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Are Mexican Business Cycles Asymmetrical?

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Abstract

We use the regime-switching econometric models in Hamilton (1989) and Filardo (1994) to study business cycles in Mexico. In particular, we characterize the ups and downs of economic activity in Mexico. As a proxy for economic activity, we use the Mexican quarterly industrial production index from the second quarter of 1972 to the third quarter of 1999. We allow the transition probabilities driving changes in economic activity to be a function of fiscal, financial, and external sector indicators. Our results show that recessions in Mexico are deeper and shorter than expansions.

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I. Introduction

Economists have been long interested in business cycles. Although, there exists an extensive literature on business cycles in developed economies, not much is known about business cycles in the developing world.[2] This paper investigates Mexican business cycles, in particular whether some fiscal, financial, and external sector indicators contain information about them.

Possible sources of Mexican business cycles such as political cycles, exchange rate stabilization plans, and market imperfections justify our choice of fiscal, financial, and external sector indicators as leading indicators.[3] Since many of these indicators track financial crises in the early warning indicators literature, they are also good candidates for the role of leading indicators of business cycles in Mexico.[4] Combining these fiscal, financial, and external sector indicators into a composite index also provides helpful information. To obtain this combination, we use principal component analysis. Since the first orthogonal principal component accounts for most of the variation in these indicators, we can easily interpret it as a composite index of vulnerabilities in the fiscal, financial, and external sectors.

We use the regime-switching econometric model in Hamilton (1989), and its extension in Filardo (1994), to estimate the average growth rates of expansions and recessions, and to assess the effectiveness of our fiscal, financial, and external sector indicators. We set the transition probabilities driving regime changes from expansions to recessions and vice versa as a function of fiscal, financial, and external sector indicators.

If structural breaks are expected to occur in a time series, regime-switching models are more appropriate to fit the data than extensions from the usual linear regression models. By not

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[2] See Hoffmaister and Roldos (1997) and Agénor, McDermott, and Prasad (1999) for a general characterization of business cycles in developing countries. See Acevedo and others (2001) for a characterization of Mexican business cycles using the HP filter, the unobservable components method, and a structural VAR with annual and quarterly real GDP data. See Mejía-Reyes (2000) for another characterization of Mexican business cycles using a regime-switching model with annual real GDP data. The latter researcher found that Mexican business cycles are asymmetrical, as we also found.

[3] Mexican business cycles can also be connected to U.S. business cycles and to terms-of-trade shocks. Our set of fiscal, financial, and external sector variables is broad enough to include variables that are related to different sources of Mexican business cycles.

[4] See Berg, Borensztein, Milesi-Ferreti, and Pattillo (1999), Evans and others (2000), Kaminsky (1999), Kaminsky and Reinhart (1999) and International Monetary Fund (1998).

imposing deterministic changes that might be conditioned on arbitrary events chosen by the researcher, regime-switching models are a more general approach to deal with structural breaks. Regime-switching models also have the advantage that the regime probabilities obtained as a subproduct from the maximization procedure can be used to access the turning points in business cycles. As pointed in Diebold and Rudebusch (1996), despite the general interest in turning points, only regime-switching models provide the framework where the concept of turning points is meaningful.

The regime-switching models, applied to quarterly industrial production index in Mexico, from the first quarter of 1972 through the third quarter of 1999, yields interesting results. First, estimates for the positive and negative growth rates with and without our fiscal, financial, and external sector indicators show stronger recessions than expansions. Second, our estimations indicate that the economy moved from an expansion to a recession in 1982, 1985–86, and 1994 and from a recession to an expansion in 1983, 1986, and 1995.

Section II summarizes possible sources of business cycles in Mexico. Section III lists our fiscal, financial, and external sector indicators. Section IV describes the regime-switching econometric model with constant time-varying transition probabilities. Section V discusses our results. The last section summarizes the main findings of the paper.

II. Sources of Mexican Business Cycles

This section briefly reviews the Mexican economic performance from 1970 to 1999, and suggests four possible sources of business cycles in Mexico: political cycles, exchange-rate-based stabilization plans, market distortions, and external factors.

The first period reviewed, from 1970 to 1981, was characterized by an import-substitution strategy (implemented since the 1950s), mounting economic distortions, particularly in the financial sectors, restrictions to foreign direct investments, and domestic and external imbalances. In response to low growth rates in the early 1970s, the Mexican government implemented expansionary fiscal policies, which in turn accelerated inflation, appreciated the local currency in real terms, and real interest rates were kept artificially low. The resulting capital outflows pressured the foreign exchange market, and the authorities were forced to devalue in 1976. The expenditure switching and reduction effect of the devaluation was short lived as the government kept spending and borrowing, encouraged by the large oil discoveries in mid-1970s. As a result, the current account deficit widened and the external debt rose. The Mexican authorities only changed policies after the collapse of oil prices in 1981 and the increases in international interest rates.

The second period, 1982 to 1988, is a period of weak economic performance, following the government default on its external debt. In February 1982, and again six months later, the authorities devalued the peso. To tackle the crisis, the Mexican government implemented an economic program supported by the IMF in late 1982. After the introduction of the economic program, internal and external imbalances decreased, inflation receded, and real GDP increased. However, domestic and external adverse shocks (the 1985 earthquake and the fall in oil prices in 1986) undermined the adjustment efforts and increased the vulnerability of the external and fiscal positions.

In the third period, 1989 to1994, the Mexican authorities implemented an exchange-rate-based stabilization program, which was complemented by incomes policies, public finance reform measures, and financial and trade liberalizations. The successful implementation of the stabilization program led to lower inflation, higher income per capita, and large capital inflows. The latter in turn prevented a reversal of the real exchange rate appreciation. Indeed, financial liberalization—coupled with weak prudential regulation and inadequate banking supervision—increased consumer credit and consumption. Imports then grew more than exports and the current account deficit tripled. Given the short-run nature of the financing flows to Mexico, the economy became quite vulnerable in 1994 to the adverse external and domestic shocks, resulting in capital outflows and a collapse of the exchange rate and output.

In the last period, 1995 to 1999, the economy recovered. After the 1994 crisis, Mexico implemented an adjustment program with IMF support. The adjustment program included a floating exchange rate, the tightening of monetary policy, fiscal consolidation, and restrained incomes policies. In addition, authorities responded to the banking crisis with several support schemes. As a result, after 1996, the economic situation improved and real GDP grew, on average, at 5 percent per year.

The four periods above can be interpreted in terms of four possible sources that we discuss next. For example, Grier and Grier (2000) argued that, when autocratic governments rule for short periods, without the possibility of reelection, they neglect the long-run benefits of public goods and confiscate assets that generate long-term flows of resources. Autocratic governments make distorted policy decisions and reduce both the quantity and quality of public goods. Investors and consumers delay private decisions and economic activity declines as the end of the presidential term nears and uncertainty in the economy increases. In the context of autocratic governments, financial crisis is simply endogenous to the political cycle.

Another source of business cycles in Mexico is the exchange-rate-based stabilization programs, as they could have been an important source in the third period mentioned above. Empirically, as report by Calvo and Vegh (1999), exchange-rate-based stabilization plans led to consumption booms, currency overvaluations, and trade deficits in countries that implemented them. The authors also report that most stabilization strategies ended with a depletion of foreign reserves, speculative attacks, and a fall in aggregate demand. In fact, Mendoza and Uribe (1999) developed a theoretical model to explain this interaction, which worked through interest rate distortions (currency risk premium) that affect savings, investment, and labor supply decisions. The calibration of their model with Mexican data simulated the consumption increase and the real exchange rate appreciation, with a worsening trade balance and a dwindling reserve.

A third possible source of Mexican business cycles is market distortion. Mishkin (1997) suggested that asymmetric information problems worsened before the end-1994 crisis in Mexico with a series of events such as the deregulation of financial markets in early 1990s; the interest rate increases following the U.S. policy response to inflationary pressures in 1994; the increase in uncertainty following the political shocks and the stock market decline in 1994; and the deterioration of cash flows of firms and households. McKinnon and Pill (1997) suggested the unlimited government insurance to almost all bank's liabilities also contributed to the 1994 financial crisis as it protected depositors from losses associated with new technologies and distorted banks' borrowing and credit decisions. Domestic residents invested more than they would have otherwise done. Since the exchange rate was fixed, banks did not hedge their currency risk positions and overborrowed.

Finally, given the fact that over 80 percent of Mexico's total trade is with the United States, and that oil contributes to about one-third of the government revenue, the business cycle in the United States and terms-of-trade shocks could also have been a major source of business cycles in Mexico, specially in the second and third periods reviewed above.

III. Fiscal, Financial, and External Sector Indicators as Business Cycle Indicators

The previous sources of business cycles in Mexico suggest some interesting leading indicators of business cycles. Table 1, first column, lists our fiscal, financial, and external sector indicators. Many of these indicators also track financial crises in the early warning indicators literature.

However, some indicators are computed in a slightly different way than in the early warning indicators literature.[5] For instance, domestic credit change as percentage of GDP is used to capture the monetary policy stance instead of deviations from a money demand function for real cash balances.[6] Instead of deviations of the real exchange rate from its trend, deviations of the real exchange rate are computed from its equilibrium value as in Dabós and Juan-Ramon (2000).[7] Appendix III shows how the deviations from the equilibrium real exchange rate were obtained.

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[5] See, for instance, Kaminsky (1999) and Kaminsky and Reinhart (1999).

