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THE REAL EXCHANGE RATE PROCESS AND ITS REAL EFFECTS: THE CASES OF MEXICO AND THE USA

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Exchange rate management is a salient macroeconomic issue, especially in developing countries. In this paper, we study political economy factors that may affect the real exchange rate (RER) process and the real economic effects of the RER. We review recent literature on the effects of elections on the exchange rate, and adapt Ball's (1992) model to show that uncertainty about the future course of policy may make more appreciated RER's less predictable. We also review the literature on the real effect of RER appreciations and of RER uncertainty. We then construct a simultaneous GARCH-M model of the joint determination of the RER and output capable of testing our hypotheses simultaneously in a single model. We estimate the model using data first from Mexico, a developing country, and the US. In Mexico we find that elections significantly affect the evolution of the RER, that more appreciated RERs are less predictable, that RER depreciations lower output growth and that RER uncertainty lowers output growth, even when controlling for its well-studied effect on trade. By contrast, none of these effects are found in the US data.

JEL classification codes: F3, F4, O42
Key words: real exchange rate volatility, economic growth, electoral cycle

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I. Introduction

One of the most important challenges facing developing nations is the choice and maintenance of an exchange rate regime. This issue is most often framed as a choice between fixed and flexible exchange rates, but from a macroeconomic standpoint, the exact nominal regime chosen is only a means to an end. What really matters is how that choice interacts with other policies to influence the behavior of the real exchange rate.

Fixed nominal rates can initially provide an effective nominal anchor against inflation, but over time, the chosen parity can become economically inappropriate, affecting the real exchange rate and inviting speculative attacks that end in large nominal devaluations to reset the real exchange rate to a sustainable level. At the other extreme, freely floating exchange rates are often thought to create excessive short-term fluctuations unrelated to economic fundamentals that cause corresponding harmful fluctuations in the real exchange rate. In an ideal world, policymakers would strive for a policy mix that delivers a real exchange rate consistent with internal and external balance, and exhibits an appropriate degree of predictability. However, in the developing world, this largely remains an un-achieved ideal, as exchange rate crises are still prevalent.

In this paper we develop a statistical model to study three important questions about real exchange rate (RER) behavior. The first question involves political influence on the RER. Specifically, we test for a detectable electoral cycle in the RER. There is a growing literature about political influence on exchange rates in an open economy, and some evidence that depreciations are correlated with elections, but little in the way of testing for a cycle. We investigate whether, on average, the RER appreciates significantly before elections and then depreciates afterward.

The second question under consideration in this paper is: Are more appreciated levels of the RER less predictable? Ball (1992) argues that when the preferences of the policymaker are private information, higher inflation rates are associated with greater uncertainty about future inflation because one must factor in the probability of a stabilization effort from a tough policymaker. We adapt this reasoning to the RER and test whether more appreciated RERs raises the conditional variance of the real exchange rate.

While statistically distinct, these two potential political economy effects on the RER process are closely related in that both work through imperfect information about the preferences or the competence of the policymaker. That is, the theoretical models behind either an electoral cycle in the RER or a link between high RER's and uncertainty about future RER movements are driven by the fact that the public does not have complete information on the policymaker.

The third question investigated is: What is the effect of the RER process on output, controlling for trade? Many studies examine the relationship between exchange rate volatility and trade, but to date, no one has investigated whether, controlling for trade effects, RER uncertainty significantly affects output growth. We also provide evidence on whether a depreciating real exchange rate is expansionary, as in textbook models, or contractionary as others argue.

We simultaneously test all of these hypotheses in a single multi-variate GARCH-M model of output and the real exchange rate, using data from a developing country (Mexico) and a developed country (the USA). We argue that Mexico is much more likely to be affected by the phenomena under study as it largely conforms to the assumptions of the underlying models, while the USA, which does not conform well to these assumptions, is included for comparison.

There are only several empirical papers only related to ours. Arize (1997) and Maloney and Azevedo (1995) estimate the conditional variance of the exchange rate with a GARCH model and then use that variance as a regressor in a second stage regression. As Kroner and Lastrapes (1993) show, this empirical methodology (two stage regression) obtains biased estimators. Instead, Kroner and Lastrapes (1993) use multivariate GARCH-M methods to investigate the RER uncertainty-trade link in five industrialized countries. This methodology is simultaneous, thus unbiased estimators are obtained. Cottani, Cavallo, and Khan (1990) examine the correlation between RER volatility and economic growth in a cross sectional analysis; however they do not consider that volatility may vary over time and only use a single variance figure for each country. Finally, Mendoza (1997) examines the cross-sectional relationship between terms of trade volatility and growth, using single variance estimators in the cross section model.

Our paper is unique in that it uses a multivariate GARCH-M model of economic growth and the RER, and tests for political economy influences on the RER process. This methodology addresses the possibility that volatility may change over time, which makes it possible to study our different hypotheses. However, the literature just revised is a good source to motivate them. In a way the literature still has yet to provide with a theoretical model that relates RER uncertainty with growth.

Our results are as follows. First, there is strong evidence of an electoral cycle in the Mexican RER. The RER is significantly more appreciated than trend during the year leading to an election, and significantly more depreciated than trend in the following year. Second, we find that lagged values of the RER are positive and significant in the RER conditional variance equation, confirming our version of Ball's model for Mexico. More appreciated RERs generate greater uncertainty about future values of the RER. Taken together, these two results imply that uncertainty about the policymaker plays an important role in the Mexican RER process. In contrast, the results for the US do not show any evidence of either an electoral cycle or a positive relationship between overvaluation and RER predictability.

