ERROR CORRECTION EXCHANGE RATE MODELING FOR MEXICO: 1980 – 2001

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Abstract
Error correction models are estimated for the nominal exchange rate between the Mexican peso and the United States dollar using quarterly data. Empirical estimation results exhibit weaknesses for all four specifications irrespective of the interest rate variable selected. Dynamic simulation properties of the models also exhibit problems. These results are similar to results obtained in earlier research for the peso using annual frequency data.

Key Words: Nominal exchange rates, Mexico, error correction modeling.
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Introduction

Exchange rate movements, both nominal and real, are frequently at the center of economic debates in many developing countries. In this study, four error correction models are estimated for the nominal exchange rate peso/dollar, using quarterly data for the period

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1980 –2001. Forecast performance is then evaluated against two random walk benchmarks. The error correction models follow traditional balance of payments and monetary constructs. None of them generate levels of accuracy superior to the random walks.

The paper is organized as follows. The second section provides a brief overview of some of the literature available on exchange rate determination and the econometric techniques utilized. In the third section, the theoretical models are introduced. Data and empirical results are reported in the fourth section. The final section summarizes the work.

Literature Review

As discussed in Edwards (1999) exchange rate models based on purchasing power parity (PPP) generally prove to be reliable only in the long run, and, as recognized by Rogoff (1996), long-run and short-run forces may influence the path of the peso/dollar exchange rate. While the availability of larger samples and the development of more powerful statistical tests allows better assessment of long-run equilibrium exchange rates, such models have exhibited large degrees of inaccuracy when confronted with short- and medium-run horizons (Wu and Wu, 2001). Hence, any serious attempt to model exchange rate movements will potentially benefit from taking into account for both short- and long-run determinants.

From an econometric perspective, cointegration and error correction theory suggest that both long-run and short-run factors play important roles in various financial markets (Engle and Granger, 1987; Modeste and Mustafa, 1999). This study attempts to provide some evidence on the implementation of models of such a nature. Four error correction models for the peso/dollar exchange rate, previously developed and tested using annual frequency data (Fullerton, Hattori and Calderón, 2001), are re-estimated using quarterly data for the period 1980-2001. Forecast performances of the models are then evaluated against a simple random walk.

Under the framework provided by Engle and Granger (1987), variables in level form represent long-run forces affecting the dependent variable under study. Short-run behavior is captured by the error correction mechanism built into the model. A principal idea behind the error correction mechanism is simply that a proportion of any disequilibrium from one period is corrected in the next period. The approach is useful since it allows for settings in which information may be incomplete and/or adjustment costs are present.

The models estimated herein draw upon an extensive body of theory that has developed over a long period of time. Early efforts examined the impacts of balance of payment changes on exchange rate dynamics (Dornbusch, 1976; Dornbusch and Fischer, 1980; Blanco and Garber, 1986). Monetary factors also play prominent roles in many of the models that have proven helpful in this area of the discipline (Ortiz and Solís, 1979; Baillie and Selover, 1987; Khor and Rojas-Suárez, 1991).

Theoretical Models

The change in international reserves form one period to another equals the balance of payments. Or, analogically, the sum of the current account, the capital account, and changes in international reserves should equal zero. Given that, the first model, based on the balance of payments approach, considers the effect of international reserves on the exchange rate.

$$S_t = a_0 + a_1(p - p^*)_t + a_2(r - r^*)_t + a_3IR_t + U_t \quad (1)$$

$$dS_t = b_0 + b_1d(p - p^*)_t + b_2d(r - r^*)_t + b_3dIR_t + b_4dS_{t-1} + b_5U_{t-1} + v_t \quad (2)$$

Variable definitions and sources are listed in Table 1. Equation (1) describes the long-run equilibrium peso/dollar exchange rate consistent with the balance of payments approach (Dornbusch and Fischer, 1980). Slope coefficients represent the effects that national price level differences, interest rate differentials, and Mexico's international reserves, respectively, have on the nominal peso/dollar exchange rate. Equation (2) describes short-run behavior of the exchange rate.