[6] See Appendix I for data sources.

[7] See Kakkar (2001) for another approach to the estimation of the equilibrium real exchange rate in Mexico.

Table 1. Mexico: First Principal Component of Fiscal, Financial, and External Sector Indicators, 1972:Q2-99:Q3

Indicator	Shortcut	Expected Coefficient Sign	Factor Loadings	Correct Sign
1-Fiscal sector				
Public sector borrowing requirement (last 12-months), percentage of GDP (last 12 months)	defgdp	+	0.02	Y
2-Financial sector				
Deviations of M1 from a money demand function	M1	+	0.03	Y
Money multiplier (M_1/reserves) , 12-moth percentage change	multiplier	-	-0.59	Y
Bank deposits, percentage of GDP (last 12 months)	deposits/GDP	-	-0.09	Y
Real interest rate on deposits,cumulativeof last 12 months	realint	+	0.15	Y
Stock index (in US$) , 12-month percentage change	stocks	-	-4.94	Y
Credit to the private sector, percentage of GDP (last 12 months)	cps	+	0.10	Y
3-External sector				
3.1-Current account				
Deviations of the real exchange rate from its equilibrium value (2 quarters lag) 1/	RER	-	-0.23	Y
Imports of goods and services, 12-month percentage change	imports	+ -	-0.11	Y
Exports of goods and services, 12-month percentage change	exports	-	-0.14	Y
Terms of trade, 12-month percentage change	tot	-	-0.12	Y
3.2-Capital account				
Reserves, 12-month percentage change	reserves	-	-4.91	Y
Ratio M2/reserves, 12-month percentage change	m2res	+	3.08	Y
Ratio short-term external debt/total external debt, 12-month percentage change	stres	+	0.63	Y
Ratio total external debt/GDP (last 12 months), 12-month percentage change	totaldebt	+	0.50	Y
U.S. real interest rate, cumulative of last 12 months	USrealint	+	0.01	Y
Mexican-U.S. real interest rate differential, cumulative of last 12 months				
	Percentage Variance		41.36	

Source: Appendix I.

1/ An increase in the deviations implies a real depreciation of the local currency and vice versa.

Although single indicators might not convey statistically significant information, their combination could result in a helpful index. An example is Filardo (1994) and Layton (1998), who included the Composite Index of Eleven Leading Indicators (CLI), the CLI's diffusion index, and the Stock and Watson Experimental Index of Seven Leading Indicators in their analysis. We could use similar composite indexes of leading indicators for Mexico, but they are only available for a shorter period than is necessary in the estimations of the next sections.[8]

Since long series for composite indexes are not available in Mexico, we compute a composite indicator of vulnerabilities in the balance of payments and the banking sector using principal components analysis. Table 1, third column, reports our estimation results using deviations from the mean for the seventeen fiscal, financial, and external sector indicators. As seen in Table 1, the first principal component accounts for 42 percent of the variance in our indicators measured with respect to their mean (deviations). Interestingly, all factor loadings have signs that correspond to the expected ones in an aggregate composite index of vulnerability.[9]

Figure 1 plots our composite index from variables in Table 1. When above zero, our composite index of vulnerability is signaling pressures either on the balance of payments or on the banking sector. Note that, in all crises in September 1976, February 1982, December 1982, and December 1994, our index was signaling pressures far in advance.[10] On the other hand, when below zero, no pressures on the balance of payments or on the banking sector exist.

How can our fiscal, financial, and external sector indicators be useful in characterizing business cycles? These indicators can be incorporated into the laws of motion that drive changes in the phases of business cycles. This is the line of research pursued in the next sections.

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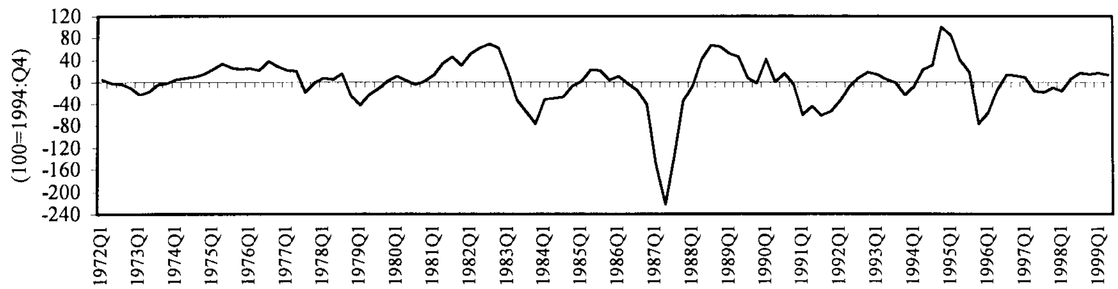
[8] Composite indexes of leading and coincident indicators of business cycles in Mexico are available in the web page *dgcnesyp.inegi.gob.mx/bie.html-ssi.*

[9] Factor loadings are the ordinary least squares coefficients obtained from a regression of each fiscal, financial, and external sector indicator on the first principal component. See Theil (1971), pp. 46–56.

[10] Kaminsky and Reinhart (1999) has a chronology of currency and banking crises for a selected group of countries.

Figure 1. Mexico: Composite Index of Vulnerabilities in the Balance of Payments and the Banking Sector, 1972:Q2-99:Q3



Source: Table 2

IV. Regime-Switching Models with Time-Varying Transition Probabilities

In this section we use the regime-switching econometric model in Hamilton (1989) and its extension in Filardo (1994) to analyze Mexican business cycles and test the predictive power of our fiscal, financial, and external sector indicators. Hamilton (1989) proposed the regime-switching econometric model to allow different probability distributions to characterize the behavior of a variable.[11] An example is the U.S. business cycles. During states of expansion, changes in GDP are centered around a positive mean, whereas, during states of contraction, changes in GDP are centered around a negative mean.

Following Hamilton (1989), we let s_t describe the state of the business cycle. For periods of expansion, s_t=1, and for periods of contraction, s_t=2. Since quarterly GDP for Mexico is only available since 1982, we use the seasonally adjusted industrial production index as a proxy for economic activity. We can express the current changes in the industrial production index as:

$$y_t = g_{s_t} + u_t, \qquad (1)$$

where y_t is the quarterly change in the industrial production index (in log); g_{st} is the mean growth rate in states s_t; and u_t is an error term with a $N(0,\sigma_{st}^2)$ distribution in state s_t. In periods of expansion (s_t=1), $g_1 \geq 0$ and the error term has a variance equal to σ_1^2. In periods of contraction (s_t=2), $g_2<0$ and the error term has a variance equal to σ_2^2. That is:

$$y_t = g_1 + u_t \text{ if } s_t\text{=1, where } u_t \sim N\left(0,\sigma_1^2\right)\text{, or} \qquad (2)$$

[11] For a summary on this literature, see Hamilton (1994), Chapter 23.

$$y_t = g_2 + u_t \text{ if } s_t\text{=2, where } u_t \sim N\left(0,\sigma_2^2\right)$$

We assume that the state variable s_t is a first-order Markov process that evolves according to a (2x2) transition probability matrix P:

$$P = \begin{bmatrix} p_{11t} & 1-p_{22t} \\ 1-p_{11t} & p_{22t} \end{bmatrix}. \quad (3)$$

where:
i) p_{11t} stands for probability of going from state 1 (expansion) at time t-1 to state 1 (expansion) at time t; ii) p_{12t} = 1-p_{11t} stands for the probability of going from state 1 (expansion) at time t-1 to state 2 (contraction) at time t; iii) p_{21t} = 1-p_{22t} stands for the probability of going from state 2 (contraction) at time t-1 to state 1 (expansion) at time t; and iv) p_{22t} stands for the probability of going from state 2 (contraction) at time t-1 to state 2 (contraction) at time t.

Note that Hamilton (1989) has a constant transition probability matrix driving changes in states. This implies that the probability that a recession (expansion) at time t follows a recession (expansion) at time t-1 is always the same and independent of the duration of the contractionary state. However, these constant transition probabilities might not be appropriate to identify business cycles since they (i) cannot increase before a contraction or an expansion begins; (ii) do not allow for the persistence of a phase (recession or expansion) over time; and (iii) do not incorporate expected durations.

To overcome these drawbacks, Filardo (1994) extended the standard regime-switching model by allowing the transition probabilities to be time-varying. His approach set the transition probabilities as a function of indicators containing information on business cycles. He then applied the extended framework to U.S. data and found that time-varying transition probabilities are better to characterize expansions and contractions in the U.S. business cycles than constant transition probabilities.

Following Filardo (1994), we allow the transition probabilities to be time-varying and dependent on our fiscal, financial, and external sector indicators. We specify logistic functions for the transition probabilities p_{iit}:

$$p_{iit} = \frac{\exp(x_t'.\Phi_i)}{1+ \exp(x_t'.\Phi_i)}, \quad (4)$$

where x_t is a vector of exogenous variables and Φ_i is a vector of parameters for the sequence of states s_{t-1}=i and s_t=i, where i=1,2. The logit function constrains the transition probabilities p_{iit} to lie in the interval $0 < p_{iit} < 1$.

Table 2 shows the expected effects of our fiscal, financial, and external sector indicators on the transition probabilities. The expected signs for the indicators correspond to the main channels through which political cycles and financial crises affect economic activity. For instance, a positive sign in the second column for indicators measuring problems in the current account is consistent with a lower current account surplus (or a higher current account deficit) increasing the chances of a balance of payment crisis and, as a consequence, an output contraction or an increase in $1\text{-}p_{11t}$. A negative sign for the transition probability p_{22t} of the same indicators implies a higher current account surplus leading to lower chances of a balance of payment crisis and an output contraction.