Third, controlling for the direct effect of trade on growth, the level of the RER has a positive and significant coefficient in the Mexican industrial production growth equation, while RER uncertainty is a negative and significant influence on industrial production growth. The US industrial production growth equation produces the same coefficient signs, but at much lower significance levels.

The paper is organized as follows. Section II contains a brief review of the macroeconomic importance of the real exchange rate. Section III reviews the existing literature on electoral influence on exchange rates, section IV adapts Ball's model of inflation and inflation uncertainty to the real exchange rate and section V discusses the linkage between real exchange rate uncertainty and economic performance. Section VI explains our choice of Mexico and the US for testing our hypotheses, describes the general statistical model we use, and presents the exact specification of the model for each case. Section VII presents our empirical results and section VIII concludes.

II. Nominal ER Regimes and the RER

The traditional views of the benefits from an exchange rate peg are (1) that it imparts stability, which is beneficial for international trade, and (2) that it provides discipline for a country's domestic policymakers.[1] Countries with a history of loose monetary or fiscal policies can import the policies of the country to which they peg. However, it is becoming widely appreciated that most ER pegs end in crisis and devaluation, and it is more and more frequently argued that, at least in the short run, an ER peg does not effectively constrain domestic policy makers. When the ER peg is held in place, even when domestic policies are too loose we see an RER appreciation, meaning cheaper imports, a consumption boom and a loss of competitiveness for the country's exports. This situation cannot go on forever. There will have to be a significant tightening of domestic policies, or more likely, a change in the nominal peg.[2] A not un-typical scenario in the developing world is, an announced systematic lowering of the peg, followed by an inability to defend the new policy that leads to a period of floating followed by the initiation of another, lower, peg.

From an economic point of view, market participants desire predictability of real values, or relative prices. However, it is not historically obvious that a fixed nominal exchange rate produces a fixed, or even easily predictable, real exchange rate, especially in the developing world. And it is precisely in the developing world where predictability is most valued, because the ability to hedge risk in with financial derivatives is generally quite limited.

Short run RER targeting, as practiced by Chile, involves repeated adjustments to the nominal exchange rate. It is, however, controversial to assume that the RER is directly under the control or even influence of the policymaker.[3] It is important to note that none of the phenomena under study in this paper requires that the policymaker can permanently target the RER.

III. Elections and the RER

Recently, Stein and Streb (1998) and Bonomo and Terra (1999b) have

[1] See Stockman (1999) for a discussion of new developments in the study of exchange rate regime choice.

[2] See Goldfajn and Valdés (1999).

[3] Calvo, Reinhart, and Végh (1995) study the possibilities for, and macroeconomic effects of, RER targeting.

developed distinct models that can produce electoral cycles in exchange rates. In Stein and Streb, politicians can signal their competence by temporarily slowing the rate of currency depreciation below its sustainable level before elections. This strategy requires a rise in the rate of depreciation after the election. Ghezzi, Stein and Streb (2000) extend this opportunistic model to generate real exchange rate cycles. For our purposes, the important feature of the Ghezzi, Stein and Streb model is that it implies an RER appreciation pre-election and an RER depreciation afterward.

Bonomo and Terra directly model the RER. Politicians are either agents of the tradable or non-tradable sector and the non-tradable sector has a majority of voters. Producers in the tradable sector, ceteris paribus, prefer a lower RER while non-tradable producers, and consumers favor an appreciated RER. The type of the policymaker is private information, which provides an incentive to signal that she is aligned with the non-tradable sector before the election by producing an appreciated RER.

There is some direct and indirect empirical evidence about the behavior of real exchange rates around elections. Ghezzi, Stein and Streb (2000) present direct evidence of an exchange rate electoral cycle in a cross country study based on 26 Latin American and Caribbean countries, while Bonomo and Terra (1999a) and Pascó-Fonte and Ghezzi (2001) portray similar evidence for Brazil and Peru, respectively.

Klein and Marion (1997) study the duration of exchange rate pegs in Latin America, finding that a transfer of power in the executive branch raises the probability that a peg will be abandoned. If we assume that the peg is abandoned in order to devalue, and that the devaluation was warranted before the election, then this finding is consistent with the idea that the RER is appreciated pre-election and depreciated post-election.[4] Similarly, Edwards (1993) shows that under democratic governments, large devaluations are more likely to occur early in a government's tenure. Finally, Stein and Streb study depreciation rates rather than discrete devaluations and find that they are notably larger immediately after elections than immediately before.

We will test the hypothesis of electoral effects on the RER directly by

[4] Similarly, Gavin and Perotti (1997) show that the probability of a switch from a fixed to flexible ER regime rises after elections.

creating an electoral dummy variable, including it in the RER equation, and examining its statistical significance.[5] Our variable takes the value +1 in the 12 months leading up to a presidential election, -1 the 12 months following an election, and 0 in all other months.

IV. Does a More Appreciated RER Create More Uncertainty?

It is plausible that high RERs are less predictable and therefore create more uncertainty. Here we give a simple example of how this might be the case. The argument is adapted from Ball's (1992) model of how higher inflation creates more inflation uncertainty.[6]

We assume that a prolonged RER appreciation hurts the export sector, creating political pressure to adjust the nominal exchange rate. However, the public does not know whether the policymaker is *tough* and will never devalue or is *soft* and will devalue in response to political pressure. When the RER is sufficiently low, neither type of policymaker will act to change it, but when the RER is sufficiently high, a *soft* policymaker will devalue. Thus with a given policymaker of unknown type, the probability of a devaluation rises with the level of the RER (even if the policymaker is actually tough).[7]

Even once a policymaker's type is known, there can still be greater uncertainty with a high RER if we assume that policymakers change randomly over time. With a low RER, the type of the new policymaker is not currently important because neither type will intervene. However, with a high RER, the type of the new policymaker is important because one will maintain the *status quo* and the other will intervene. The possibility of a future devaluation rises, ceteris paribus, as the level of the RER rises, meaning that uncertainty about the future RER is a positive function of the current level of the RER.

