from Mexico [1]. A possible objection to the use of crude oil prices to measure p^r is that this misses movements in other export prices. For example, the data show that while oil was 67 percent of total exports in 1980, it fell to about 37 percent in 1990, as manufacturing exports rose in importance. To look at this, I also constructed an alternative measure of p^r that differed only in that it used a price index for total exports in the numerator. It turns out that since crude oil prices are by far the most volatile export price, the price index for total exports is highly positively correlated with the crude oil price index. The R^2 from a regression of the two alternative measures of p^r is 0.97. Therefore, the two measures of p^r produce similar results in practice.

The issues involved in the measurement of p^n are discussed extensively in Little, Cooper, Corden and Rajapatirana (1993, pp. 258-263). I follow their recommendation (p. 260) in choosing a measure that uses the domestic CPI, rather than the domestic WPI, in order to achieve higher coverage of (Mexican) non-traded goods prices. Other than this, the choice is dictated mainly by data availability. I use a real exchange rate measure published on a monthly frequency by the Bank of Mexico. It is calculated as $(P/P^*) * (E^*/E)$, where P* is a price index for 133 trading partners, P is the Mexican CPI, E is the nominal peso per U.S. dollar exchange rate and E* is a rest-of-world/U.S. dollar exchange rate. Hence a rise in this variable is equivalent to a rise in the relative prices of non-traded goods, or an appreciation in the real exchange rate. A consistently-calculated series is available from the first quarter in 1979 to the present.

Table 1 presents a summary of the other variables used in the empirical work.

4 Testing the model and estimating misalignment

We now ask how well this non-traded model performs against the evidence for Mexico. In particular, does it fit the data reasonably well, and with the anticipated signs on the explanatory variables? If so, do the results argue for amendments to previous views about what variables are important in thinking about equilibrium exchange rates? Is there evi-

[1] *Indicadores Economicos, August 1987 IV-H-47(e)*

dence of cointegration, so that we can support the use of this model to estimate parameters of a long run, equilibrium relationship? If so, what do the estimates suggest about the equilibrium for the Mexican Peso? Was it overvalued in late 1994, on the eve of the exchange rate crisis? If so, by how much? Could the crisis have been predicted by this model?

The starting point is table 2, where several regression results are presented. The first two columns contain the least squares estimates with t-ratios in parentheses (which are based on standard errors that are robust to serial correlation and heteroscedasticity). The strongest result is the importance of the oil price variable, which is statistically significant no matter what other variables are included in the regression. In the preferred regression (column 3) it has a t-ratio of 8.126. In figure 1, I show a graph of $p^n - e$, along with p^rso that the reader may see what is driving this result. The figure shows that the oil price was high in the early 1980s, when the relative price of non-traded products was also high. Both declined sharply in 1986, and both reached similar levels after the 1994 exchange rate crisis. The scatter diagram in figure 2 shows the positive bi-variate relationship between these two variables, to illustrate why the regressions estimate a strongly positive coefficient.

The second important variable appears to be capital inflows. Like the terms of trade, this variable is also always significant, regardless of the presence of other variables or the estimation method. The importance of capital flows in the early 1990s is widely acknowledged as an important determinant of Mexico's real appreciation, and the data appears to corroborate these views. In figure 3, I show the positive bi-variate relationship between the relative price of non-traded goods and capital inflows. [2]

Turning now to magnitudes, if we compare unit-standard deviation changes in each of

[2]The evidence on whether the data are non-stationary is the following. If we look at standard augmented Dickey-Fuller tests, the following variables have test statistics quite close to the 95 percent critical values: $p^n - e$,rD, CF, $e - (m - m^*)$, $i - i^*$ and $y - y^*$. At the 5 percent level, we would fail to reject the null of non-stationarity and conclude that these variables have unit roots. However, since these tests have low power against stationary alternatives, there is an argument for using higher critical values. At slightly higher critical values, these variables would appear stationary. For three variables, the evidence of non-stationarity is stronger: p^r, e and $m - m^*$. From the evidence in table 2 however, I get similar substantive results whether the data are treated as stationary or non-stationary.

the explanatory variables in the regression in column 1, the results also suggest that the terms of trade and capital flow variables have had the largest effects during the sample period on the real exchange rate. The point estimate says that if the oil price rose by one standard deviation, non-traded prices would rise by 17.8 percent. And if capital inflows rose by one standard deviation, the real exchange rate would rise by 10.3 percent. The three remaining variables (share of government spending, and average tariff, and debt-service payments) are insignificant. Nevertheless, if we still take the point estimates at face value, the magnitudes suggest that unit standard deviation changes would have small impacts on the real exchange rate, with none of the estimates exceeding 4 percent. In sum, these preliminary results suggest that two variables, the terms of trade and capital inflows, are both statistically and quantitatively important. In contrast, the other variables have rather small and insignificant effects. The second regression in table 2 drops the insignificant regressors and re-estimates the model with just the resource price variable and the capital flow variable.

These least squares results are taken as a guide as to what variables to include in more sophisticated estimation techniques, which generally require lots of data relative to the number of estimated parameters. The third regression in table 2 reports the dynamic least squares procedure recommended in Stock and Watson (1993) for estimating parameters of (possibly) co-integrated data. The essential difference between this estimation technique and least squares is the inclusion of a number of lags and leads of first differences of the I(1) variables to control for short run dynamics and possible correlation between the error terms. In the case of the third regression, there is one contemporaneous first difference and one lag and lead of the first difference of the two variables, which amounts to an additional 6 right hand side regressors (3 additional variables associated with each of the two regressors).

Note that both estimates continue to point to the importance of the terms of trade and capital flows, with estimated long run elasticities that are quite close to the simple least squares estimates. In the final column, Johansen (1988) estimates of the cointegrating vector are presented, and again the point estimates are close to the other estimation techniques.

In summary, a parsimonious representation of the cointegrating vector linking the real exchange rate, terms of trade and capital flows from all of these results would be (-1 .53 .031).

To show that there is indeed evidence for cointegration between these three variables, table 3 presents the results of Johansen (1988) cointegration tests. The results indicate evidence for two statements, first that there is cointegration at the five percent level, and second that there is a single cointegrating vector. Noting that r stands for the number of cointegrating vectors, this can be seen from the result that the test rejects $r = 0$ in favor of $r = 1$ (establishing cointegration), and then fails to reject $r \geq 1$. If in fact r is less than or equal to one, but not zero, then it must be exactly one.

It may be argued that cointegration is a rather strong result that other exchange rate models often do not satisfy (see for example the models surveyed in Frankel and Rose, 1994). A finding of cointegration provides statistical support to claims that certain variables determine long run equilibria. Another way to put this is that if the model is true, the real exchange rate data should behave as though it is striving to revert to the equilibrium defined by the model: that is, deviations from this norm should be stationary.