As shown in Table 2, the expected signs for the coefficients in the transition probabilities p_{11t} and p_{22t} are opposite. Filardo (1994) and Layton (1997b) emphasized that these opposite signs imply an increase in the probability of being in state s_t=j at time t regardless of the state at time t-1. If an indicator increases and if Φ_{11} and Φ_{22} have, respectively, positive and negative signs, then both p_{11t} and $p_{21t}=1-p_{22t}$ increase. The probability of being in state 2 at time t then decreases.

Instead of current indicators in the transition probabilities, we use lagged ones. The assumption is that lagged indicators are uncorrelated with the contemporaneous state. According to Filardo (1999), this is a reasonable assumption as long as information variables are predetermined with respect to the state of the business cycle at time t.[12] If this condition is violated, we cannot extend Hamilton's filtering method to time-varying transition probability models, hence we need to use other methods to find maximum likelihood estimates.

To accommodate autocorrelation in the residuals, we can replace the white noise error term u_t with an AR(q) process:

$$u_t = \sum_{i=1}^{q} \beta_i u_{t-i} + \varepsilon_t , \tag{5}$$

where q is the number of lags, γ_t is an error term with a $N(0,\sigma_1^{\,2})$ distribution if s_t=1 and $N(0,\sigma_2^{\,2})$ if s_t=2. This is equivalent to the following model for the series y_t:

$$y_t - g_{s_t} = \sum_{i=1}^{q} \beta_i (y_{t-i} - g_{s_{t-i}}) + \varepsilon_t . \tag{6}$$

[12] For further details, see Filardo (1999).

The parameters g_1, g_2, σ_1, σ_2, β_1, β_2, β_3, ..., and β_q and the elements in vectors Φ_1 and Φ_2 (all comprised in the vector θ) can be estimated by the filter described in Appendix I.[13]

V. Results

Appendix I shows how the data set in estimations was constructed. Economic activity in Mexico is proxied by the quarterly industrial production index (seasonally adjusted with a two-sided moving average). This index is plotted in Figure 2 from the first quarter in 1972 through the third quarter in 1999.

A simple inspection of Figure 2 illustrates the difficulty in classifying changes in the industrial production index as contractionary or expansionary. Even if some filter eliminates seasonality, classifying observations is still difficult. A negative change in the industrial production index after a sequence of positive changes, for instance, does not necessarily imply a contractionary phase since economic activity might still increase in the next quarter.

The estimated models contain two autoregressive coefficients:

$$y_t - g_{s_t} = \beta_1\left(y_{t-1} - g_{s_{t-1}}\right) + \beta_2\left(y_{t-2} - g_{s_{t-2}}\right) + \varepsilon_t \qquad (7)$$

where ε_t has a $N(0,\sigma^2)$ distribution, and the transition probabilities p_{iit} driving changes in regime are:

$$p_{iit} = \frac{\exp(\Phi_{i0} + \Phi_{i1}x_{t-1})}{1 + \exp(\Phi_{i0} + \Phi_{i1}x_{t-1})} \qquad (8)$$

Likelihood ratio statistic tests—not shown in the text—applied to the model with constant transition probabilities led to the choice of two lags for the autoregressive process and only one variance. This simplified version increased the speed at which the GAUSS program converged.

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[13] To minimize the problem of multiple local maxima, extra terms representing prior information about the means g_k and variances σ_k are added to the log-likelihood function above as in Hamilton (1991):

$$L(\theta) = \sum_{t=1}^{T} \log(f(y_t \mid I_{t-1}, x_t; \theta)) - \sum_{k=1}^{2}(a_k/2)\log\sigma_k^2 - \sum_{k=1}^{2} b_k/\left(2\sigma_k^2\right) - \sum_{k=1}^{2} c_k\left(m_k - g_k\right)/\left(2\sigma_k^2\right)$$

where m_k is the prior expectation for g_k, the ratio b_k/a_k is the prior for σ_k, and the parameters a_k and c_k are the weights placed on priors. Values for the priors used in estimations are a_k=0.2, b_k=1, c_k=0.1, and m_k=0.

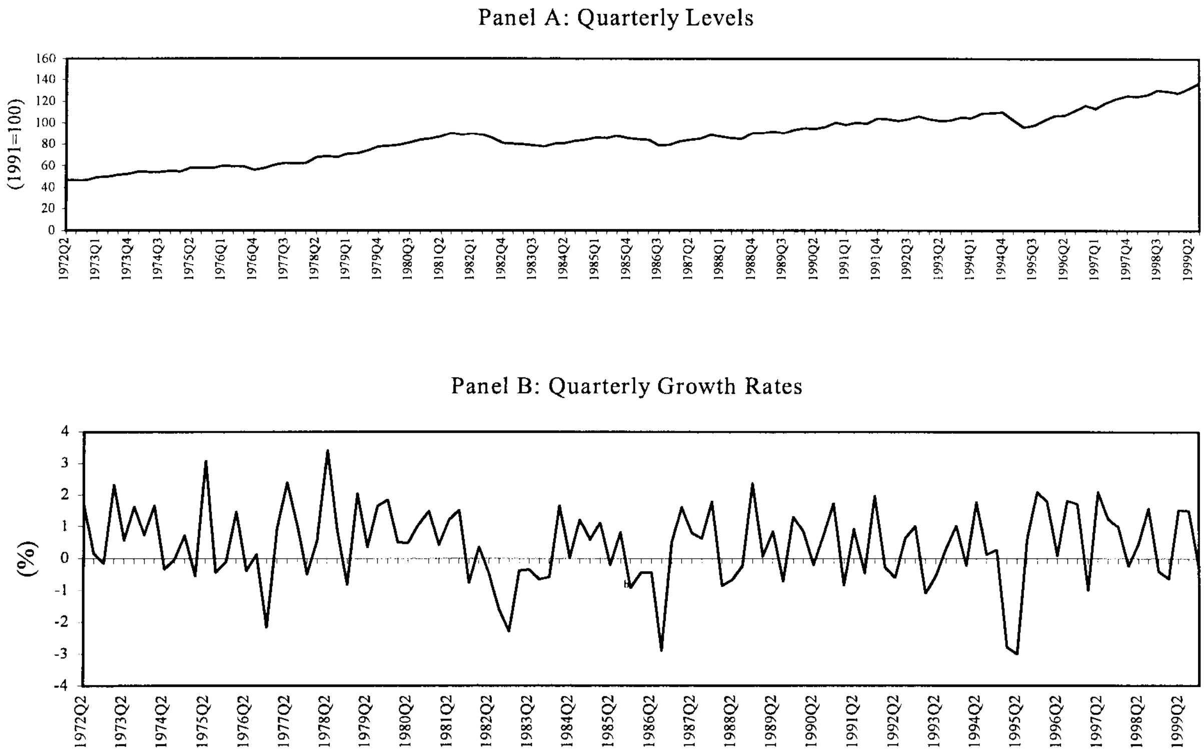
Table 2. Mexico: Expected Signs for the Effects of Fiscal, Financial and External Sector Indicators on the Transition Probabilities P_{11t} and P_{22t}

Indicator	Effect on p_{11t}	Effect on p_{22t}
1-Fiscal sector		
defgdp	+	-
2-Financial sector		
M1	+	-
multiplier	+	-
deposits	+	-
realint	-	+
stocks	+	-
cps	+	-
3-External sector		
3.1-Current account		
RER	+	-
imports	+	-
exports	+	-
tot	+	-
3.2-Capital account		
reserves	+	-
m2res	-	+
stres	-	+
totaldebt	+ -	- +
USrealint	-	+
realdif	-	+
4-Composite Index	-	+

Source: Table A.1

Note: The indicators are: defgdp=public sector borrowing requirement (last 12-months), percent of GDP (last 12 months); M1=deviations of M1 from a money demand function; multiplier=money multiplier (M1/base reserve), 12-month percent change; deposits=bank deposits, percent of GDP (last 12 months); realint=real interest rate on time deposits; stocks=stock index deflated by CPI, 12-month percent change; cps=credit to the private sector, percent of GDP (last 12 months); RER=deviations of the real exchange rate from its equilibrium value, where an increase in the deviations implies a real depreciation of the local currency and vice-versa.; imports=imports of goods and services, 12-month percent change; exports=exports of goods and services, 12-month percent change; tot=terms of trade, 12-month percent change; reserves=reserves, 12-month percent change; m2res=ratio M2/reserves, 12-month percent change; stres=ratio short-term debt/total external debt, 12-month percent change; U.S.realint= U.S. real interest rate; realdif=Mexican-U.S. real interest rate differential; and composite index=first principal component of the fiscal, financial, and external indicators in Table 1.

Figure 2. Mexico: Industrial Production Index (SA), 1972:Q2–99:Q3
Levels and Growth Rates



Source: IMF, *International Financial Statistics*.

Table 3 reports maximum likelihood estimates for the parameters in the constant and the time-varying transition probability models, their corresponding t-statistics, and the likelihood ratio tests for the null hypothesis that the time-varying transition probability models are not statistically different from the constant ones.[14] If an indicator does not contain any information that helps predict business cycles, the coefficients Φ_{11} and Φ_{21} in the time-varying transition probabilities are not statistically different from zero and the likelihood ratio statistic test does not reject the null hypothesis that the time-varying model is statistically equivalent to the constant one.