Table 1. Variable Definitions and Data Sources

Variable	Definition and Sources
S	Natural logarithm of the nominal exchange rate (new pesos/dollar, quarterly averages. Source: December 2002 IMF *International Financial Statistics CD-ROM*.
p	Natural logarithm, Mexico GDP implicit price deflator, 1993=100, quarterly averages. Source: INEGI, *Sistema de Cuentas Nacionales*.
p*	Natural logarithm, United States GDP implicit price deflator, 1995=100, quarterly averages. Source: December 2002 IMF *International Financial Statistics CD-ROM.*
r_{TB}	3-month Treasury Bill rate, Mexico. Source: December 2002 IMF *International Financial Statistics CD-ROM*. Data for the third quarter of 1986 are from *Cuadernos Mensuales de Información Económica,* Banco de México.
r_{CD}	3-month Certificate of Deposit rate, Mexico. Source: December 2002 IMF *International Financial Statistics CD-ROM*. Data for the first three quarters of 1980 and 1981 are from *Cuadernos Mensuales de Información Económica*, Banco de México.
r_{TB}*	3-month Treasury Bill rate, United States. Source: December 2002 IMF *International Financial Statistics CD-ROM.*
r_{CD}*	3-month Certificate of Deposit rate, United States. Source: December 2002 IMF *International Financial Statistics CD-ROM*.
IR	Natural logarithm, liquid international reserves, Mexico, end of quarter. Source: December 2002 IMF *International Financial Statistics CD-ROM.*
m	Natural logarithm, M1 money supply, Mexico, billions of new pesos. Source: December 2002 IMF *International Financial Statistics CD-ROM*. Data for 1980- 1985 are from *Cuadernos Mensuales de Información Económica*, Banco de México.

m*	Natural logarithm, M1 money supply, United States, billions of dollars. Source: December 2002 IMF *International Financial Statistics CD-ROM.*
y	Natural logarithm, Mexico real GDP, 1993 base year. Source: December 2002 IMF *International Financial Statistics CD-ROM*.
y*	Natural logarithm, United States real GDP, 1996 base year. Source: December 2002 IMF *International Financial Statistics CD-ROM*.
U	Balance of payments approach equilibrium error term.
W	Monetary approach equilibrium error term.
v	Balance of payments approach white noise random disturbance.
z	Monetary approach white noise random disturbance.
d	Difference operator.
t	Time period index.
*	Denotes foreign country variable, United States.

Lagging Equation (1) one period and solving for U_{t-1} yields the following expression:

$$U_{t-1} = S_{t-1} - a_0 - a_1(p - p^*)_{t-1} - a_2(r - r^*)_{t-1} - a_3 IR_{t-1} \qquad (3)$$

Substituting (3) in (2) and rearranging generates the balance of payments error correction equation:

$$dS_t = c_0 + c_1 d(p - p^*)_t + c_2 d(r - r^*)_t + c_3 dIR_t + c_4 dS_{t-1} + c_5 S_{t-1} + c_6(p - p^*)_{t-1} + c_7(r - r^*)_{t-1} + c_8 IR_{t-1} + v_t \qquad (4)$$

where $c_0 = b_0 - b_5 a_0$; $c_i = b_i \ldots i \chi (1, 2, 3, 4, 5)$; $c_6 = b_5 a_1$; $c_7 = b_5 a_2$; $c_8 = b_5 a_3$.

As presented in Fullerton, Hattori, and Calderón (2001), Equation (4) includes the effects of both short-run and long-run forces on (percentage) changes in the peso/dollar nominal exchange rate. Arithmetic signs for the coefficients in Equations (1) and (2) imply certain traits for the parameters in (4). Namely, $c_1>0$, $c_2<0$, $c_3<0$, c_4 ambiguous, $c_5>0$, $c_6>0$, $c_7<0$, and $c_8<0$.

The second theoretical model is based on the monetary approach of exchange rates determination. As in the previous model, long run forces are represented by variables in the level form.

$$S_t = f_0 + f_1(p - p^*)_t + f_2(r - r^*)_t + f_3(m - m^*) + f_4(y - y^*)_t + W_t \quad (5)$$

Expected coefficient signs for equation (5) are $f_1>0$, $f_3=1$, $f_4<0$. As discussed in Fullerton, Hattori, and Calderón (2001), the sign for f_2 is unclear. Depending upon model structure and assumptions regarding price flexibility (rigidity), it can be either positive or negative.

Equation (6) represents the short-run behavior of the exchange rate; the W_{t-1} term captures the effect of both short run and long run forces.

$$\begin{aligned} dS_t = {} & g_0 + g_1 d(p - p^*)_t + g_2 d(r - r^*)_t + g_3 d(m - m^*)_t \\ & + g_4 d(y - y^*)_t + g_5 dS_{t-1} + g_6 W_{t-1} + z_t \end{aligned} \quad (6)$$

Expected signs are $g_1>0$, $g_3>0$, $g_4<0$, g_5 and g_2 ambiguous and $g_6>0$.