In our empirical work, we examine this hypothesis by including the lagged

[5] Of course, this will be a joint test of the validity of our electoral variable and the significance of electoral effects.

[6] For empirical evidence on the relevance of Ball´s model, see Grier and Perry (1998) who find strong link between higher inflation and greater uncertainty in each of the G-7 countries.

[7] Goldfajn and Valdés (1999) show that appreciations have a longer duration in the build up than in the return phase and are more likely to occur in fixed exchange regimes.

level of the RER in the equation for the conditional variance of the RER, testing whether appreciated RERs in the past are associated with less predictable RERs in the present.[8]

V. The RER Process and Economic Growth

We have identified above two political economy effects on the RER process. In this section we consider the real effects of the RER process (both the mean and conditional variance) on economic growth. In the textbook open economy macro model, real depreciations are growth enhancing. They stimulate the external demand for a country's exports and increase the internal demand for the country's products relative to imported goods. However, there is a growing literature arguing that, especially in developing countries, real depreciations can be contractionary.[9] One of the main channels whereby a devaluation can be contractionary is through its effect on domestic firms' costs. If firms rely on imported inputs a real depreciation raises their costs. A second important channel is through a real depreciations effect on external debt, and the solvency of firms. We will test for the effect of RER fluctuations on growth by including the lagged RER in our output growth equation.

Many papers also derive a link between RER uncertainty and exports. These papers generally rely on risk adverse exporters with limited portfolio diversification and imperfect hedging opportunities to create an RER uncertainty-export linkage.[10] That is, a risk adverse exporting firm that maximizes the expected utility of profits is found to reduce its output when the degree of unhedgeable exchange rate risk rises.

Here we extend this reasoning to non-exporting firms by noting that their

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[8] The empirical validity of this theoretical argument is also indirectly supported by the findings of Goldfajn and Valdés, who show that large appreciations are almost always followed by nominal devaluations.

[9] Agenor and Montiel (1996) provide a comprehensive theoretical discussion of this issue in chapter 7. Interest in the possibility of contractionary devaluations sprang from influential papers by Cooper (1971) and Krugman and Taylor (1978).

[10] Côté (1994) provides an excellent survey on the relationship between exchange rate volatility and trade from both theoretical and empirical points of view.

profits may also be affected by exchange rate swings if they have costs that are denominated in a different currency than their revenues. A risk averse, imperfectly competitive firm who sells domestically, but either imports productive inputs or has foreign currency denominated loans also faces exchange rate risk. If that risk cannot be hedged, then the firm's production decision will be affected in an analogous manner to the firm with domestic currency costs but foreign currency revenues that is typically considered.

We thus believe that exchange rate uncertainty can affect overall national output and not just the volume of exports.[11] We will test for the real effects of RER uncertainty by including the estimated conditional variance of the RER as an explanatory variable in the output growth equation of our simultaneous GARCH-M model. To establish that the effect of RER uncertainty on output growth is general and not confined to its effect on exports, we will include export growth as an explanatory variable in the model. In this manner, only the portion of RER uncertainty that is uncorrelated with export growth will be allowed to influence output growth.

VI. Empirical Application

A. Choice of Countries

We are simultaneously testing for the existence of political economy effects on the RER process and real effects of the RER process on growth. The political economy models are driven by uncertainty about the policymaker, while the real effect of the RER process on growth depends on an economy having limited hedging potential, undiversified producers, and significant external debt or imported inputs. We therefore seek a country that

[11] Mendoza (1997) provides a theoretical model of the link between terms of trade uncertainty and economic growth. He considers a stochastic, one sector, endogenous growth model with a representative, risk adverse, agent. He assumes that the agent cannot insure against fluctuations in the return to savings denominated in the price of imported goods (which is what is consumed in the model). He then shows that increased terms of trade uncertainty can either raise or lower average growth rates depending on the degree of risk aversion extant. With a low (high) level of risk aversion, increased uncertainty will lower (raise) growth. The welfare effects of increased uncertainty, though, are unambiguously negative.

both has some intrinsic interest for study and conforms to the preconditions listed above.

Our choice is Mexico. It is an important developing country, which provides the intrinsic interest, and it conforms well to the above preconditions. Consider the assumption of uncertainty about the policymaker. There has been significant uncertainty about exchange rate policy in Mexico. Over our sample period Mexico has used a crawling peg, an exchange rate band, a peg to the dollar, a more or less free float, and are currently debating dollarization! Typically, changes from one regime to another are prompted or accompanied by a crisis.[12]

Mexico is also a good fit with respect to the assumptions necessary for real RER effects on economic growth. First, the Peso futures market began trading in March of 1995, indicating that hedging opportunities were attenuated over almost all our sample period.[13] Second, Mexican businesses import a large share of their inputs, heightening the sensitivity of their profits to exchange rate fluctuations. Between 1970 and 1997, the average composition of Mexican imports was 19.5% capital goods, 70.7% intermediate goods, and only 9.7% consumer goods.[14] Third, many large Mexican firms are closely held, meaning that owners are not well diversified and can be expected to be risk averse with respect to their own firms' profits. For example, La Porta, Lopez-de-Silanes, Shleifer, and Vishny (1996) show that in their sample of 49 countries, the average percentage of common stock held by the 3 largest private shareholders in the 10 largest firms is 40%. In contrast the figure for Mexico is 64%, which is the highest concentration in the sample.[15]

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[12] While it is true all Mexican presidents of the last 70 years have come from the same political party until the year 2000, they have had widely varying policy aims. See Grier and Grier (2000) for a discussion of the uncertainty created by presidential change in Mexico.