[14] We undertake the estimations of the many statistical models in this section with GAUSS. The GAUSS code implemented for the estimations is a modified version of the routines maxseek and procs provided by James Hamilton. These routines incorporate changes to allow time-varying transition probabilities. The algorithm used for maximization of the likelihood function is BFGS. We perform about 1,400 estimations with different initial parameters for each model. The reported estimates in Table 5 correspond to the local maxima with the highest likelihood.

Table 3. Mexico: Maximum-Likelihood Estimates for a Two-State Regime-Switching Model, 1972:Q2-99:Q3

	Constant transition probabilit.	Time varying transition probabilities																	
		Fiscal sector	Financial sector						External sector										Composite Index
									Current account				Capital account						
		defgdp	DC	multiplier	deposits	realint	stock	cps	RER	imports	exports	tot	reserves	m2res	sttotaldebt	totaldebt	USrealint	realdif	
g_1	0.71	0.71	0.74	0.78	0.80	0.68	0.70	0.68	0.66	0.63	0.60	0.71	0.66	0.70	0.69	0.62	0.70	0.69	0.70
	(6.91)	(6.98)	(6.50)	(8.05)	(2.07)	(6.67)	(7.49)	(6.91)	(5.83)	(7.21)	(7.08)	(6.98)	(7.19)	(6.76)	(7.12)	(7.35)	(6.50)	(6.91)	(7.42)
g_2	-1.11	-1.10	-1.01	-0.99	-0.90	-1.20	-1.09	-1.14	-1.17	-1.98	-2.23	-1.11	-1.56	-1.10	-1.13	-1.78	-1.11	-1.16	-1.09
	(3.17)	-(3.24)	-(3.10)	(3.54)	-(1.64)	(2.78)	-(3.40)	(3.16)	-(3.13)	(2.91)	(3.66)	-(3.27)	(2.35)	(2.87)	(3.13)	-(3.37)	-(3.18)	(2.96)	-(3.20)
β_1	-0.20	-0.19	-0.19	-0.26	-0.16	-0.19	-0.19	-0.19	-0.19	-0.19	-0.14	-0.21	-0.17	-0.20	-0.20	-0.18	-0.18	-0.19	-0.19
	(1.73)	-(1.61)	-(1.53)	(2.09)	-(0.89)	(1.63)	-(1.65)	(1.63)	-(1.67)	(1.67)	(1.36)	-(1.72)	(1.40)	(1.68)	(1.70)	-(1.66)	-(1.46)	(1.67)	-(1.56)
β_2	-0.22	-0.21	-0.22	-0.27	-0.28	-0.21	-0.22	-0.21	-0.21	-0.13	-0.13	-0.23	-0.16	-0.22	-0.22	-0.15	-0.20	-0.21	-0.21
	(1.99)	-(1.87)	-(1.90)	(2.29)	-(0.96)	(1.81)	-(1.99)	(1.94)	-(2.07)	(1.09)	(1.17)	-(1.97)	(1.41)	(1.92)	(1.98)	-(1.43)	-(1.78)	(1.88)	-(1.91)
σ_1	0.97	0.98	0.98	0.95	0.95	1.00	0.99	1.00	1.01	0.99	1.01	0.98	1.00	0.99	0.99	1.01	0.99	0.99	0.99
	(12.49)	(12.58)	(12.07)	(12.39)	(5.16)	(12.55)	(12.87)	(12.55)	(11.31)	(13.27)	(13.93)	(12.11)	(12.81)	(12.46)	(12.56)	(13.65)	(11.81)	(12.62)	(12.85)
Φ_{10}	2.70	3.08	2.64	2.46	0.99	2.57	2.81	4.43	4.14	2.41	2.51	2.69	2.75	2.81	2.80	3.60	3.23	2.50	3.15
	(4.10)	(2.50)	(2.13)	(4.30)	(0.19)	(3.95)	(4.02)	(2.35)	(1.69)	(3.84)	(3.37)	(4.22)	(3.00)	(3.76)	(4.28)	(4.64)	(2.27)	(3.66)	(3.47)
Φ_{11}		0.07	-0.02	-0.03	0.06	-0.07	0.01	-0.09	0.18	0.05	0.11	-0.02	0.06	-0.01	0.01	-0.02	-0.22	-0.04	-0.19
		(0.46)	-(0.23)	-(1.47)	(0.31)	-(0.88)	(0.85)	-(1.10)	(1.12)	(1.87)	(2.17)	-(0.39)	(1.83)	-(0.58)	(0.64)	-(1.48)	-(0.78)	-(0.64)	-(1.47)
Φ_{20}	0.62	-0.25	-1.52	0.51	-5.03	0.65	0.60	0.89	0.79	-0.40	-0.39	0.52	-0.51	0.51	0.78	7.99	-1.04	0.65	-0.08
	(0.93)	-(0.20)	-(0.75)	(0.82)	-(0.89)	(0.86)	(0.76)	(0.57)	(0.94)	-(0.36)	-(0.37)	(0.70)	-(0.32)	(0.69)	(0.98)	(0.86)	-(0.61)	(0.81)	-(0.09)
Φ_{21}		-0.11	0.19	-0.03	0.26	0.02	-0.02	-0.01	-0.02	0.02	-0.01	-0.01	-0.01	0.01	0.02	-0.12	0.34	0.00	0.10
		-(0.78)	(1.08)	-(1.06)	(1.01)	(0.30)	-(1.08)	-(0.11)	-(0.10)	(0.43)	-(0.28)	-(0.28)	-(0.27)	(0.40)	(0.47)	-(0.83)	(1.09)	(0.04)	(0.89)
Loglikelil	-68.15	-67.57	-67.48	-67.35	-67.37	-67.53	-66.75	-67.58	-65.91	-67.34	-66.08	-68.15	-65.56	-67.88	-68.00	-67.09	-66.70	-67.54	-65.68
LR test	--	1.16	1.34	1.59	1.56	1.23	2.81	1.13	4.49	1.63	4.15	0.01	5.19	0.53	0.30	2.13	2.91	0.43	4.95

Notes:

i) The indicators are: defgdp=public borrowing sector requirement (last 12-months), percentage of GDP (last 12 months); DC=domestic credit, 12-month change as percentage of GDP (last 12 months); multiplier=Money multiplier (M1/base reserve), 12-month percentage change; deposits=bank deposits, percentage of GDP (last 12 months); realint=real interest rate on time deposits; stocks=stock index deflated by CPI, 12-month percentage change; cps=credit to the private sector, percentage of GDP (last 12 months); RER=deviations (two lags) of the real exchange rate (Peso/US$) from its equilibrium value; imports=imports of goods and services, 12-month percentage change in the last quarter; exports=exports of goods and services, 12-month percentage change; tot=terms of trade, 12-month percentage change; reserves=reserves, 12-month percentage change; m2res=ratio M2/reserves, 12-month percentage change; sttotaldebt=ratio short-term debt/total external debt, 12-month percentage change; USrealint= U.S. real interest rate; realdif=Mexican-U.S. real interest rate differential; and composite index=first principal component of the fiscal, financial, and external indicators in Table 1;

ii) The transition probabilities are equal to: $p_{11t}=\exp(\Phi_{10}+\Phi_{11}*\text{indicator})/(1+\exp(\Phi_{10}+\Phi_{11}*\text{indicator}))$; $p_{22t}=\exp(\Phi_{20}+\Phi_{21}*\text{indicator})/(1+\exp(\Phi_{20}+\Phi_{21}*\text{indicator}))$;

iii) The critical values for the chi-squared distribution with 2 degrees of freedom, at the 5 percent and 10 percent levels, are equal to 5.99 and 4.60, respectively; and

iv) Numbers in parentheses are t-statistics.

For the constant transition probability model, phases of contraction and expansion in Mexico are asymmetric. In times of expansion industrial production grows at average rate of 0.7 percent per quarter. In periods of contraction industrial production decreases at the average rate of 1.2 percent per quarter. Recessions are thus deeper than expansions. The estimates for the constant transition probabilities p_{11} and p_{22} are equal to 0.94 and 0.65, respectively, and are plotted as straight lines in the first panel of Figure 3. These values for the transition probabilities imply higher degree of reversion from a recession to an expansion (p_{21}=1-0.65=0.35) than vice-versa (p_{12}=1-0.94=0.06). In addition, the expected duration of expansions in Mexico is:

$$(1-p_{11})^{-1} = (1-0.94)^{-1} = 16.6 \text{ quarters,} \tag{9}$$

while the expected duration of contractions is:

$$(1-p_{22})^{-1} = (1-0.66)^{-1} = 2.94 \text{ quarters.} \tag{10}$$

Figure 4 plots smoothed probabilities for state 1 or the expansionary state. Smoothed probabilities represent "the smoothed inference about the regime process was in at date t based on data obtained through some later date T."[15] If expansion is defined as a period when smoothed probabilities exceed 0.5 as in Hamilton (1989), then we can use these probabilities to construct a business cycle chronology in Mexico and compare it with other chronologies. Table 4 reports those comparisons.