If we express equation (5) at time t-1 and rearrange, it yields:

$$W_{t-1} = S_{t-1} - f_0 - f_1(p - p^*)_{t-1} - f_2(r - r^*)_{t-1} - f_3(m - m^*)_{t-1} - f_4(y - y^*)_{t-1} \quad (7)$$

Substituting (7) into (6) the error correction equation for the monetary approach of exchange rate determination is the following:

$$\begin{aligned} dS_t = {} & h_0 + h_1 d(p - p^*)_t + h_2 d(r - r^*)_t + h_3 d(m - m^*)_t + h_4 d(y - y^*)_t \\ & + h_5 dS_{t-1} + h_6 S_{t-1} + h_7(p - p^*)_{t-1} + h_8(r - r^*)_{t-1} + h_9(m - m^*)_{t-1} \\ & + h_{10}(y - y^*)_{t-1} + z_t \end{aligned} \quad (8)$$

Algebraic signs discussed for Equations (5) and (6) also imply certain behavioral traits for the coefficients in (8). Expected arithmetic signs for the parameters include: $h_1>0$, h_2 unknown, $h_3>0$,

$h_4<0$, h_5 ambiguous, $h_6>0$, $h_7>0$, $h_9>0$, and $h_{10}<0$. The expected sign for h_8 is unknown, but is the same as that of h_2.

Subsequent to parameter estimation, a series of out-of-sample simulations are conducted using each of the error correction equations. The simulations are calculated for the 2002-2003 sample period. To assess the reliability of the model-based forecasts, additional extrapolations are generated using simple and drift random walk procedures. Forecast errors from each method are then used to calculate Theil inequality coefficients as a means of quantifying relative simulation accuracy.

Data and Empirical Results

Data for domestic (Mexico) and foreign (United States) market variables are obtained from the December 2003 *International Financial Statistics CD-ROM* database published by the International Monetary Fund. As noted in Table 1, missing observations occur in several quarters for three of the variables included in the sample. In those instances, the missing estimates are calculated using monthly economic indicators published by the central bank research department at Banco de México.

Quarterly data for the 1980-2001 sample period are used in parameter estimation. Results for the monetary approach are fairly weak, while those for the balance of payments models exhibit slightly better econometric traits. Statistical output for the balance of payments model using 90-day Treasury Bill rates appears in Table 2. Balance of payment empirical outcomes with 90-day Certificates of Deposit rates are shown in Table 3. Monetary model estimates, also using the 90-day T-Bill and CD rates are summarized in Tables 5 and 5, respectively. Table 6 examines out-of-sample simulation accuracy of the four equations relative to simple and drift random walk benchmarks for 2002 and 2003. Theil inequality measures are employed for the latter exercise (Pindyck and Rubinfeld, 1998).

Estimation results shown in Table 2 for the balance of payments approach using 90-day T-Bill rates are substantially more satisfactory than those reported using annual frequency data in Fullerton, Hattori, and Calderón (2001). In the cases of three model coefficients, however, counter-intuitive arithmetic signs are obtained. In two other cases, although the estimated parameters exhibit the expected algebraic signs, they do not satisfy the 5-percent significance criterion. Given the size of the F-statistic, however, plus the number of right-hand-side variables, multicollinearity may be playing in a role in the cases of the small t-statistics. Although the dependent variable has been differenced prior to modeling, the equation still obtains a relatively high coefficient of determination, 0.62.

Table 2 Balance of Payments Estimation Results using 3-month Treasury Bill Rate.
Sample: 1980Q1 – 2001Q4. Included observations: 86 after adjusting endpoints for lags and differences.

Regressor	Coefficient	Std. Error	t-Statistic	Prob
Constant	0.566723	0.131446	4.311465	0.0000
$d(p - p^*)_t$	0.796849	0.232016	3.434455	0.0010
$d(r_{TB} - r_{TB}^*)_t$	0.003829	0.000916	4.178068	0.0001
dIR_t	-0.038577	0.035176	-1.096665	0.2762
dS_{t-1}	-0.118527	0.097854	-1.211257	0.2295
S_{t-1}	0.0001	-0.327779	0.081544	-4.019676
$(p - p^*)_{t-1}$	0.361521	0.089943	4.019462	0.0001
$(r_{TB} - r_{TB}^*)_{t-1}$	0.003088	0.000812	3.802007	0.0003
IR_{t-1}	-0.072298	0.022207	-3.255694	0.0017
R-squared	0.622859	Mean dependent var.		0.071356
Adjusted R-squared	0.583676	Std. Dev. dependent var.		0.115309
Std. Err. regression	0.074401	Akaike info. criterion		-2.259941
Sum squared resid.	0.426231	Schwarz info. criterion		-2.003090
Log likelihood	106.1775	F-statistic		15.89599
Durbin-Watson stat.	1.926049	F-statistic Probability		0.000000