With this evidence that the variables are cointegrated, the next step is to use the estimated long run parameters to derive a time series that represents the long run equilibrium exchange rate. This shadow equilibrium exchange rate can then be compared with the actual real exchange rate to draw conclusions about exchange rate overvaluation.

The evidence on exchange rate misalignment is summarized by the data in figure 4. The solid line is the log of the actual real exchange rate series. The dotted line is the simulated equilibrium generated by multiplying the actual data on capital flows and oil prices with their respective long run coefficients from regression 3 in table 2. The dashed line is the simulated equilibrium using only the oil price coefficient. The simulated equilibrium with both variables is labeled "CF and Pr" and the simulated equilibrium with only the oil price is labelled "Pr".

There are two reasons for simulating the equilibrium exchange rate with and without capital flows. The first is simply to see the contribution of the capital flow variable to the equilibrium, and compare it with the oil price's contribution. The second reason is to address the popular notion that an appreciation driven by capital inflows is more transitory or less sustainable that an appreciation driven by other fundamentals. For example, many observers argued in the early 1990's that since a high fraction of the capital inflows in Mexico were short term assets, they were hot money", and thus easily reversed. The corollary was that the appreciation was being sustained by a temporary phenomena and could easily collapse. For those who wish to treat capital flows as different from other fundamentals, figure 4 provides estimates of how much the capital inflows appreciated the equilibrium exchange rate and what the equilibrium would have been if they were zero.

The first conclusion to observe from figure 4 is that the implied periods of real exchange rate disequilibrium are smaller in magnitude and shorter in duration than would be the case in a purchasing power parity approach, or any other approach where the equilibrium is time-invariant. For example, if the equilibrium real exchange rate was equal to the sample mean over this period, the standard deviation of the gap between actual and equilibrium would be about 0.19 (in this calculation, the sample stops in 1994:4 to eliminate the recent exchange rate crisis). If instead the equilibrium is given by the time series in figure 4, the standard deviation would be either 0.11 or 0.15, depending on whether capital flows are included. So by this measure the implied disequilibrium can be reduced by about 40 percent compared with the purchasing power parity approach.

Second, figure 4 shows that the model indicates real exchange rate overvaluation just before each of the three major nominal devaluations over the sample period: in 1982, 1986 and 1994. In the first of these episodes, world oil prices began falling in the summer of 1981; this reduced the equilibrium price of non-traded goods, as shown by the fall in the equilibrium exchange rate during 1981-1982. In late 1981, the Mexican President vowed to defend the Peso "like a dog", and indeed the Central Bank lost almost all of its reserves until it devalued in early and mid 1982. In figure 4 this episode shows up in terms of a decline in the equilibrium real exchange rate, along with a continued rise in the actual real exchange rate followed by a sharp fall at the time of the nominal devaluation. The second episode in 1986 followed a period in which the Central Bank was attempting to fight inflation by reducing the rate of nominal depreciation. One can see the resulting appreciation of the real exchange rate as non-traded price inflation exceeded nominal depreciation during 1984-1985. As in 1981, a decline in oil prices in early 1986 precipitated this devaluation. However, unlike 1981, this devaluation was executed swiftly, so that with the quarterly data exhibited in the figure, it appears as a simultaneous decline in the actual and equilibrium real exchange rate. Interestingly, figure 4 suggests that the authorities actually devalued too sharply in 1986, overshooting the equilibrium and thus exacerbating the inflationary consequences. Indeed, in 1987-1988 inflation became the dominant economic problem in Mexico. This illustrates the point that an accurate assessment of exchange rate equilibria can be important for inflation stabilization, because a nominal devaluation that is too large can spark unnecessary inflation to undo the disequilibrium in relative non-traded prices.

Now we turn to the Peso crisis around the December 1994 devaluation. Figure 4 suggests that the Peso was overvalued on the eve of the crisis. The numbers suggest that the overvaluation was about 25 percent. Indeed, the model suggests that even if we take into account the high levels of capital inflows in 1993 and early 1994, the peso was still overvalued on the eve of the crisis in late-1994. This is evidence against the assertions by several Mexican officials during this period that the Peso was not overvalued. The results suggest that Peso overvaluation began to be a problem in early 1993 and persisted until the crisis in late 1994. However, in defense of the Mexican authorities, the model suggests that the real appreciation during 1987-1992, which was also controversial, was justified by the fundamentals.

Regarding the period after the crisis in December 1994 - January 1995, figure 4 shows evidence that the real Peso overshot its log run equilibrium, but that by the last quarter of 1996, it had appreciated back to a level that was quite close to the equilibrium simulated by the model in this paper. The point estimates for the final quarter of 1996 suggest that the real exchange rate was about 5 percent undervalued. Overall, the behavior of the real exchange rate since the crisis is fairly consistent with the predictions of this model.

5 Evidence from forward exchange rate market

Since the oil price variable appears important in determining equilibrium in the exchange rate in this paper, and since this result is not emphasized in the literature on the Mexican Peso, this section looks at further evidence on this question. The evidence comes from the future exchange market in 1981.

In June of 1981, the world price of oil fell unexpectedly and suddenly by about 12 percent. At the same time, there was active trading in futures contracts for the Mexican Peso in New York, so data is available on both the current nominal exchange rate and 6-month future exchange rates. With this data, it is possible to compare future and current exchange rates and thus calculate a proxy for market expectations of the future path of the exchange rate. In addition, other important economic variables were reasonably constant during the two months of June and July 1981 so that this episode comes reasonably close to a controlled experiment on the impact of a terms of trade decline on exchange rate expectations.

The question is, did the future exchange rate market behave as though the model in this paper was governing views about the equilibrium real exchange rate? If so, we would expect that if the oil price fall was not accompanied by a nominal devaluation, then the market would expect such a devaluation to be imminent and bid up the future exchange rate. At the time, the Bank of Mexico was intervening to defend the current exchange rate but did not have any control over the future rate. If instead the market was behaving as though the terms oil price decline was not important, then there should be no effect on future exchange rates.

Table 4 presents data at a monthly frequency on the three key variables: the current nominal exchange rate, the 6-month future exchange rate, and an index of oil prices. In the third column, one can see the decline in the price of oil starting in June 1981. In the first column, one can see that the current nominal exchange rate was not substantially adjusted.

And in the second column, one can see that the 6-month future exchange rate did in fact depreciate, and did so at roughly the same time that the oil price declined. Therefore, this evidence supports the idea that market expectations behaved as though the terms of trade decline did have an important effect on the equilibrium real exchange rate. It is consistent with the idea that the market was using a model similar to that in this paper to assess the likelihood of a nominal devaluation.