The first two columns in Table 4 contain peaks and troughs in business cycles computed by the Federal Reserve Bank of Dallas (FRBD) and by the Center for International Business Cycle Research (CIBCR) and reported in Phillips, Vargas, and Zarnowitz (1996). We obtain the other columns by identifying the turning points in the smoothed probabilities for state 1 in Figure 4. The economy would be in an expansionary (recessionary) phase only when the smoothed probabilities for state 1 are greater than 0.5 (less than 0.5) for at least 2 quarters as in Layton (1996).[16] We observe that the chronology using the constant transition probabilities resembles the ones computed by the FRBD and the CIBCR. The only exceptions are the peak

[15] Hamilton (1994), p. 694. For further details, see Appendix II.

[16] Layton (1996) used monthly data. His criterion for defining a contraction was that if at least five of the smoothed probabilities in a row were less than 0.5. The translation of this monthly criterion into a quarterly criterion corresponds to at least two of the smoothed probabilities in a row being less than 0.5.

and the trough in the third quarters of 1993 and 1994, respectively.[17] Our univariate approach to business cycles thus performs well in terms of characterizing the inflection points of business cycles when compared to the results in Phillips, Vargas, and Zarnowitz (1996).

We then ask the following question: if business cycles in Mexico follow political cycles and financial crises, can fiscal, financial, and external sector indicators that track vulnerabilities in the external and banking sectors help us to obtain more precise characterizations of business cycles? We use the time-varying regime-switching econometric model in Filardo (1994) to answer this question. Table 3, column 2 to19, reports our results from estimations using our fiscal, financial, and external sector indicators. For the fiscal and financial indicators, the coefficients Φ_{11} and Φ_{21} are not statistically different from zero at the 5 percent level. In addition, likelihood ratio tests do not reject the null hypothesis that time-varying transition probability models with fiscal and financial indicators are equivalent to the model with constant transition probabilities. Thus, individually, our fiscal and financial indicators do not contain information that helps to characterize business cycles.

Inappropriate fiscal and financial indicators could be the cause of these weak results. Other financial and fiscal indicators may do a better job. In addition, it is rather surprising that financial indicators do not convey any information. In Mexico, asymmetric information and adverse selection problems increased after the 1990 stabilization and the following financial liberalization. The result was a financial boom, with excessive risk-taking by banks. The lending boom turned into loan losses and a deterioration of banks' balance sheets, with the consequent constraint on banks' ability to lend.

On the other hand, one external sector indicator, namely changes in the foreign exchange reserves, does perform well. The other external sector indicators do not add any statistically relevant information and the loglikelihood ratio statistics for these indicators do not reject the null hypothesis that the models with these indicators in the transition probabilities are equivalent to the model with constant transition probabilities. The coefficients Φ_{11} and Φ_{21} for reserves have the positive and negative signs, respectively. This implies that if foreign exchange reserves increase, the risk of currency crises decreases and the probability that the economy will remain in the expansionary state in the next period increases.

The composite index with our fiscal, financial, and external indicators contains as much information as reserves. The estimated signs for the coefficients Φ_{11} and Φ_{21} are negative and positive, respectively. An increase in the composite indicator leads to a decrease in the probabilities p_{11t} and $1-p_{22t}$. If the Mexican economy is in expansion at time t-1 and signs of a currency and banking crisis develop, the probability that the economy will remain in the expansionary state at time t decreases, while the probability of the economy entering a contractionary state increases.

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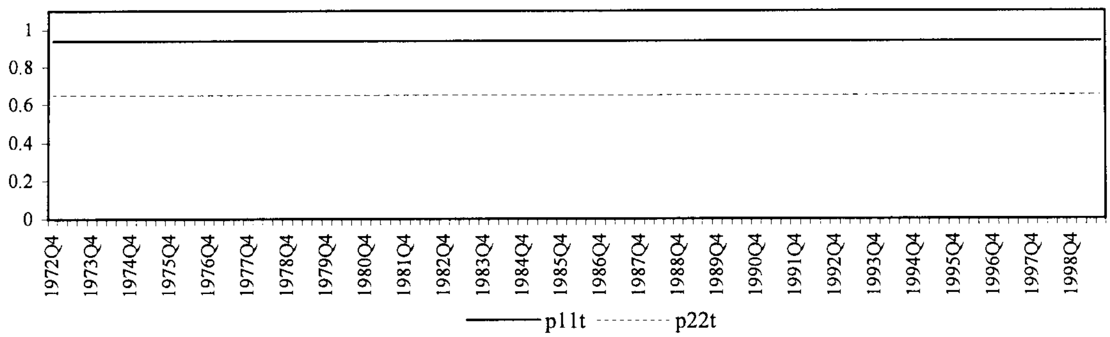
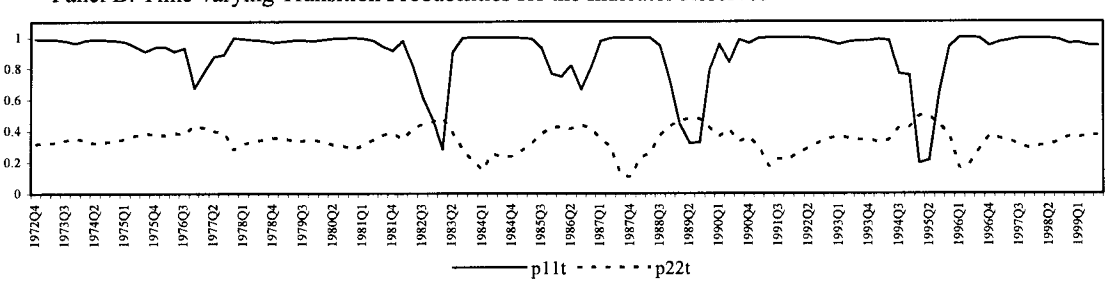
[17] Henriques, Sadorsky, and Verma (1998) reported that the 1993 recession in Mexico was different from the others because it was caused by a slowdown in natural resource intensive sectors.

Figure 3. Mexico: Constant and Time-varying Transition Probabilies p_{11t} and p_{22t} for the Indicator Reserves and the Composite Index, 1972:Q2–93:Q3

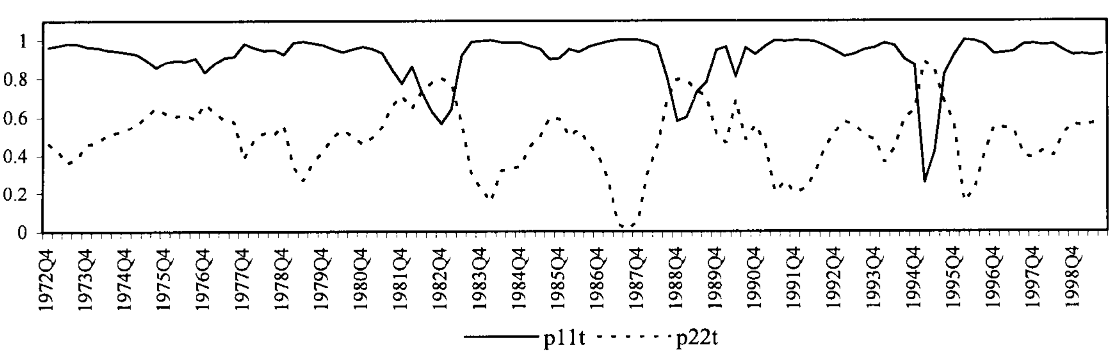
Panel A: Constant Transition Probabilities



Panel B: Time-varying Transition Probabilities for the Indicator Reserves



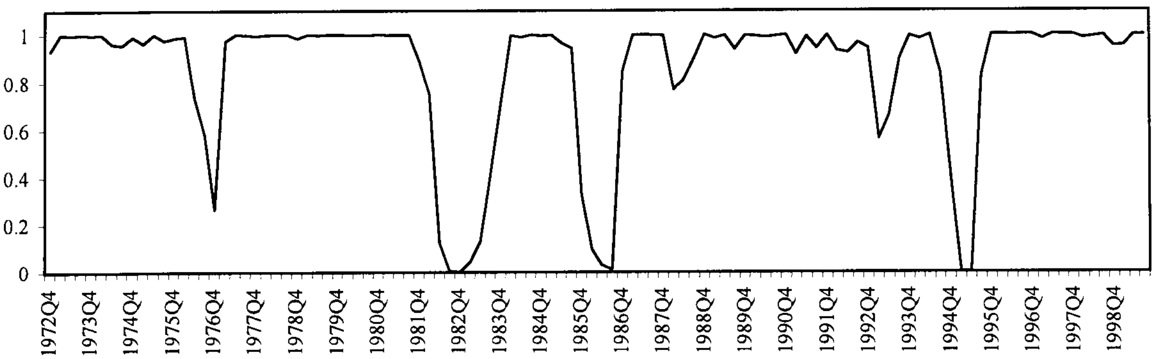
Panel C: Time-varying Transition Probabilities for the Composite Index