[13] During the 1980s some Peso forwards, called Coberturas, existed in México. These were OTC instruments and were mainly used for interbank hedging. That is, they were poorly utilized by manufacturing firms (see Chesney, Hernández & Marois, 2000).

[14] Source: Secofi (http://www.inegi.gob.mx/). As it may be noted, intermediate and capital goods accounted for approximately 80 per cent of total imports during the period under study. Moreover, 60 per cent of these two types of imports can be strictly assigned to the manufacturing sector (see Máttar and Peres, 1999).

[15] See their Table 10, column 2, for details.

We also study a country where fewer of the prerequisites hold, and see if any of the results found in the case of Mexico change when the type of country under consideration changes. We thus repeat our analysis using the US, a country that has a more consistent exchange rate regime, greater hedging opportunities and more diversified corporate ownership.

B. Statistical Preliminaries

In order to properly estimate any relationship between the real exchange rate process and output, we must determine the order of integration of the series, choose models for each series, and then construct a simultaneous MGARCH-M system capable of testing our hypotheses. In this section we consider each of these necessary steps. The data used here are the Mexican real exchange rate[16] with a base year of 1990 obtained from J. P. Morgan, industrial production indices for Mexico and the US taken from the IMF and Citibase respectively, and real exports for Mexico, also from the IMF.[17] All data is expressed as monthly observations and the period under study is 1970.01 to 1998.12.

B.1. Order of Integration

Consider first the order of integration of our four series. The case for Mexican industrial production is straightforward. Augmented Dickey Fuller (ADF) tests with a linear trend and anywhere from 1 to 12 lagged differences never reject the null hypothesis of a unit root in the level of industrial production. However, the unit root hypothesis can always be rejected with ADF tests from 1 to 12 lagged differences for the growth rate. Mexican Industrial production is not trend stationary, but rather is clearly integrated of

[16] This real exchange rate is computed using Consumer Price Index and P* with respect to 111 countries.

[17] The Appendix contains summary statistics for the variables. US industrial production was obtained seasonally adjusted, and the Mexican series were seasonally adjusted using the procedure in the EVIEWS software package.

order one [I(1)]. Similar results are obtained for US industrial production, and real Mexican exports.[18]

However, the case of the Mexican real exchange rate is different. While several studies have shown that nominal exchange rates are random walks, our series for the Mexican RER rate is trend stationary. ADF tests using a linear trend and from 1 to 12 lagged differences reject the null of non-stationarity 10 of 12 times. The non-rejections come with lags of 3 or 4 difference terms. An inspection of the correlogram for the real exchange rate reveals that the most logical selections of a lag length would be 5 or 9 lags. Therefore we proceed with a model where the conditional variance of the exchange rate potentially affects the growth rate of industrial production, and where a linear trend term belongs in the exchange rate equation.

B.2. Granger Causality between the RER and Output Growth

We need to capture any relevant relationship between the mean of the real exchange rate and industrial production growth, to avoid the possibility of generating a spurious relationship between the conditional variance of one series and the mean of another in our MGARCH-M model. A series of pairwise Granger causality tests reveals that the real exchange rate statistically causes industrial production growth, but that economic growth does not statistically cause the real exchange rate. Kamin and Rogers (2000) find the same results using bi-variate Granger causality tests with quarterly data for 1980.1-1996.2. Additional Granger causality tests reveal no link between US and Mexican industrial production growth, but there is a significant contemporaneous correlation that we interpret as coming from US growth rates to Mexican growth. We thus incorporate the lagged RER and the contemporaneous US industrial production growth rate into our equation for the Mexican industrial production growth.[19]

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[18] US industrial production fails the ADF test 11 of 12 times, Mexican IP and real exports fail 12 of 12 times. All three series pass ADF tests in their logged differences 12 of 12 times.

[19] In a series of Granger tests using from 1 to 6 lags, the RER always causes Mexican IP growth at the 0.01 level while Mexican IP growth never causes the RER. In the case of US and Mexican IP growth, neither causes the other at the 0.05 level in tests using from 1 to 6 lags.

B.3. Controlling for the Effects of Trade on Growth

Given that there is some evidence that RER uncertainty affects trade and also evidence that trade affects growth, it is important to control for trade when testing whether RER uncertainty directly influences growth. As discussed above, the existing cross-sectional studies that demonstrate an uncertainty-growth linkage did not include any trade variables in the growth equation. Thus they are unable to distinguish between the hypothesis that uncertainty affects trade which affects growth, and the hypothesis that uncertainty directly affects growth.

Here we include real export growth in the Mexican IP growth equation to capture the effects of trade on growth. The inclusion of this variable means that only the part of RER uncertainty uncorrelated with real export growth can influence industrial production growth. Since we are using the export variable as a control, we experimented with lag lengths to find the best fitting version of the variable. Consequently we use a six-month moving average of real export growth in our MGARCH-M model.

The statistical model for the real exchange rate will be an ARMA with a linear trend term and our election dummy. Preliminary OLS estimates of such models produce single equation R^2s of over 0.90. The model for industrial production growth will be ARIMA with the addition of the lagged exchange rate, lagged export growth, and growth in US industrial production. Preliminary OLS estimates of such models produce single equation R^2s of around 0.35. We will choose the exact ARMA terms used in the GARCH-M system to insure that the residuals, squared residuals and cross residuals are white noise.