6 Purchasing Power Parity

This section looks at purchasing power parity calculations in the Mexican case. Following the survey in Dornbusch (1988) purchasing power parity refers to the application of the law of one price (in the long run, perfect substitutes should have the same price in any two locations) to price aggregates. Nominal exchange rate equilibria are then computed by manipulating the equation $P = EP^*$.

As is well known, the relative form of purchasing power parity states that nominal exchange rates will move to establish some constant ratio between price indices in two economies. This hypothesis may be expressed by taking log first differences of the equation P/EP*=constant. By looking at any of the graphs of the real exchange rate in this paper, it is easy to see that this approach applied to Mexico implies large and protracted deviations of the actual real exchange rate from equilibrium. For example, if the equilibrium were the mean of $p^n - e$ over the sample period, the average deviation would be 19 percent and the periods of misalignment typically would exceed one year. This result is not really sensitive to which Mexican price index is used: it can be replicated with a large number of Mexican price indexes, including agriculture and sectors within manufacturing that may seem on a-priori grounds to be potentially tradeable. Hence the general implication of large and protracted deviations from equilibrium obtains with a number of different price indexes.

How exactly does one distinguish the approach in this paper from this purchasing power parity approach? The first way is that the model in this paper implies that the equilibrium is not a straight line but instead varies over time as the economic fundamentals change. If this results in a disequilibrium that is smaller and of shorter duration, then that can be regarded as evidence in favor of the model over the PPP alternative. Another way to look at the contrast is that the PPP approach predicts that the fundamental variables do not enter the equilibrium, so that a finding that they do may be regarded as a rejection of the PPP approach.

A second approach to defining nominal exchange rate equilibria is to use wages rather than prices. The underlying hypothesis is that nominal exchange rates will move to achieve equality between average wages in two locations.

Table 5 displays Mexico's actual nominal exchange rate for two years, 1980 and 1990, along the top row, and then displays what the equilibrium would be when various countries' average wages are used to calculate equilibrium. The table shows that there is a large dispersion in the equilibrium exchange rate depending on the choice of country. This dispersion remains substantial even when the choice is restricted to countries that are close to Mexico or have similar per-capita incomes (compare Venezuela with Chile in 1980 or Costa Rica and Chile in 1990). This approach also seems to yield too much ambiguity to serve as a practical guide to nominal exchange rate equilibria.

7 A monetary model applied to the Mexican crisis

In this section I compare a third approach to thinking about exchange rate equilibria: the monetary model in the tradition of Frenkel (1976) and Mussa (1976). There are a number of variants of this model, but generally they are built on some combination of three equations: a money demand equation, an uncovered interest parity equation, and a purchasing power parity equation [3].

Here I derive an estimable equation by using two of these equations; money demand and purchasing power parity. There are two countries, Mexico and the United States, with a money demand relationship that holds in both economies and a purchasing power parity equation that holds between prices in the two economies. Subtracting the U.S. money

[3]These models are discussed in Obstfeld and Rogoff (1996, p. 526)

demand from the Mexican money demand, we have.

$$m - m^* - (p - p^*) = \alpha(y - y*) - \beta(i - i^*) + v^m - v^u \tag{22}$$

The purchasing power parity relationship is as follows.

$$p - p^* = e + v^p \tag{23}$$

With the v"s representing error terms. Substituting for $p - p^*$, and rearranging, we have the following estimable equation.

$$e - (m - m^*) = -\alpha(y - y*) + \beta(i - i^*) - v^m + v^u - v^p \tag{24}$$

Note first that this equation contains the restriction implied by the model that the coefficient on $m - m^*$ is 1.0. Moreover, since e and $m - m^*$ are logs of nominal variables, they both have positive trends over time. However, the evidence supports the idea that although both are individually non-stationary, the difference between the two is stationary. In addition, there is no clear evidence that either $y - y^*$ nor $i - i^*$ are non-stationary, so that this equation may be estimated by ordinary least squares.

The estimates of this equation are in table 6. Note that the coefficient on $m - m^*$ is restricted to 1.0. The model fits the data reasonably well ($R^2 = 0.54$) , and the estimated coefficients are correctly signed and significant. The fit of the equation is illustrated in figure 6.

The point of this exercise is to compare this model with the model in this paper in terms of accounting for Mexico's 1994 crisis. We have already seen that the model in this paper suggested that the real exchange rate was overvalued on the eve of the crisis. This is shown in the simulated equilibrium exchange rates in figure 4 as well as the out-of sample forecasts of the model in figure 5. In this sense, the model in this paper would have "predicted" the crisis.

In figure 7, I show the out-of-sample forecasts from the monetary model. Note that throughout the forecast period (1992:I-1996:IV) actual $e - (m - m^*)$ is above the forecast.

This means that the nominal exchange rate, e, would have had to fall (appreciate) to bring it in line with the monetary fundamentals. Therefore, if anything, this monetary model would have suggested that Mexico's exchange rate was undervalued in the years before the crisis. This is the first contrast with the model in this paper.

The second difference between the two models is that the variables in the monetary model tended to change contemporaneously with the exchange rate, so that the monetary fundamentals would not have provided any advance warning of an impending crisis. This is illustrated in figure 7 by the fact that both the nominal exchange rate and the forecasted exchange rate rose together between 1994:IV and 1995:I. It is also shown by the data in table 7. Note that for the monetary fundamentals to signal that a devaluation was warranted, the monetary variables must move in the following directions: $m - m^*$ should rise, $i - i^*$ should rise, and $y - y*$ should fall. However, from the data in table 7, none of the variables moved strongly in these directions in the quarters leading up to the crisis in December 1994. It was only in the first quarter of 1995, after e had risen sharply, that we observed a sharp rise in $i - i^*$ and a decline in $y - y^*$. These data are consistent with the idea that the monetary variables moved along with the exchange rate. It is hard to find evidence that monetary disequilibrium precipitated the crisis, or that the monetary fundametals moved in such a way as to predict the crisis. However, it is possible that events moved so quickly that we cannot observe evidence of monetary disequilibrium at the quarterly frequencies used in this paper.

8 Conclusion

Because of advances in communications and information technology, the Mexican crisis of December 1994 had global implications, leading some to label it the first financial crisis of the 21st century. This paper proposes the traditional non-traded model as a constructive framework in which to think about exchange rate misalignment, estimates and tests it using Mexican data and then uses the results to interpret recent Mexican exchange rate policy, including the 1994 crisis. It is argued that the data are quite supportive of this approach, and indeed that the crisis itself could have been foreseen based on data that was available in 1994.