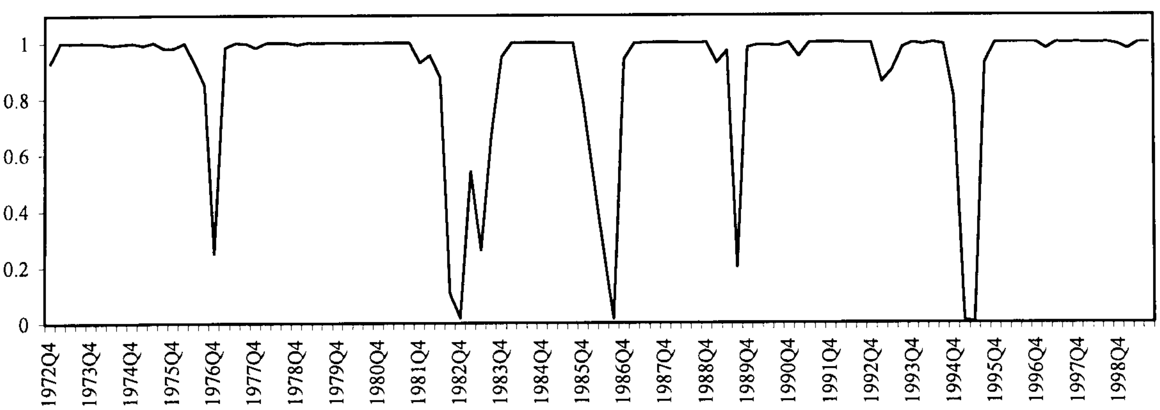
Note: The indicators are: reserves=reserves, 12-month % change; and composite index= first principal component of the fiscal, financial, and external indicators in Table 1.
The transition probabilities are computed as:
$p_{11t}=\exp(\Phi_{10}+\Phi_{11}*\text{indicator})/(1+\exp(\Phi_{10}+\Phi_{11}*\text{indicator}))$ and
$p_{22t}=\exp(\Phi_{20}+\Phi_{21}*\text{indicator})/(1+\exp(\Phi_{20}+\Phi_{21}*\text{indicator}))$.

Figure 4. Mexico: Smoothed Probabilies for the Expansionary State, Computed with Constant and Time-varying Transition Probabilities (TVTP) for the Indicator Reserves and the Composite Index, 1972:Q2–93:Q3

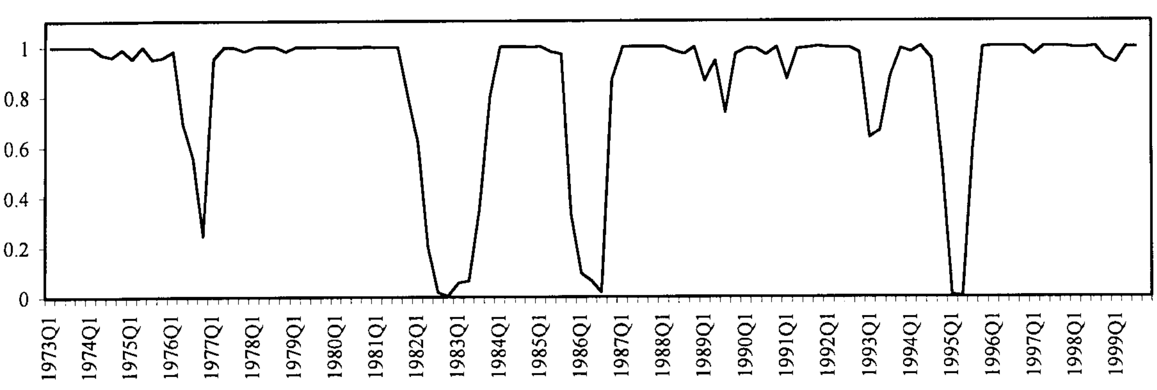
Panel A: Smoothed Probabilities Computed with Constant Transition Probabilities



Panel B: Smoothed Probabilities Computed with TVTP and the Indicator Reserves



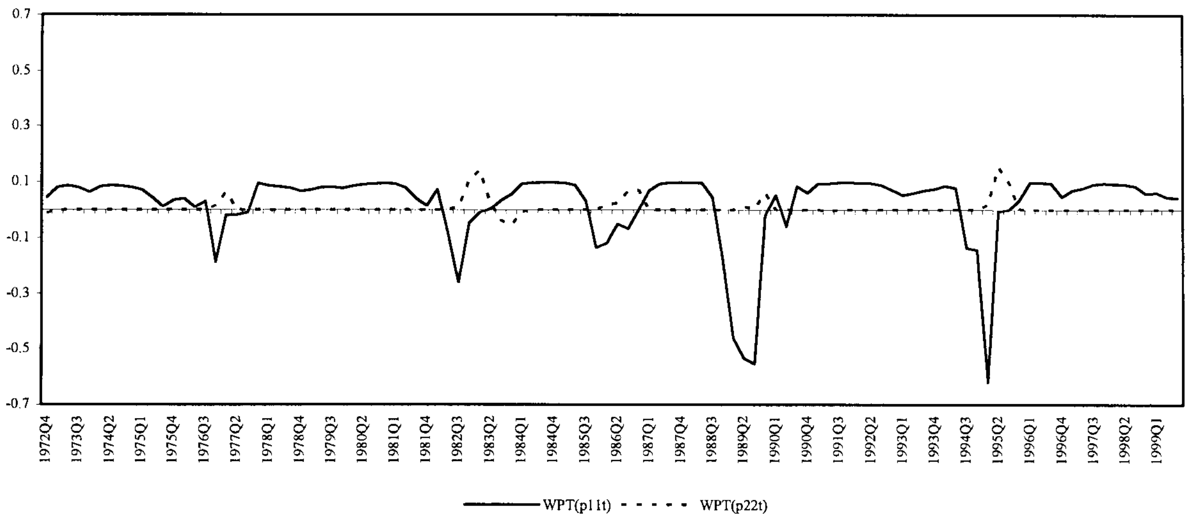
Panel C: Smoothed Probabilities Computed with TVTP and the Composite Index



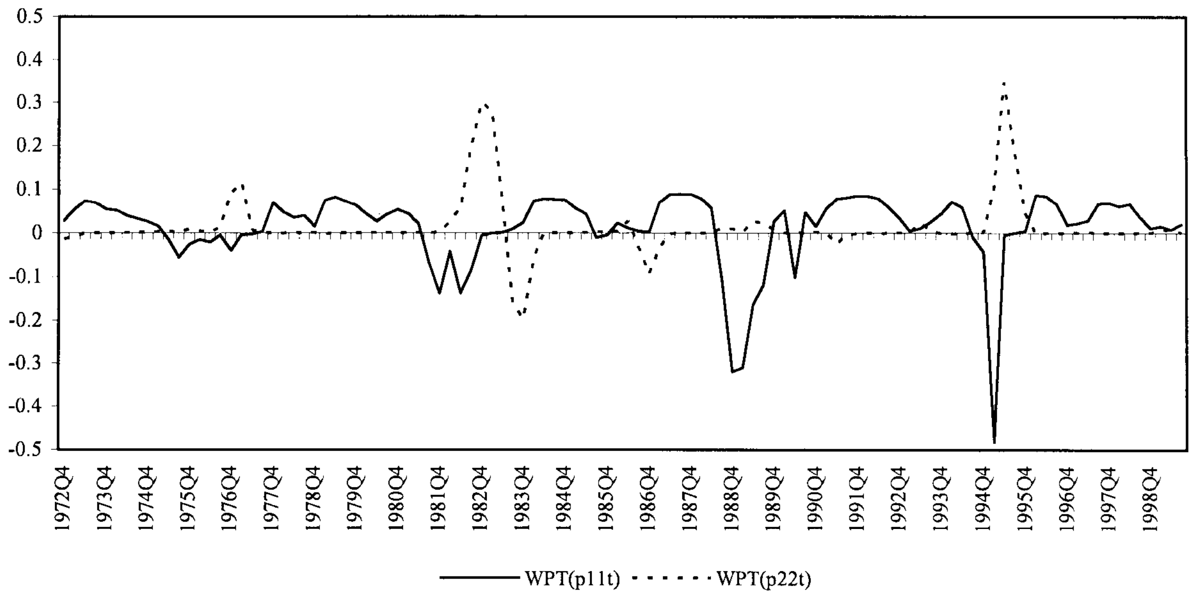
Note: The indicators are: reserves=reserves, 12-month % change; and composite index=first principal component of the fiscal, financial, and external indicators in Table 1.

Figure 5. Mexico: Weighted Transition Probabilities WTP(p_{11t}) and WTP(p_{22t}) for the Indicator Reserves and the Composite Index, 1972:Q2-99:Q3

Panel A: Weighted Transition Probabilities WTP(p_{11t}) and WTP(p_{22t}) for the Indicator Reserves



Panel B: Weighted Transition Probabilities WTP(p_{11t}) and WTP(p_{22t}) for the Composite Index



Source: Figure 3

Note: The indicators are: reserves=reserves, 12-month % change; and composite index=first principal component of the fiscal, financial, and external indicators in Table 1.

Time-varying transition probabilities for the foreign exchange reserves indicator and the composite index are plotted in Figure 3. The time-varying transition probability p_{11t} for both indicators shows some downward spikes, which roughly correspond to the periods of crises in September 1976, February 1982, December 1984, and December 1994. The transition probability p_{22t} for reserves does not vary as much as the probability p_{11t} in the period from the second quarter of 1972 to the third quarter of 1999. However, for the composite index indicator, the transition probability p_{22t} is close to zero in the third quarter of 1987. This implies that the expansionary state is an absorbing state in the sense that the set of possible states for the next period does not include the recessionary state.