Since RER volatility might be correlated with financial crisis, for the Mexican case we include the interest rate (IR) in the RER, RER variance, and output equations to account for that.

C. GARCH-M System for Testing our Hypotheses

The system of equations to be estimated has the following general form:

$$RER_t = \alpha_0 + \Sigma\, \alpha_i\, RER_{t-i} + \beta_0\, Trend_t + \varphi\, Electoral\ Cycle \qquad (1)$$

$$+ \xi_1 IR_{t-1} + \Sigma\, \beta_i\, \varepsilon_{t-i} + \varepsilon_t$$

$$\sigma^2\varepsilon_t = \gamma_0 + \gamma_1\,\varepsilon^2_{t-1} + \gamma_2\,\sigma^2\,\varepsilon_{t-1} + \gamma_3\,RER_{t-1} + \gamma_4\,IR_{t-1} \quad (2)$$

$$Y_t = \theta_0 + \Sigma\theta_i Y_{t-i} + \Sigma\phi_i\,v_{t-i} + \Phi_1 YUSA_t + \Phi_2\,RER_{t-1} + \Phi_3\,Exports_{t-1} \quad (3)$$

$$+ \Phi_4\,IR_{t-1} + \delta\,\sigma^2\varepsilon_t + v_t$$

$$\sigma^2 v_t = \lambda_0 + \lambda_1\,v^2_{t-1} + \lambda_2\,\sigma^2 v_{t-1} \quad (4)$$

$$COV_t = \rho(\sigma\,\varepsilon_t\,\sigma\,v_t) \quad (5)$$

Equation (1) is the real exchange rate equation (RER), with ARMA terms, a linear trend, the interest rate (IR) and the electoral variable (Electoral Cycle equals +1(-1) the year before (after) a Presidential election and 0 otherwise). Equation (2) is a modified GARCH (1,1) model of the conditional variance of the real exchange rate that also contains the lagged RER as an exogenous variable to test whether appreciated RERs are less predictable and one period lagged interest rate to control for financial crisis. Equation (3) is the industrial production growth equation (Y), with ARMA terms, the lagged real exchange rate, US industrial production growth (YUSA), lagged real export growth (Exports, a 6 month moving average of export growth), the conditional variance of the real exchange rate and one period lagged interest rate. Equation (4) is a GARCH (1,1) model of the conditional variance of industrial production growth, and equation (5) is a simple, constant correlation, model of the covariance of the two error terms.

For testing the hypotheses discussed above, the key coefficients are φ, the effect of elections on the RER, γ_3, the effect of the lagged RER on its conditional variance, and δ, which gives the effect of the conditional variance of the real exchange rate on the growth rate of industrial production controlling for trade effects. A positive and significant value of φ would indicate an electoral cycle in the RER consistent with the models of Streb and Stein, and Bonomo and Terra. A positive and significant value for γ_3 would imply that more appreciated RER's are less predictable, consistent with our extension of Ball's inflation model to the real exchange rate. A negative and significant estimate of δ means that RER uncertainty lowers output growth. For the Mexican case the inclusion of interest rate in equations (1) to (3) could strength these results.

VII. Results

A. Benchmark Case: Mexico

Table 1 presents our maximum likelihood estimates of the GARCH-M model given in equations 1-5 above.[20] To determine the exact ARMA terms included in the mean equations we initially considered up to 12 auto-regressive terms, retaining the ones with significant coefficients. In the industrial

Table 1. RER and Industrial Production Growth in Mexico, 1971.01 - 1998.12

Variable	Estimated coefficient	T-statistic
Constant (α_0)	23.45	4.59
RER_{t-1} (α_1)	0.66	6.79
RER_{t-2} (α_2)	0.08	1.99
RER_{t-5} (α_5)	0.11	1.98
RER_{t-6} (α_6)	-0.04	-3.57
RER_{t-10} (α_{10})	-0.08	-3.98
$Trend_t$ (β_0)	-0.022	-2.99
Electoral cycle (φ)	1.67	3.49
IR_{t-1} (ξ_1)	-0.09	-1.67
$\varepsilon_{t-1}(\beta_1)$	0.33	4.23
ε_{t-6} (β_6)	0.03	2.57
$\varepsilon^2_{t-1}(\gamma_1)$	0.98	2.54
$\sigma^2\varepsilon_{t-1}(\gamma_2)$	0.07	3.01
$RER_{t-1}(\gamma_3)$	0.078	4.05
$IR_{t-1}(\gamma_4)$	0.091	1.29

[20] We estimate the model by assuming that the two error terms are multi-variate normal, choosing a set of starting values for all the coefficients of the model and then using the well-known BHHH algorithm to arrive at a coefficient matrix that maximizes the value of the likelihood function.