To summarize, the main evidence in favor of the model is the following. The model predicts cointegration and we find cointegration. The model also predicts that the oil price should help determine the equilibrium exchange rate, and the evidence for this appears supportive. Further evidence from the futures market in the early 1980's shows that the future exchange rate did depreciate in response to the decline in the price of oil in the summer of 1981.

This result is consistent with the view that oil price shocks were important in the market's perception about exchange rate misalignment, and is also consistent with the predictions of the non-traded model.

The empirical results in the paper suggests that even though the real Peso has fluctuated dramatically during the 1980's, much of this represented an equilibrium response to shocks in the exogenous variables in the model. Once these are taken into account, the periods of disequilibrium are much smaller and shorter-lived than would be predicted by other models with constant equilibrium real exchange rates such as the purchasing power parity model. The fact that the disequilibria are smaller in magnitude and shorter in duration than the purchasing power parity model may also be taken as evidence in support of the model.

The paper also finds that capital flows have an important effect on the equilibrium exchange rate but that several other commonly-mentioned variables do not, such as government spending shares, tariffs, and debt servicing payments. Perhaps surprisingly, the evidence instead supports a fairly parsimonious model where the long-run exchange rate is a function of Mexico's external terms of trade and level of capital inflows.

Before the 1994 crisis, the argument was made by several Mexican officials that the Peso was not overvalued. The evidence here suggests that it was indeed overvalued by about 25 percent. However, assuming no inflation in non-traded prices, a nominal devaluation to about 4.7 New Pesos to the Dollar would have been sufficient to restore relative price equilibrium. The exchange rate of 6.5 in June 1995 clearly exceeded this. So the nominal decline of the Peso in 1995 was not only an adjustment to a new, lower equilibrium. As argued in Sachs, Tornell and Velasco (1995), there also seems to have been an element of self-fulfilling panic during which the economy lacked a nominal anchor. But by 1996, cumulative inflation in non-traded prices has been sufficient to restore real non-traded prices to within five percent of the real equilibrium predicted by the model in this paper.

Table 1

DATA

Variable name	Description
p^r	Natural log of the ratio of crude oil prices to import prices: $Ln(P^{oil}/P^m)$. P^{oil} is the dollar price of West-Texas Intermediate crude oil, P^m is an index of import prices in dollars. Source, The World Bank commodities division and the Bank of Mexico, unpublished data.
g	The ratio of nominal expenditures by the Federal Public Sector (including public enterprises) to nominal GDP. The source is *Indicadores Economicos*, various issues, International Financial Statistics, International Monetary Fund, and the Bank of Mexico's web page.
t	Weighted average of ad-valorem percentage tariff rates in 59 sectors, where the weights are production in each sector. These data are reported for 1980 and then biannually between 1985 and 1992. Tariff rates in Mexico did not change dramatically before 1985, when Mexico joined the GATT. This is apparent from the tariff data, which shows that the average tariff in 1980 was 22.8 and in 1985, 23.5, so data for the intervening quarters was obtained by linear interpolation. For data after 1985, the biannual observations were interpolated to obtain quarterly data.
rD	Nominal interest rate on ten-year treasury bonds times total external debt of Mexico, from the World Debt Tables, World Bank.
p^n-e	Proxy for ratio of prices of non-traded goods to prices of traded goods, in logs. Source is the Bank of Mexico which reports a time series on EP^*/P, where P^* is a 133-country index of external prices, from the International Monetary Fund, E is an effective nominal exchange rate (pesos per unit of foreign currency), and P is the Mexican CPI, (see *Indicadores Economicos*, cuadro IV-17). The series used is quarterly (79:1-92:4), obtained by taking the average of the reported monthly series (July 1980 = 100), and is then updated to 1997:II by the author using monthly data on prices exchange rates and foreign price indexes. Throughout this paper I use the log of the <u>inverse</u> of this series, so that an increase represents a rise in non-traded prices. The issues involved in using this as a measure of relative non-traded prices are discussed in Little et. al. (1995).
CF	Capital account balance measured so that a positive number is a capital inflow to Mexico. Source: Bank of Mexico, *Indicadores Economicos*, various issues, and Bank of Mexico's web page.
m-m*	Log of base money plus demand deposits (M1) in Mexico minus the log of base money and demand deposits in the U.S. Source Bank of Mexico and Survey of Current business, department of commerce.
i-i*	Nominal interest rate on 3-month Mexican government debt minus nominal interest rate on 1-year U.S. Treasury bills.
y-y*	Log of real-per-capita GDP in Mexico minus log of real per-capita GDP in the U.S.

Table 2. Estimates of Long Run Equilibria

Dependent variable is the real exchange rate: $p^n - e$

	Estimation Method			
	Ordinary Least Squares		Stock & Watson (1993)	Johansen (1988)
Constant	1.587 (5.880)	1.735 (6.459)	2.065 (7.36)	2.039
p^r	0.672 (7.590)	0.602 (9.686)	0.528 (8.126)	0.531
g	-0.795 (-0.853)	-	-	-
t	0.0003 (0.048)	-	-	-
rD	0.00015 (1.120)	-	-	-
CF/1000	0.0302 (3.269)	0.0345 (7.322)	0.0339 (7.371)	0.0312
Adjusted R^2	0.646	0.648	0.639	-
Regression standard error	0.123	0.124	0.112	-
Mean of Dependent Variable	4.342	4.334	4.371	-

Notes: Robust T-ratios are given in parentheses below the estimated coefficients. These t-ratios are based on Newey and West (1987) standard errors that are robust to general forms of serial correlation and heteroscedasticity. Stock and Watson (1993) refers to their dynamic least squares procedure recommended to estimate parameters of a cointegrating vector. This procedure entails running a regression on levels with lags and leads of the first differences of all the explanatory variables (the estimated coefficients on these additional terms are not shown). Regression 3 has one first difference term and one lead and one lag of the first difference for each of the two explanatory variables. Johansen (1988) refers to the maximum likelihood estimates of a cointegrating relationship from his vector autoregressive model. The VAR has five lags and there are no trends in either the variables or the data generating process. The maximum sample is 1979:1-1997:1, but there is right and left truncation to allow for the lags and leads.

Table 3

Johansen Test for Cointegration

Null	Alternative	Test Statistic	95% Critical Value	90% Critical Value
r = 0	r = 1	29.02	22.00	19.77
r<= 1	r = 2	5.69	15.67	13.75

Notes: This table reports results from tests for cointegration using Johansen's (1988,1989) vector autoregression procedure. The letter 'r' in the second and third columns stands for the number of cointegrated vectors. The table shows that at the five percent level, the null hypothesis that the number of co-integrating vectors is zero (r=0) is rejected; but the null that the number is less than or equal to one (r<=1) is not rejected. Hence the results support the inference that there is exactly one cointegrating relationship. The variables in the cointegrating relation are the log of the real exchange rate, the log of the export price (Pr) and capital flows. The results are from the maximal eigenvalue test. The estimate of the cointegrating vector is (-1 0.531 0.0312). The likelihood ratio test based on the trace statistic also supported the inference that r=1. The sample is 79:I-97:I.