Table 4. Mexico: Turning Points in Business Cycles

Dallas Fed Index		CIBCR Index		Smoothed Probabilities					
				Constant TP		Time-varying TP			
						Reserves		Composite Index	
Peak	Trough	Peak	Trough	Peak	Trough	Peak	Trough	Peak	Trough
Q4 1981		Q4 1981		Q1 1982		Q2 1982		Q1 1982	
	Q2 1983		Q3 1983		Q3 1983		Q2 1983		Q3 1983
Q3 1985		Q3 1985		Q3 1985		Q1 1986		Q3 1985	
	Q4 1986		Q4 1986		Q3 1986		Q3 1986		Q3 1986
Q3 1992		Q4 1992		...		...		...	
	Q3 1993		Q3 1993		...		...		...
Q4 1994		Q3 1994		Q3 1994		Q4 1994		Q4 1994	
	N.A.		N.A.		Q2 1995		Q2 1995		Q2 1995

Source: Phillips, Vargas, and Zarnowitz (1996) and Figure 3.

Note: The indicators are: reserves=reserves, 12-month percent change; and composite index=first principal component of the fiscal, financial, and external indicators in Table 1.

The chronologies generated by the time-varying transition probabilities with reserves and the composite index are also similar to the FRBD and the CIBCR. With the exception of the third quarter of 1993 and 1994, the number of peaks and troughs in the time-varying transition probabilities chronology is the same as in the FRBD and the CIBCR chronologies. However, the turning points are slightly different, with either a lead or a lag of one quarter. Yet, according to Figure 4, smoothed probabilities for the expansionary state in the first and second quarter of 1993 are around 60 percent for the composite index, a drop from the 99 percent level in the previous quarters. This is a sign of a mild recession in those two quarters.

Comparing our results with other econometric methodologies shows that, as pointed in Diebold and Rudebusch (1996), only regime-switching models provide the framework where the concept of turning points is meaningful. Acevedo and others (2001) identified the permanent and cyclical components of growth cycles in Mexico using the Hodrick-Prescott filter and structural vector autoregressions. Their estimates of the potential real GDP and output gap led to the periods of expansion from 1980:Q1 to 1982:Q2 and from 1991:Q1 to

1994:Q1, when average actual real GDP growth exceeded potential real GDP by 1.7 and three-fourths of a percentage point, respectively. Since the output gap measures the difference between actual and potential real GDP growth rates, both negative and small positive values for actual GDP growth rate imply fewer periods of expansion than the ones computed with regime switching models.

To assess the marginal contribution of the time-varying transition probabilities, Filardo (1994) suggested the weighted transition probabilities. These weighted transition probabilities take into account the fact that the time variation for $p_{11t}=p(s_t=1|s_{t-1}=1, x_t)$ or $p_{11t}=p(s_t=2|s_{t-1}=2, x_t)$ is only important when the previous state in the economy is $s_{t-1}=1$ or $s_{t-1}=2$. In addition, they also subtract the mean of the transition probabilities since we are only interested in the marginal contribution of the time varying transition probabilities. For p_{11t}, the weighted transition probability then is:

$$WTP\left(p_{11t}\right)=\left(p_{11t}-\overline{p}\right).p(s_{t-1}=1\,|\,I_{t-2},x_{t-1})\,, \qquad (11)$$

where $p(s_{t-1}=1|I_{t-2}, x_{t-1})$ is the regime probability of being in state 1 at time t-1; and for p_{22t}, the weighted transition probability is:

$$WTP\left(p_{22t}\right)=\left(p_{22t}-\overline{p}\right).p(s_{t-1}=2\,|\,I_{t-2},x_{t-1}), \qquad (12)$$

where $p(s_{t-1}=1|I_{t-2}, x_{t-1})$ is the regime probability of being in state 2 at time t-1.[18]

Figure 5 plots the weighted transition probabilities for both reserves and the composite index. The marginal contribution of time-varying transition probabilities is the deviations from zero. Spikes in the weighted transition probability $WTP(p_{11t})$ for both reserves and the composite index correspond to the peaks in Table 4. On the other hand, the spikes in the weighted transition probability $WTP(p_{22t})$ are only clear for the composite index. Therefore, Figure 5 provides evidence that reserves and a combination of fiscal, financial, and external sector indicators do contain helpful information about Mexican business cycles.

VI. Conclusions

We use the regime-switching econometric methodology to analyze Mexican business cycles from 1972 to 1999. Specifically, we estimated constant and time-varying transition probability models as in Hamilton (1989) and Filardo (1994), respectively. For the time-varying transition probability model, we allowed the transition probabilities to be a function of fiscal, financial, and external sector indicators.

We obtained interesting results. First, estimates for the positive and negative industrial production growth rates in all models show deeper recessions than expansions in Mexico.

[18] See Appendix II.

However, for the model with constant transition probabilities, estimates for these probabilities show that recessions are shorter than expansions. Second, the Mexican economy moved from an expansion to a recession in 1982, 1985–86, and 1994 and from a recession to an expansion in 1983, 1986, and 1995. This chronology of expansions and recessions closely resembled the results of other researchers.[19] Finally, our smoothed probabilities did capture the inflection points in business cycles, except in the third quarters of 1993 and 1994

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[19] In particular, the results resembled the ones by the Federal Reserve Bank of Dallas (FRBD) and by the Center for International Business Cycle Research (CIBCR) and reported in Phillips, Vargas, and Zarnowitz (1996).

Mexico: Data Sources, 1972:Q2–99:Q3

	Sector	Shortcut	Units	Source
1	Fiscal sector			
1.a	Public sector borrowing requirement (last 12 months), percentage of GDP (last 12 months)	cgovgdp		
	Public sector borrowing requirement		Pesos (millions)	Banco de Mexico
	Gross domestic product (interpolated)		Pesos (billions)	IMF, *International Financial Statistics*
2	Financial sector			
2.a	Deviations of M1 from a money demand function	M1		
	Money		Pesos (millions)	IMF, *International Financial Statistics*
	Consumer price index		Percent per annum	IMF, International Financial Statistics
	HHLD consumption expenditures, including NPISHS		Pesos (billions)	IMF, *International Financial Statistics*
2.b	Money multiplier (M/Reserves), 12-month percent change	multiplier		
	Money		Pesos (millions)	IMF, *International Financial Statistics*
	Reserve money		Pesos (millions)	IMF, *International Financial Statistics*
2.c	Bank deposits, percentage of GDP (last 12 months)	deposits		
	Demand deposits		Pesos (millions)	IMF, *International Financial Statistics*
	Time, savings, and currency deposits		Pesos (millions)	IMF, *International Financial Statistics*
	Gross domestic product (interpolated)		Pesos (billions)	IMF, *International Financial Statistics*
2.d	Real interest rate on deposits	realint		
	3-month deposit rate		Percent per annum	Global Financial Database
	Consumer price index		Percent per annum	IMF, International Financial Statistics
2.e	Stock index deflated by CPI, 12-month percent change	stocks		
	From 1972:Q2 to 1975:Q4:			
	Industrial share prices		Index number	IMF, *International Financial Statistics*
	Exchange rate (end-of-period)		Pesos per U.S. dollar	IMF, *International Financial Statistics*
	From 1975:Q1 to 2000:Q3			
	S&P/IFCG-M price index (US$)		Index number	Datastream
	Consumer price index		percent per annum	IMF, *International Financial Statistics*
2.f	Credit to the private sector, percent of GDP (the last 12 months)	cps		
	Domestic credit		Pesos (millions)	IMF, *International Financial Statistics*
	Claims on central government (net)		Pesos (millions)	IMF, *International Financial Statistics*
	Gross domestic product (interpolated)		Pesos (billions)	IMF, *International Financial Statistics*
3	External sector			
3.1	Current account			
3.1.a	Deviations of the real exchange rate (peso/US$) from its equilibrium value	rer		
	Relative price of exports to consumer price		Index number	Dabós and Juan-Ramón (2000)
	Ratio of net capital flows to GDP		Percent	Dabós and Juan-Ramón (2000)
	External terms of trade		Index number	Dabós and Juan-Ramón (2000)
3.1.b	Imports in goods and services, 12-month percent change	impres		
	Imports		U.S. dollars (thousand)	Banco de Mexico
3.1.c	Exports in goods and services, 12-month percent change	exports		
	Exports		U.S. dollars (thousand)	Banco de Mexico
3.1.e	Terms of trade, 12-month percent change			
	Terms-of-trade index		Index number	Banco de Mexico
3.2	Capital account			
3.2.a	Reserves, 12-month percent change	reserves		
	Gold in million ounces		Fine troy ounces (millions)	IMF, *International Financial Statistics*
	Gold London average second fixing		U.S. dollars per Ounce	IMF, *International Financial Statistics*
	Total reserves minus gold		U.S. dollars (millions)	IMF, *International Financial Statistics*
	Exchange rate (end-of-period)		Pesos per U.S. dollar	IMF, *International Financial Statistics*

Mexico: Data Sources, 1972:Q2–99:Q3 (continued)