Table 1. (Continued) RER and Industrial Production Growth in Mexico, 1971.01 - 1998.12

Variable	Estimated coefficient	T-statistic
Constant (θ_0)	-28.88	-1.95
Y_{t-1} (θ_1)	-0.35	-2.87
Y_{t-2} (θ_2)	-0.22	-2.76
Y_{t-7} (θ_7)	-0.08	-2.29
Y_{t-8} (θ_8)	-0.13	-3.21
$YUSA_t$ (Φ_1)	0.22	4.50
RER_{t-1} (Φ_2)	0.25	4.44
$Exports_{t-1}$ (Φ_3)	0.16	2.34
IR_{t-1} (Φ_4)	-0.09	-1.34
$\sigma^2\varepsilon_t$ (δ)	-0.69	-2.99
Constant (λ_0)	66.56	3.76
v^2_{t-1} (λ_1)	0.15	5.02
COV_t (ρ)	-0.014	-1.65

	Residual diagnostics		
	RER	Y	Cross
Q (5)	3.04	5.87	3.46
Q (10)	7.11	8.12	9.93
Q (20)	16.94	16.47	17.88
Q^2 (5)	0.42	2.79	
Q^2 (10)	0.79	7.43	
Q^2 (20)	1.66	16.89	
Log of the likelihood function: -2,312.68			

Notes: Joint estimates. Exports is a six month moving average of real export growth. The sample is 336 monthly observations from 1971.01-1998.12. The critical values at the 0.05 level for both the Q and Q^2 stats are 11.70, 18.31 and 31.41 at 5, 10, and 20 lags. The maximization method is BHHH.

production growth equation, this was sufficient to produce white noise residuals and squared residuals. The real exchange rate equation required an additional step of considering up to 12 moving average terms to produce both residuals and squared residuals without any auto-correlation. The conditional variance of output growth, while significantly time varying, is not very persistent and is best modeled as an ARCH(1) instead of a GARCH(1,1) process.

The final model for the evolution of the mean of the real exchange rate includes the first, second, fifth, and sixth lags of the RER along with first and sixth order moving average terms. The estimated output growth equation includes the first, second, seventh, and eighth lags of output growth. None of the key results in the paper are sensitive to the exact ARMA representations chosen. The ones reported here represent the minimum number of variables needed to produce clean residuals.

Our first hypothesis, the existence of an electoral cycle in the RER, is confirmed in equation 1 by the positive (1.67) and significant (t-statistic of 3.49) coefficient on our electoral dummy. In our sample, the Mexican RER is significantly appreciated above trend leading up to an election and depreciated in the aftermath. The coefficient of 1.67 may seem small, given the large swings observed in the Mexican RER series. However, accounting for the ARMA structure of the overall equation produces a peak to trough effect of the electoral cycle of around 16 points on the RER index, which is about equal to one standard deviation in the historical data. Thus the effect is sizable, even though the coefficient seems modest. The variable included to account for financial crisis, interest rate, was not statistically significant, though it has a negative sign, which may suggest that increases in interest rates depreciates RER, a standard result in the literature.

The hypothesis that more appreciated RER's are less predictable is also supported in the estimated model. In the equation for the conditional variance of the RER, the lagged level of the RER is positive (0.078) and significant (t-statistic of 4.05). This coefficient may also seem small, and in this case it is indicative of a relatively small effect. A two standard deviation rise in the RER raises uncertainty in the next period by only 1.01 units , while the sample median of the estimated conditional variance of the RER is about 6.5. Further, given that the auto-regressive term in the conditional variance equation is only 0.07, this modest effect is not very long lasting either. The lagged interest rate has a positive sign but it is not statistically significant. This may suggest that higher interest rates might cause higher volatility. To account for this, this rate was included in the output equation as it is interesting to investigate to what extent the relationship between RER volatility and product is driven by one of interest rate and output.

Turning to the real effects of the RER process, we find that in our model and sample, real depreciations lower, rather than raise, growth. The coefficient for the lagged RER is positive (0.25) and significant (t-statistic of 4.44) in the output growth equation. This result is consistent with the findings of Kamin and Rogers who use a different sample and model. We also find that controlling for US growth, Mexican exports growth, and the level of the RER, RER uncertainty is a negative (coefficient of -0.069) and significant (t-statistic of 2.99) determinant of output growth. US industrial production growth is a positive and marginally significant influence on Mexican growth, while real export growth is positive and significant at the 0.01 level. Note that IR has a negative sign but it is not statistically significant. This in fact strengthens the result of the negative relationship between RER volatility and output.[21]

The effect of both the mean and conditional variance of the RER on output growth in Mexico is substantial. Consider a comparison of the two effects. Based on a comparison of coefficients, the impact of uncertainty shocks is bigger than the impact of changes in the average RER. A 10 point rise in the RER is predicted to raise industrial production growth by 2.1 percentage points next period, while a 10 point rise in the RER conditional variance is associated with around a 8 percentage point decline in output growth during the same period. However, given that the average RER is much more persistent series than is the conditional variance of the RER, the effect of mean shocks will generally last longer than the effect of uncertainty shocks.

It is important to remember that our results on the real effects of the RER process on industrial production growth arise in a model where export growth is included in the industrial production growth equation. That is to say, these

[21] Different estimations of equation 1 yield strong statistical significance to a negative relationship between RER volatility and output. That is, the result is robust to different estimations.

RER effects on industrial production growth are not coming through their influence on exports, but rather through their direct influence on aggregate economic activity.[22]

B. Comparison Case: USA

While Mexico has a varied history of ER policies with much active management and restricted hedging possibilities, the US is largely the opposite. US exchange rate intervention is not unknown, but the US has been more or less a free-floating country since the demise of the Bretton Woods system. Further, the dollar is widely traded in futures and forward markets. We thus expect to observe smaller RER influences on output growth and smaller political economy effects on the RER. In fact, if we were to observe the same size effects in the USA that we do in Mexico, we would have to seriously question our explanations for the existence of the effects.