Table 3 reports estimation results for the balance of payments specification using 90-day CD rates. Once again, these results are generally favorable, albeit with some empirical flaws. As with its T-Bill counterpart equation, both of the interest rate regression coefficients and the parameter for the one-period lag of the exchange rate logarithm exhibit counter-intuitive signs. Two other parameters are statistically insignificant at the 5-percent level. Given the overall goodness of fit, the latter may be a consequence of multicollinearity and probably does not represent a fatal obstacle for the model.

Table 3. Balance of Payments Estimation Results using 3-month Certificate of Deposit Rate.
Sample: 1980Q1 – 2001Q4. Included observations: 86 after adjusting endpoints for lags and differences.

Regressor	Coefficient	Std. Error	t-Statistic	Prob
Constant	0.668867	0.141687	4.720742	0.0000
$d(p - p^*)_t$	0.798105	0.229890	3.471681	$_t$0.0009
$d(r_{TB} - r_{TB}^*)_t$	0.004768	0.001221	3.905342	0.0002
dIR_t	-0.061982	0.034903	-1.775807	0.0797
dS_{t-1}	-0.150098	0.096929	-1.548531	0.1256
S_{t-1}	-0.369547	0.084053	-4.396569	0.0000
$(p - p^*)_{t-1}$	0.418519	0.094640	4.422243	0.0000
$(r_{TB} - r_{TB}^*)_{t-1}$	0.004196	0.000994	4.221490	0.0001
IR_{t-1}	-0.087035	0.023127	-3.763338	0.0003
R-squared	0.627010	Mean dependent var.		0.071356
Adjusted R-squared	0.588258	Std. Dev. dependent var.		0.115309
Std. Err. regression	0.073990	Akaike info. criterion		-2.271007
Sum squared resid.	0.421540	Schwarz info. criterion		2.014157
Log likelihood	106.6533	F-statistic		16.17999
Durbin-Watson stat.	1.916050	F-statistic Probability		0.000000

Estimation results for the monetary specification using 90-day T-Bill rates are summarized in Table 4. A variety of problems are observed therein. Perhaps the most disconcerting is that fully half of the coefficients exhibit counterintuitive algebraic signs. That pattern also emerges in the parameters shown in Table 5 for the monetary model using the 90-day CD rates. Given these outcomes, the error correction monetary equations do not seem to hold very much promise for modeling the exchange rate in Mexico using quarterly data.

Table 4. Monetary Model Estimation Results using 3-month Treasury Bill Rate.
Sample: 1980Q1 – 2001Q4. Included observations: 86 after adjusting endpoints for lags and differences.

Regressor	Coefficient	Std. Error	t-Statistic	Prob
Constant	1.272914	0.651681	1.953278	0.0545
$d(p - p^*)_t$	0.569789	0.284856	2.000275	0.0491
$d(r_{TB} - r_{TB}^*)_t$	0.004493	0.001030	4.362646	0.0000
$d(m - m^*)_t$	-0.015689	0.112351	-0.139644	0.8893
$d(y - y^*)_t$	0.284686	0.346172	0.822382	0.4135
dS_{t-1}	-0.119750	0.114892	-1.042279	0.3006
S_{t-1}	-0.193133	0.101239	-1.907685	0.0603
$(p - p^*)_{t-1}$	0.261703	0.141470	1.849890	0.0683
$(r_{TB} - r_{TB}^*)_{t-1}$	0.002988	0.000982	3.041829	0.0032
$(m - m^*)_{t-1}$	-0.049614	0.056111	-0.884213	0.379
$(y - y^*)_{t-1}$	0.698693	0.431715	1.618413	0.1098
R-squared	0.585943	Mean dependent var.		0.071356
Adjusted R-squared	0.530735	Std. Dev. dependent var.		0.115309
Std. Err. regression	0.078990	Akaike info. criterion		-2.120043
Sum squared resid.	0.467953	Schwarz info. criterion		-1.806115
Log likelihood	102.1619	F-statistic		10.61344
Durbin-Watson stat.	1.968920	F-statistic Probability		0.000000

Table 5. Monetary Model Estimation Results using 3-month Certificate of Deposit Rate.
Sample: 1980Q1 – 2001Q4. Included observations: 86 after adjusting endpoints for lags and differences.