	Sector	Shortcut	Units	Source
3.2.b	Ratio M2/Reserves, 12-month percent change	m2res		
	Money		Pesos (millions)	IMF, *International Financial Statistics*
	Quasi-money		Pesos (millions)	IMF, *International Financial Statistics*
	Gold in million ounces		Fine troy ounces (millions)	IMF, *International Financial Statistics*
	Gold London average 2nd fixing		U.S. dollars per ounce	IMF, *International Financial Statistics*
	Total reserves minus gold		U.S. dollars (millions)	IMF, *International Financial Statistics*
	Exchange rate (end-of-period)		Pesos per U.S. dollar	IMF, *International Financial Statistics*
3.2.c	Ratio short-term debt/Total debt, 12-month percent change	stres		
	Short-term debt outstanding (interpolated)			
	From 1972:Q2 to 1990:Q4 (interpolated):		U.S. dollars	World Bank Global Development Finance
	From 1991:Q1 to 1999:Q2		U.S. dollars	Bank for International Settlements
	Gold in million ounces		Fine troy ounces (millions)	IMF, *International Financial Statistics*
	Gold London average 2nd fixing		U.S. dollars per ounce	IMF, *International Financial Statistics*
	Total reserves minus gold		U.S. dollars (millions)	IMF, *International Financial Statistics*
3.2.d	Ratio total external debt/GDP (last 12 months), 12-month percentage change	totaldebt		
	Total debt stock until 1998		U.S. dollars	World Bank Global Development Finance
	Total debt stock in 1999		U.S. dollars	IMF, World Economic Outlook
	Exchange rate (end-of-period)		Pesos per U.S. dollar	IMF, *International Financial Statistics*
	Gross domestic product (interpolated)		Pesos (billions)	IMF, *International Financial Statistics*
3.2.e	U.S. real interest rate	USrealint		
	U.S. 3-month certificate of deposit (secondary market)		Percent per annum	Federal Reserve Board
	U.S. consumer price index		Index number	IMF, *International Financial Statistics*
3.2.f	Mexican-U.S. real interest rate differential	intdif		
	Mexican 3-month deposit rate		Percent per annum	Global Financial Database
	Mexican consumer price index		Percent per annum	IMF, *International Financial Statistics*
	U.S. 3-month certificate of deposit (secondary market)		Percent per annum	Federal Reserve Board
	U.S. consumer price index		Index number	IMF, *International Financial Statistics*
4	4-Economic activity			
4.a.	IPI, quarterly percentage change	ipi		
	Industrial production index		Index number	IMF, *International Financial Statistics*

Maximum Likelihood Estimation of Regime-Switching Models

The parameters g_1, g_2, Φ_1, Φ_2, N_1, N_2, N_3, ... ,N_q, and the elements in vectors M_{11} and M_{22} (all comprised in the vector 2) can be estimated by the filter described in Hamilton (1994):

(i) the joint density function of y_t and s_t is computed by multiplying the conditional density of y_t by the filter probabilities:

$$f(y_t, s_t, ..., s_{t-q}, | I_{t-1}, x_t; \theta) = f(y_t | s_t, ..., s_{t-q}, I_{t-1}; \theta).p(s_t, ..., s_{t-q}, | I_{t-1}, x_t; \theta) \qquad (13)$$

where I_{t-1} is the information set at time t-1 and the conditional density function $f(y_t|s_t,\ldots, s_{t-q},I_{t-1}; 2)$ is the Normal distribution:

$$f(y_t | s_t, ..., s_{t-q}, I_{t-1}; \theta) = \frac{1}{\sqrt{2\pi\sigma_{st}^2}} \exp\left(\frac{\left(y_t - g_{s_t} - \sum_{i=1}^{q} \beta_i \left(y_{t-i} - g_{s_{t-i}} \right) \right)^2}{2\sigma_{st}^2} \right) \qquad (14)$$

(ii) the sum of the joint density functions over all states s_t yields the unconditional density function of y_t:

$$f(y_t | I_{t-1}, x_t; \theta) = \sum_{s_t=1}^{2} \sum_{s_{t-1}=1}^{2} \cdots \sum_{s_{t-q}=1}^{2} f\left(y_t, s_t, ..., s_{t-q} | I_{t-1}, x_t; \theta\right) \qquad (15)$$

(iii) to update filter probabilities, the following Bayesian rule is used:

$$p(s_t, ..., s_{t-q} | I_t; \theta) = \frac{f(y_t, s_t, ..., s_{t-q} | I_{t-1}, x_t; \theta)}{f(y_t | I_{t-1}, x_t; \theta)} \qquad (16)$$

(iv) finally, filter probabilities at time t+1 are obtained by multiplying the updated probability $p(s_t,\ldots,s_{t-q}|I_t; 2)$ by the transition probability $p(s_{t+1}|s_t, x_{t+1})$:

$$p(s_{t+1}, s_t, ..., s_{t-q} | I_t, x_{t+1}; \theta) = p(s_{t+1} | s_t, x_{t+1}).p(s_t, ..., s_{t-q} | I_t; \theta) \qquad (17)$$

where:

$$p(s_{t+1} | s_t, x_{t+1}) = \frac{\exp(x_{t+1}'.\Phi_{stst+1})}{1 + \exp(x_{t+1}'.\Phi_{stst+1})} \qquad (18)$$

and then summing over s_{t-q}:

$$p(s_{t+1},\ldots,s_{t-q+1)} \mid I_t, x_{t+1};\theta) = \sum_{s_{t-q}=1}^{2} p(s_{t+1},\ldots,s_{t-q} \mid I_t, x_{t+1};\theta) \qquad (19)$$

Our exogenous information variables are assumed to be uncorrelated with the contemporaneous state. Violation of this condition implies that Hamilton's filtering method cannot be extended to time-varying transition probability models, hence other methods need to be used.

As a by-product of steps (i) and (ii), the sample log-likelihood can be computed:

$$L(\theta) = \sum_{t=1}^{T} \log(f(y_t \mid I_{t-1}, x_t;\theta)) \qquad (20)$$

To minimize the number of multiple solutions – that is, the number of local maxima – extra terms that represent prior information about the means g_k and variances Φ_k are added to the log-likelihood function as in Hamilton (1991):

$$L(\theta) = \sum_{t=1}^{T} \log(f(y_t \mid I_{t-1}, x_t;\theta)) - \sum_{k=1}^{2} (a_k/2)\log\sigma_k^2 - \sum_{k=1}^{2} b_k/(2\sigma_k^2) - \sum_{k=1}^{2} c_k\,(m_k - g_k)/(2\sigma_k^2) \qquad (21)$$

where m_k is the prior expectation for g_k, the ratio b_k/a_k is the prior for Φ_k, and the parameters a_k and c_k are the weights placed on priors.

Given the last regime probabilities $p(s_T|I_T;2)$, smoothed probabilities are obtained through the following algorithm:

$$P(s_t \mid I_T;\theta) = P(s_t \mid I_t;\theta) \otimes [P'\cdot[P(s_{t+1} \mid I_T)(\div)P(s_{t+1} \mid I_t)]] \qquad (22)$$

where P(.|.) stands for a (2x1) vector of filter or smoothed probabilities and where the symbols θ and ()) stand for the multiplication and division of element by element in the vectors, respectively.

Estimation of the Deviations of the Real Exchange Rate from Its Equilibrium Value

This appendix estimates deviations of the real exchange rate from its equilibrium value and is based on Dabós and Juan-Ramón (2000). They suggested the following econometric model:

$$RERX_t = \beta_0 + \beta_1 ky_t + \beta_2 ETT_t + \beta_3 PRO_t + u_t , \tag{23}$$

where RERX is the log of the relative price of exports to consumer prices; ky is ratio of the net capital flow to GDP; ETT is the log of the external terms of trade; and PRO is a trend variable that captures increases in productivity.

Table A1. Mexico: Aumented Dickey-Fuller (ADF) Test for the Order of Integreation of the Relative Price of Exports to Consumer Price, the Ratio of Net Capital Inflows to Gross Domestic Product, and Terms of Trade, 1971:Q3-99:Q2

Variable	ADF Statistic	Critical Values at the 5 percent Level	Lags	Constant Included	Trend Included
ΔRERX	-5.25	-1.94	4	No	No
Δky	-4.75	-1.94	4	No	No
ΔETT	-5.85	-1.94	4	No	No
RERX	-2.46	-3.15	4	Yes	Yes
ky	-3.21	-2.89	4	Yes	No
ETT	-0.71	-2.89	4	Yes	No

Source: Dabós and Juan-Ramón (2000).

Table A.1 shows Augmented Dickey-Fuller tests applied on RERX and ETT. We reject the null hypothesis that these series are integrated of order 2, I(2), at the 5 percent level. These tests still reveal that both variables are integrated of order one, I(1). Then, there might exist a linear cointegration among them that is stationary and yields I(0) residuals.

As in Dabós and Juan-Ramón (2000), we use the Engle and Granger (1987) methodology to test for a long-run relationship. First, we regress RERX on ky, ETT, and PRO. Table A4.2 shows parameter estimates for this regression. Then, we apply the Augmented Dickey-Fuller test on the residuals of the regression. Table A4.3 shows our results of the latter test. We reject the null hypothesis that our regression residuals contain a unit root. This implies a stationary long-run relationship between RERX, ky, ETT, and PRO.

Table A2 . Mexico: Regression Estimates for the Equilibrium Real Exchange Rate Model, 1971:Q3-99:Q2

Variable	Parameter Estimates
Const.	0.16
	(8.13)
ky	-16.49
	(-17.72)
ETT	0.68
	(9.81)
Time trend	-0.0036
	(-5.69)

Source: Dabós and Juan-Ramón (2000).

Table A3. Mexico: Aumented Dickey-Fuller (ADF) Test for the Order of Integration of the Estimated Residuals in the Equation for the Equilibrium Real Exchange Rate , 1971:Q3-99:Q2

Variable	Test Value	5 % Critical Value	Lags	Constant Included	Trend Included
Residual	-4.98	-3.78	4	No	No

Source: Dabós and Juan-Ramón (2000).

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