Here we report estimates of our 5 equation system using US data. The only differences[23] are (1) instead of using the US growth rate as an exogenous regressor, in the output growth equation, we use the lagged Treasury Bill interest rate, and (2) the exact ARMA terms chosen to eliminate any patterns in the residuals differ from the Mexican case.[24] The results are shown in Table 2. The first important point here is that there is no evidence of political economy effects on the RER. That is to say, the election cycle variable is insignificant in the RER mean equation and the lagged RER is insignificant in the conditional variance equation. Second, neither the lagged RER nor lagged

[22] The real effects of the RER process are not dependent on including the political economy effects in the RER. Dropping the election cycle variable in the RER mean equation and the lagged RER in the conditional variance equation slightly raises the t-statistics on the lagged RER and the RER conditional variance in the output growth equation. Here we do not include interest rate as in equation 1, because it did not turn out to be important.

[23] Obviously, the Mexican interest rate is not included either.

[24] Another difference is that the US real exchange rate contains less evidence against the unit root hypothesis than does the Mexican RER. In ADF tests, the null hypothesis of a unit root can be rejected only about half the time and only at the 10% significance level. However, the results reported in the paper are insensitive to whether the level or the growth rate of the US RER is used. We report results using the levels in order to make comparisons to the Mexican results easier.

Export Growth is a significant regressor in the US output growth equation. Third, while the RER conditional variance has a large negative coefficient in the US output growth equation (-1.67) it is only significant at the 0.20 level (t-statistic of 1.43).

Table 2. RER and Industrial Production Growth in the USA, 1971.01 - 1996.11

Variable	Estimated coefficient	T-statistic
Constant (α_0)	3.73	2.30
RER_{t-1} (α_1)	0.61	3.02
RER_{t-2} (α_2)	0.35	1.77
Electoral cycle (φ)	-0.07	-0.52
ε_{t-1} (β_1)	0.61	3.85
ε_{t-12} (β_{12})	0.11	1.95
Constant (γ_0)	-0.02	1.91
ε^2_{t-1} (γ_1)	0.004	0.89
$\sigma^2\varepsilon_{t-1}$ (γ_2)	0.10	1.97
RER_{t-1} (γ_3)	0.80	6.71
Constant (θ_0)	3.37	0.66
Y_{t-1} (θ_1)	0.24	3.53
Y_{t-2} (θ_2)	0.06	1.29
Y_{t-3} (θ_3)	0.07	1.34
RER_{t-1} (Φ_2)	0.05	0.93
$Exports_{t-1}$ (Φ_3)	0.06	0.51
IR_{t-1} (Φ_4)	-0.65	-3.67
$\sigma^2\varepsilon_t$ (δ)	-1.61	-1.43
Constant (λ_0)	51.2	10.5
v^2_{t-1} (λ_1)	0.26	3.64
COV_t (ρ)	0.142	2.02

Table 2. (Continued) RER and Industrial Production Growth in the USA, 1971.01 - 1996.11

	Residual diagnostics		
	RER	Y	Cross
Q(5)	6.41	4.05	8.48
Q(10)	12.63	6.06	17.34
Q(20)	21.56	17.45	25.37
$Q^2(5)$	2.32	3.15	
$Q^2(10)$	3.75	9.34	
$Q^2(20)$	7.52	20.74	
Log of the Likelihood Function: -1,618			

Notes: Joint estimates. IR_{t-1} is the lagged three-month US Treasury Bill interest rate. Exports is a six month moving average of real export growth. The sample is 311 monthly observations from 1971.01-1996.11. The critical values at the 0.05 level for both the Q and Q^2 stats are 11.70, 18.31 and 31.41 at 5, 10, and 20 lags. The maximization method is BHHH.

In sum, while we find significant conditional heteroskedasticity in both the Mexican and US series for the RER and industrial production growth, none of the effects discussed in this paper and found in the Mexican sample appear in the US data. We believe that this constitutes evidence in favor of our explanations for the existence of the effects in the Mexican data. Our explanations are valid conditional on certain political or institutional factors that are found in Mexico. The facts that these factors are much less prevalent in the US, and that the Mexican results are not found in the US data, support the idea that our explanations for the Mexican effects are correct.[25]

VIII. Conclusion

We study the real exchange rate process and its real effects using Mexican data from 1971 to 1998. We find evidence of a sizeable electoral cycle in

[25] Dropping the insignificant political economy variables has no effect on the significance of the RER variables in the output growth equations.

Mexican real exchange rates and a significant but small positive effect of more appreciated RER's on the conditional variance of the RER. In both of these cases, the effect on the RER is predicted by models where either the preferences or competence of the policymaker are private information. By comparison, neither effect appears in US data. Further, an appreciated RER is significantly positively correlated with economic growth, while increased RER uncertainty is significantly negatively correlated with growth in our model for Mexico, but not in the US model.

Thus we find, in a developing country, substantial political economy effects on the RER process, and substantial real effects of the RER process on industrial production growth. In our developed country experiment, none of these effects appear.

Our results cast further doubt on the proposition that an undervalued RER promotes growth, show for the first time that RER uncertainty can have direct effects on economic performance holding constant their potential influence on exports, give the most direct evidence so far for the existence of an electoral cycle in the RER, and provide the first demonstration that more appreciated RER's are less predictable. We find these results in a country with a political-institutional context consistent with the assumptions necessary to generate the results (Mexico) and we do not find them in a country (the US) whose political-institutional context is inconsistent with the theoretical assumptions.

The countries we have chosen in some sense represent extremes. Mexico has had an extremely variable RER, little opportunity for hedging, and many ER regimes. In the US, the RER is much less variable, much more easily hedged, and there has been basically one ER regime. One important extension of this work will be to consider additional extreme case countries to see if the contrast in results is robust. Another important extension will be to consider intermediate case countries.