Regressor	Coefficient	Std. Error	t-Statistic	Prob
Constant	0.941279	0.627614	1.499773	0.1379
$d(p - p^*)_t$	0.679508	0.283699	2.395172	0.0191
$d(r_{TB} - r_{TB}^*)_t$	0.005317	0.001388	3.829702	0.0003
$d(m - m^*)_t$	-0.065161	0.116631	-0.558690	0.5780
$d(y - y^*)_t$	0.274334	0.352702	0.777808	0.4391
dS_{t-1}	-0.103019	0.114931	-0.896351	0.3729
S_{t-1}	-0.221742	0.105782	-2.096209	0.0394
$(p - p^*)_{t-1}$	0.303896	0.146616	2.072727	0.0416
$(r_{TB} - r_{TB}^*)_{t-1}$	0.003080	0.001101	2.797084	0.0065
$(m - m^*)_{t-1}$	-0.063002	0.057099	-1.103373	0.2734
$(y - y^*)_{t-1}$	0.487996	0.422398	1.155299	0.2516
R-squared	0.567269	Mean dependent var.		0.071356
Adjusted R-squared	0.509572	Std. Dev. dependent var.		0.115309
Std. Err. regression	0.080751	Akaike info. criterion		-2.075931
Sum squared resid.	0.489058	Schwarz info. criterion		-1.762003
Log likelihood	100.2651	F-statistic		9.831793
Durbin-Watson stat.	1.961838	F-statistic Probability		0.000000

In addition to the estimation weaknesses outlined in the preceding paragraphs, out-of-sample simulation results for all of the error correction models also exhibit empirical shortcomings. As shown in Table 6, the Theil U-statistics for all four of the error correction models indicate that their respective forecast performances are less accurate than those provided by two random walk alternatives (Pindyck and Rubinfeld, 1998). Besides high levels of inaccuracy, the simulations are also biased. Those outcomes are reminiscent of earlier exchange rate forecast studies that uncover out-of-sample simulation difficulties (Meese and Rogoff, 1983). They are also comparable to the results obtained for Mexico using annual frequency data by Fullerton, Hattori, and Calderón (2001).

Table 6. Theil Inequality Forecast Accuracy Coefficients.
Sample: 2002Q1 – 2003Q4

Model	Theil U	Bias Prop	Variance Prop	Covariance Prop
Balance Payments 90-Day T-Bill Rate	0.2163	0.8220	0.0021	0.1758
Balance Payments 90-Day CD Rate	0.1433	0.7544	0.0287	0.2169
Monetary 90-Day CD Rate	0.1085	0.6380	0.0165	0.3455
Random Walk Last Observation	0.1052	0.6841	0.0002	0.3157
Random Walk Drift	0.1082	0.0001	0.3978	0.6021

Conclusion

This paper re-estimates four previously developed error correction models for the nominal exchange rate peso/dollar using quarterly data. The models are based on balance of payments and monetary approaches of exchange rate determination. The error correction framework offers an attractive platform for analyzing the peso due to its ability to simultaneously handle both short- and long-term financial dynamics. Data requirements are not excessive, allowing estimation to occur even for developing economies where information is limited.

Estimation results for both theoretical approaches are superior to what has previously been reported for Mexico using annual frequency data. While that is encouraging, all four error correction equations also included coefficients that exhibit counterintuitive arithmetic signs. Econometric imperfections do not always translate into simulation ineffectiveness (the converse also holds). Accordingly, a series of out-of-sample simulations are utilized to examine model reliability. In no case do any of the estimated equations generate forecasts that are more accurate than those associated with comparative random walk benchmarks.

Evidence to date suggests that error correction balance of payment and monetary models for the peso/dollar exchange rate are not very reliable using annual and quarterly data. These results do not, however, preclude additional tests employing monthly frequency data. Of course, data constraints may shorten the sample period, inadvertently jeopardizing the statistical power of the long run features of the model. Surrogates for the real GDP and implicit price deflator variables would also be required. Fortunately, industrial production and consumer price index series are available for Mexico and most other developing economies. Given the results obtained thus far, the likelihood of acceptable error correction modeling and simulation performances for the peso does not appear to be very high.

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