Table 4. Oil Prices and the Future Peso-Dollar Exchange Rate, 1981

	Current Nominal Exchange Rate	6-month future Exchange Rate	Oil Price Index
January 1991	23.4	26.1	1.00
February	23.5	25.8	1.00
March	23.7	26.1	1.00
April	23.9	26.2	0.97
May	24.1	26.8	0.97
June	24.4	28.1	0.87
July	24.6	31.1	0.91
August	24.8	31.7	0.87

Source: *Indicadores Economicos,* Bank of Mexico, various years.

Table 5

Mexico's equilibrium nominal exchange rate implied by equating wages across countries

	1980	1990
Actual Nominal Exchange Rate	22.95	2810
Equilibrium, calculated with Average wage data in:		
USA	6.30	420
Spain	11.07	580
Greece	18.00	760
Hong Kong	33.41	1350
Republic of Korea	32.63	9700
Singapore	37.61	1050
Bolivia	45.13	5160
Chile	28.22	1890
Costa Rica	30.23	3710
Ecuador	28.22	-
El Salvador	39.05	8910
Paraguay	-	4520
Peru	-	18820
Venezuela	12.90	-

Notes: In order to make the 1980 and 1990 figures comparable, the numbers above do not reflect the currency reform in 1993 when three 0's were eliminated from the Peso. These figures give the level of the Peso/Dollar nominal exchange rate required to equate manufacturing wages between Mexico and each country. For each country I calculate $(w^{mex}/w^{i})*E^{i}$, where w^{mex} is the average wage in Mexico, w^{i} is the average wage in the comparison country, and E^{i} is the nominal exchange rate of the local currency in country "i" versus the dollar. The wage data are average monthly wages in manufacturing and were obtained from various issues of the ILO yearbook.

Table 6. Estimates of a monetary model of Mexico's nominal exchange rate, 1978-1996

Dependent variable: log of the Peso-U.S. dollar nominal exchange rate

Constant	43.29
	(2.82)
m-m*	1.00
i-i*	0.011
	(2.09)
y-y*	-6.74
	(-3.11)
Sample: N=73 (78Q2 - 96Q2)	
Adjusted R^2	0.54
Standard error of the regression	0.47
Mean of dependent variable	-3.51

Notes: The t-ratios in parentheses below the estimated coefficients use Newey and West (1987) standard errors that are robust to general forms of serial correlation and heteroscedasticity.

Table 7. Values of key variables around the time of the 1994 exchange rate crisis

Date	e	m-m*	i-i*	y-y*	p - e
94Q1	1.2119	4.8456	6.6500	6.9884	4.4746
94Q2	1.2214	4.7905	12.0700	6.9866	4.4651
94Q3	1.2250	4.7748	10.5900	6.9875	4.4693
94Q4	1.6724	4.8635	10.0000	6.9814	4.4587
95Q1	1.9195	4.7175	43.7100	6.9591	3.9200
95Q2	1.8420	4.6704	54.7700	6.9425	4.0450
95Q3	1.8593	4.7126	31.1300	6.9349	4.0990
95Q4	2.0337	4.9780	42.0900	6.9601	3.8970