Appendix

Table A.1. Summary Statistics

Variable	Mean	Std. deviation	Source
Mexican IP growth	4.02	38.99	IMF (IFS)
US IP growth	2.86	9.68	CITIBASE
Mexican real export growth	9.01	149.60	IMF (IFS)
US real export growth	5.46	94.68	IMF (IFS)
Mexican RER	120.55	19.59	JP Morgan
US RER	104.87	10.18	JP Morgan
US T-bill rate	6.91	2.78	IMF (IFS)

References

Agenor, P., and P. Montiel (1996), *Development Macroeconomics*, Princeton, Princeton University Press.

Arize, A. (1997), "Conditional Exchange Rate Volatility and the Volume of Foreign Trade: Evidence from Seven Industrialized Countries," *Southern Economic Journal* **64**: 235-254.

Ball, L. (1992), "Why Does High Inflation Raise Inflation Uncertainty?," *Journal of Monetary Economics* **29**: 371-388.

Bonomo, M., and C. Terra (1999a), "The Political Economy of Exchange Rate Policy in Brazil: An Empirical Assessment," *Revista Brasileira de Economia* **53**: 411-432.

Bonomo, M., and C. Terra (1999b), "Elections and Exchange Rate Policy Cycles," Mimeo, Rio de Janeiro, Getulio Vargas Foundation.

Calvo, G., Reinhart, C., and C.Végh (1995), "Targeting the Real Exchange Rate: Theory and Evidence," *Journal of Development Economics* **47**: 97-133.

Chesney, M., Hernández Trillo, F., and B. Marois (2000), *El Manejo del Riesgo Cambiario: Las Opciones sobre Divisas*, Mexico, Limusa Publishing Co.

Cooper, R. (1971), "Currency Devaluation in Developing Countries," Essays in International Finance **86**, Princeton, Princeton University.

Côté, A. (1994), “Exchange Rate Volatility and Trade: A Survey,” Working Paper 94-5, Bank of Canada.

Cottani, J., Cavallo, D., and M. Khan. (1990), “Real Exchange Rate Behavior and Economic Performance in LDCs,” *Economic Development and Cultural Change* **39**: 61-76.

Edwards, S. (1994), “The Political Economy of Inflation and Stabilization in Developing Countries,” *Economic Development and Cultural Change* **42**: 235-66.

Engle, R. (1982), “Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of U.K. Inflation,” *Econometrica* **50**: 987-1008.

Gavin, M., and R. Perotti (1997), “Fiscal Policy in Latin America,” in B. Bernanke and J. Rotemberg, eds., *NBER Macroeconomics Annual 1997,* Cambridge, MA, MIT Press.

Ghezzi, P., Stein, E.H., and J. M. Streb (2000), “Real Exchange Rate Cycles around Elections,” Mimeo, IDB.

Goldfajn, I., and R. Valdés (1999), “The Aftermath of Appreciations,” *Quarterly Journal of Economics* **114**: 229-262.

Grier, R., and K.B. Grier (2000), “Political Cycles in Non-Traditional Settings, Theory and Evidence for Mexico,” *Journal of Law and Economics* **43**: 239-63.

Grier, K., and M.J. Perry (1993), “The Effect of Money Shocks on Interest Rates in the Presence of Conditional Heteroskedasticity,” *Journal of Finance* **48**: 1445-1455.

Grier, K., and M.J. Perry (1998), “On Inflation and Inflation Uncertainty in the G-7 Countries,” *Journal of International Money and Finance* **17**: 671-89.

Kamin, S., and J. Rogers (2000), “Output and the Real Exchange Rate in Developing Countries: An Application to Mexico,” *Journal of Development Economics* **61**: 85-109.

Klein, M., and N. Marion (1997), “Explaining the Duration of Exchange-rate Pegs,” *Journal of Development Economics* **54**: 387-404.

Kroner, K., and W. Lastrapes (1993), “The Impact of Exchange Rate Volatility on International Trade: Reduced Form Estimates Using the GARCH-in-mean Model,” *Journal of International Money and Finance* **12**: 298-318.

Krugman, P., and L. Taylor (1978), "Contractionary Effects of Devaluation," *Journal of International Economics* **8**: 445-56.

La Porta, R., Lopez-de-Silanes, F., Shleifer, A., and R. Vishny (1998), "Law and Finance," *Journal of Political Economy* **106**: 1113-55

Maloney, W., and R. Azevedo (1995), "Trade Reform, Uncertainty, and Export Promotion: Mexico 1982-1988," *Journal of Development Economics* **48**: 67-89.

Máttar, J., and W. Peres(1999), "La Inversión en México después de las Reformas Económicas," Mimeo, Center for US-Mexican Studies, University of California, San Diego.

Mendoza, E. (1997), "Terms of Trade Uncertainty and Economic Growth," *Journal of Development Economics* **55**: 323-356.

Pascó-Fonte, A., and P. Ghezzi (2001), "Exchange Rates and Interest Groups in Peru, 1950-1996," in J. Frieden and E. H. Stein, eds., *The Currency Game: Exchange Rate Politics in Latin America*, Washington, D.C., IDB.

Reiss, P., and F. Wolak (2002), "Structural Econometric Modeling: Rationales and Examples from Industrial Organization," *Handbook of Econometrics*, forthcoming.

Stein, E.H., and J.M. Streb (1998), "Elections and the Timing of Devaluations," Mimeo, Washington, D.C., IDB.

Stockman, A. (1999), "Choosing an Exchange Rate System," *Journal of Banking & Finance* **23**: 1483-1498.