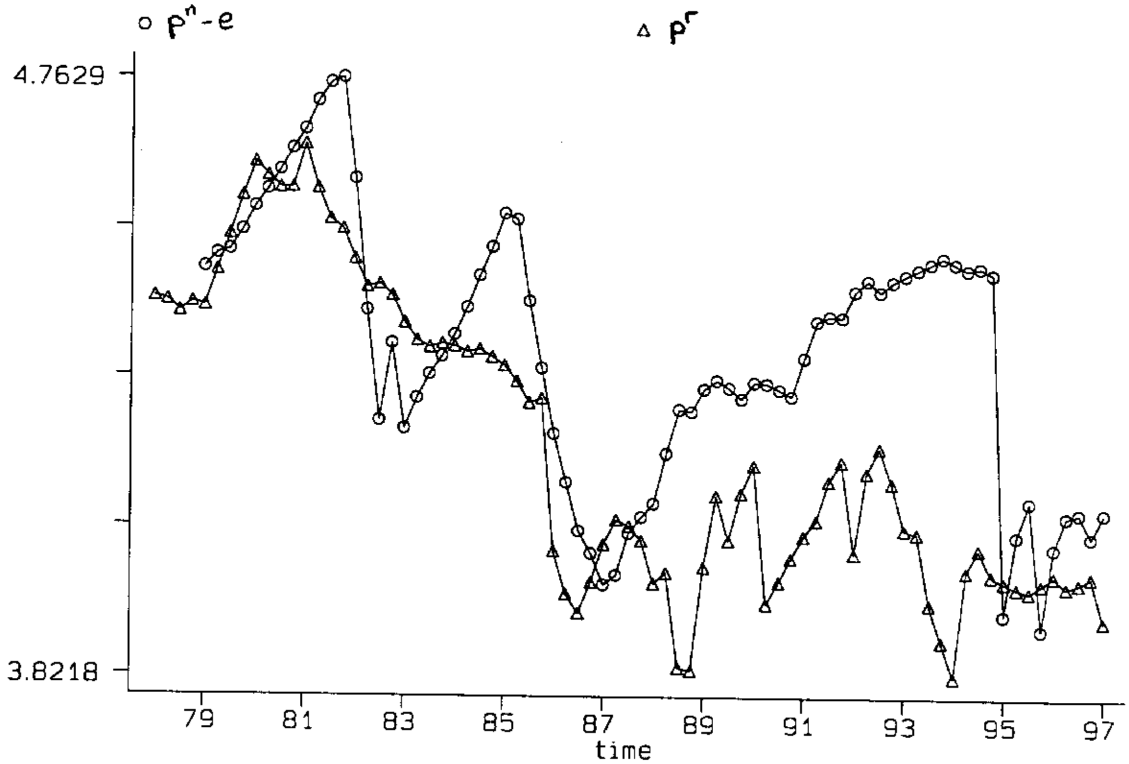


Figure 1

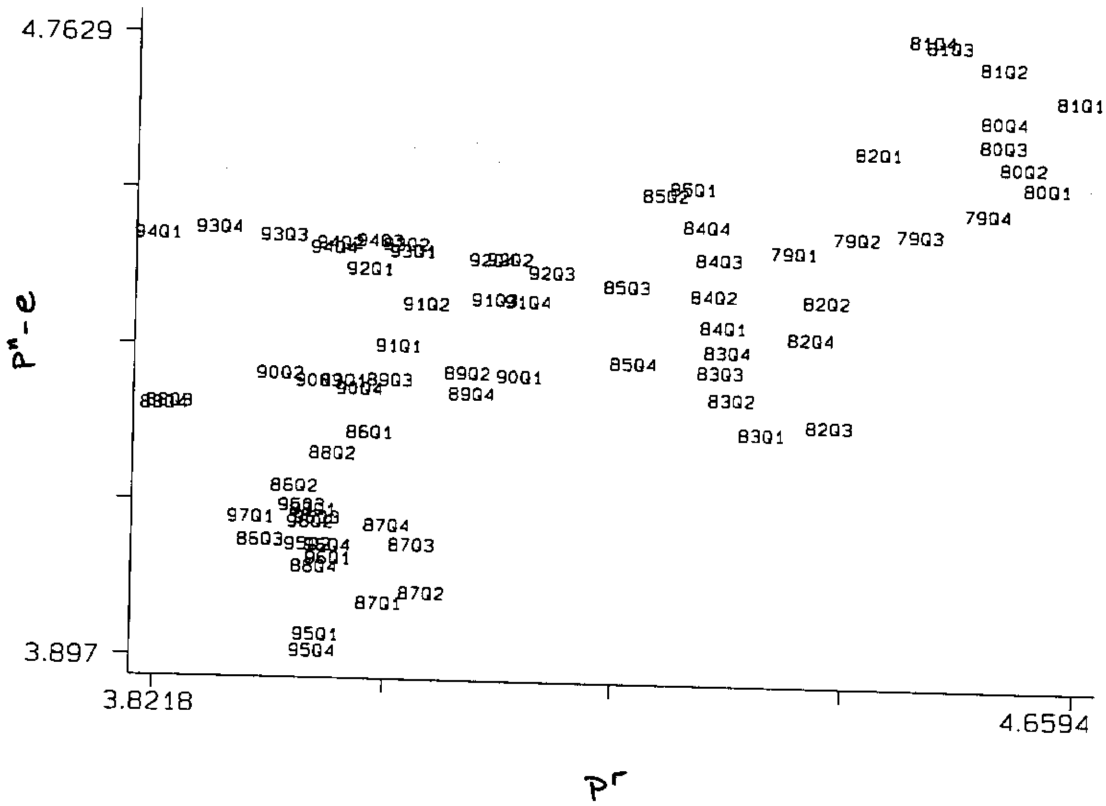


Figure 2

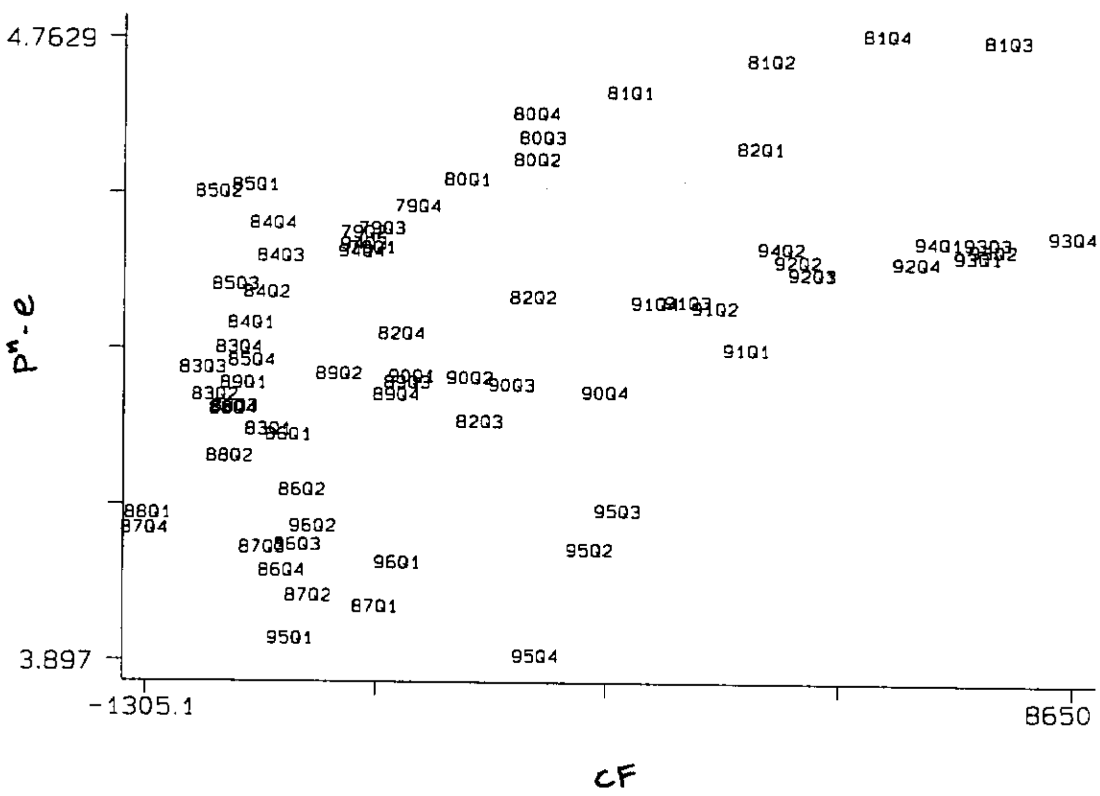


Figure 3

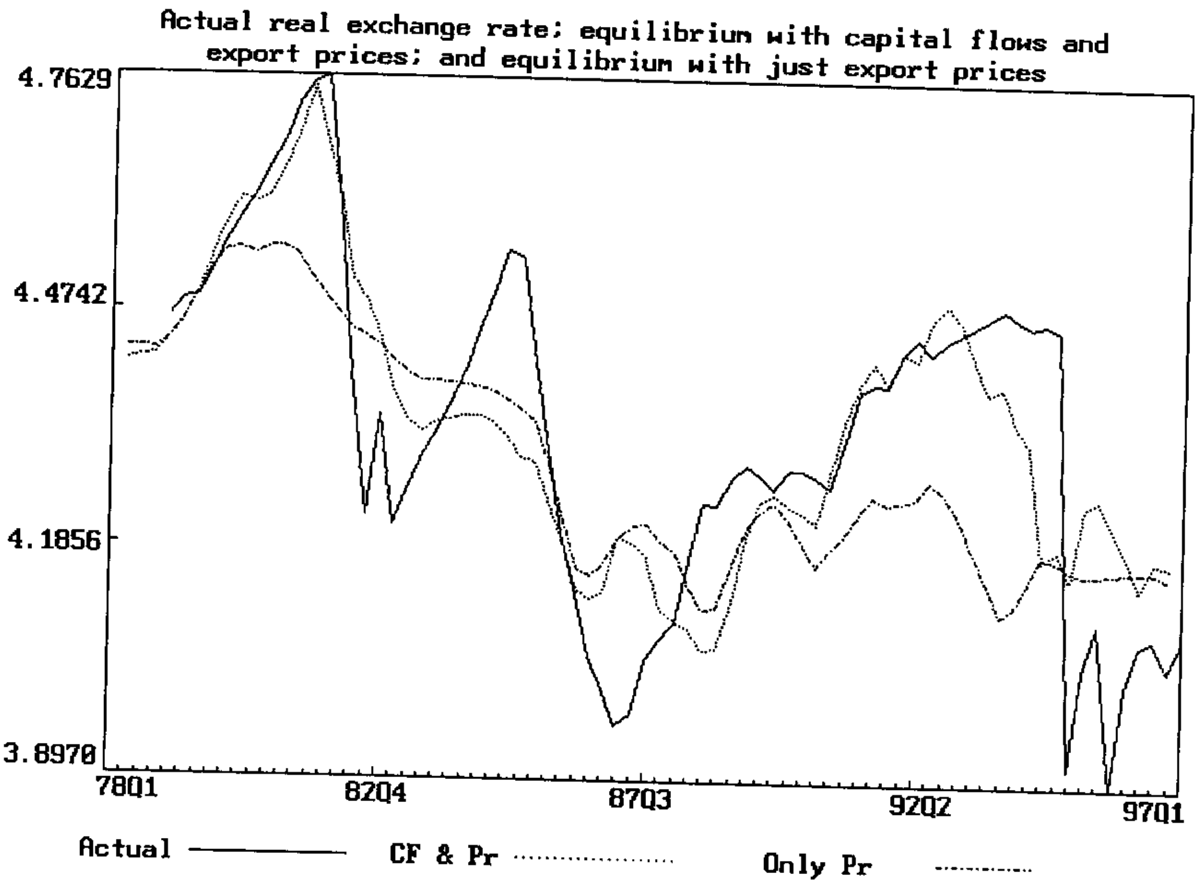

Actual real exchange rate; equilibrium with capital flows and export prices; and equilibrium with just export prices
4.7629
4.4742
4.1856
3.8970
78Q1
82Q4
87Q3
92Q2
97Q1
Actual
CF & Pr
Only Pr

Figure 4

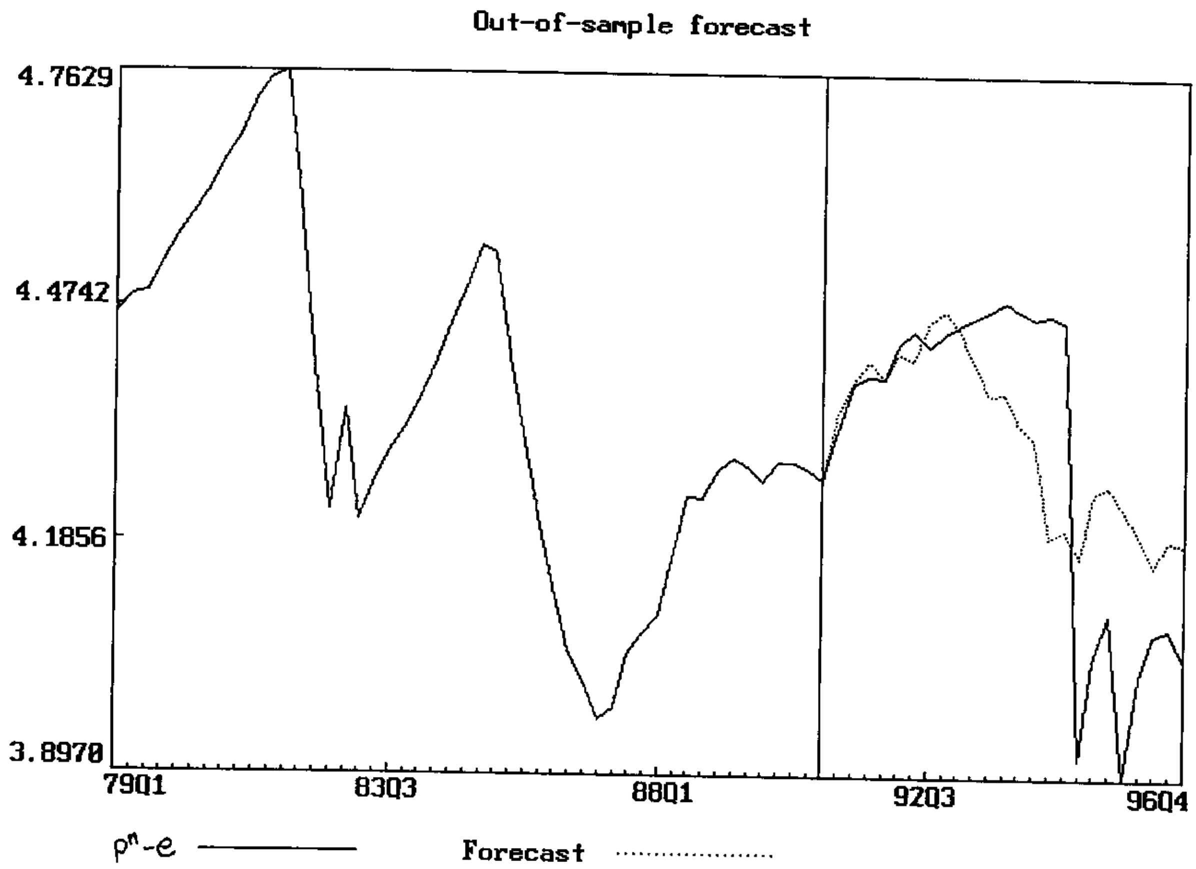

Out-of-sample forecast
4.7629
4.4742
4.1856
3.8970
79Q1
83Q3
88Q1
92Q3
96Q4
p^n-e
Forecast

Figure 5

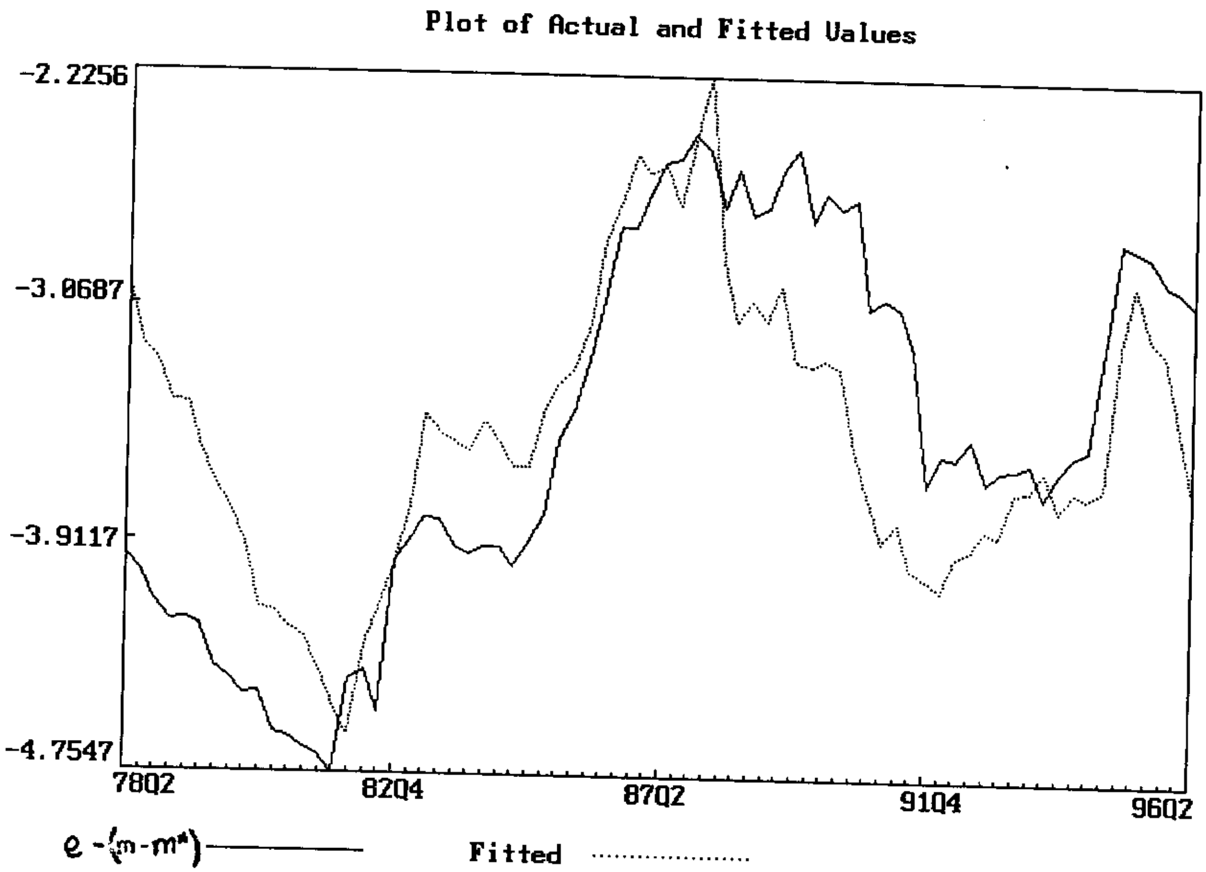
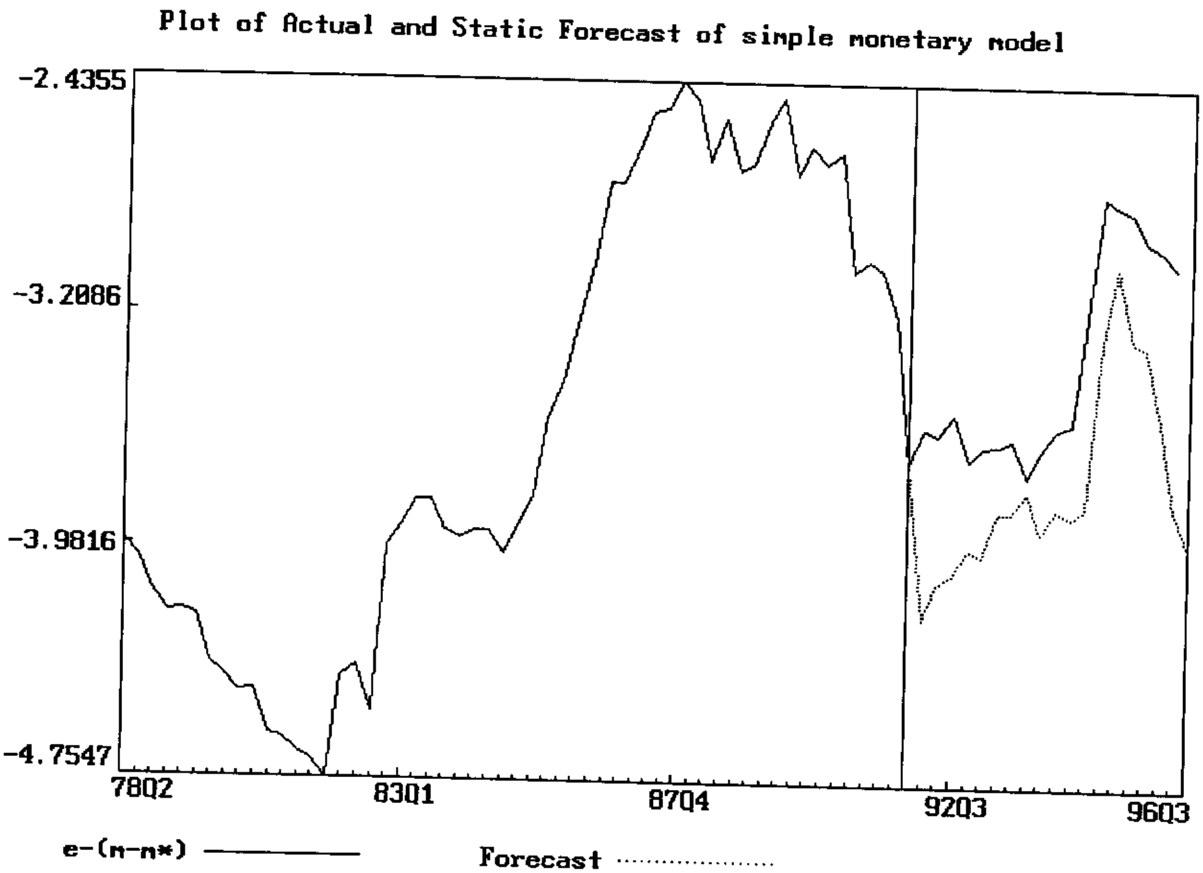

Plot of Actual and Fitted Values
-2.2256
-3.0687
-3.9117
-4.7547
78Q2
82Q4
87Q2
91Q4
96Q2
e -(m-m*)
Fitted

Figure 6



Plot of Actual and Static Forecast of simple monetary model
-2.4355
-3.2086
-3.9816
-4.7547
78Q2
83Q1
87Q4
92Q3
96Q3
e-(m-m*)
Forecast

Figure 7

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