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Do on/off time series models reproduce emerging stock market comovements?

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Abstract

Using nonlinear modeling tools, this study investigates the comovements between the Mexican and the world stock markets over the last three decades. While the previous works only highlight some evidence of comovements, our paper aims to specify the different time-varying links and mechanisms characterizing the Mexican stock market through the comparison of two nonlinear error correction models (NECMs). Our findings point out strong evidence of time-varying and nonlinear mean-reversion and links between Mexico and the world stock market, which reflects the significant development of Mexican stock market during the last decades. The specification of the nature of these links is interesting for investment decisions in emerging markets.

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1. Introduction

Emerging stock markets are considered since several years as an exciting and promising area for investment because they offer high returns and several good portfolio diversification opportunities. The financial liberalization of emerging markets and the implementation of several ongoing structural adjustment programs have increased their development. Emerging economies have recently shown macroeconomic stability, low inflation and reduced budget deficits. As a result, emerging market capitalization has grown from 4% of world market capitalization in 1987 to 13% in 1996, and it reached around 23% in 2008. These changes have increased the appetite of international investors and have particularly stimulated the comovements process between emerging and developed stock markets. However, as shown by Bekaert and Harvey (1995), emerging markets are not homogeneous and their financial dynamics differ significantly as they depend on both internal and external factors: international, regional and specific economic, financial and political variables.

In order to better understand the dynamics of emerging stock markets, this article focuses on a major emerging market which has increased in activity and relevance throughout the last two decades: Mexico. Mexico is the biggest Latin American market almost fully accessible to foreign investors. In fact, in the last two decades foreign investment barriers were reduced, country funds were introduced and depository receipts (DR) were listed in order to improve the comovements between Mexico and the world market. These comovements are particularly important since they should drive to a lower cost of capital, bigger investment opportunities and higher economic growth (Bekaert and Harvey, 2003). Therefore, the investigation of the stock market dynamics for Mexico should lead to a better view of investment opportunities in Mexico, while the specification of the comovements between Mexican and the World stock markets provides information about diversification and investment strategies.

Unlike previous studies on emerging stock market comovements (De Santis and Imrohoroglu, 1997; Gérard *et al.*, 2003; Adler and Qi, 2003; Phylaktis and Ravazzolo, 2004; Bekaert *et al*. 2005], our approach enables us to specify the nature of links between stock markets in a nonlinear framework over three last decades. It also allows testing whether the comovements are symmetric or asymmetric, continuous or discontinuous, constant or variable, and linear or nonlinear. It is clear that the answers to these questions are important because they help to improve the understanding of the comovement dynamics between emerging and developed stock markets, and thus to provide crucial tools for international portfolio diversification while taking into account different types of interdependence.

In the literature, several microeconomic and macroeconomic factors seem to justify the nonlinearity in stock price dynamics such as transaction costs (Dumas, 1992; Anderson, 1997), the information asymmetry and behavioral heterogeneity (De Grauwe and Grimaldi, 2006; Boswijk *et al.*, 2007). Indeed, these market imperfections may induce discontinuity and inertia effects in arbitrage preventing stock price adjustment to be instantaneous and linear. Interestingly, the nonlinear tools that we apply in this paper should identify different regimes of convergence and divergence between stock prices. This yields evidence of the different types of time-varying links between developed and emerging stock prices. Such findings are also important and should have several economic implications for investors to define for example their investment strategies. Indeed, while analyzing the coexistence of different regimes for which stock price comovements are or not activated according to the size of stock price deviations, the investors shall identify whether it is promising to invest in emerging markets or not. More the markets are divergent, more it is important to diversify. Thus, the advantage of nonlinearity is to define a dynamic adjustment process enabling investors to enter or not the market according to the investment opportunities and to the market state.

This article is organized according to the following outline. The second section will briefly discuss the literature review. The econometric tools will be briefly presented before discussing the empirical results in the third section. Finally, the last section will conclude.

2. Brief Literature Review

In the literature, several authors focus on financial integration between Mexico and developed stock markets using different tools and tests. For example, Bekaert and Harvey (1995), Adler and Qi (2003), and Carrieri *et al.* (2007) make use of the capital asset pricing model (CAPM). Overall, these studies show significant comovements between Mexico and the world market, they also point out a decrease in the links in 1994 (due to the Mexican crisis) and an increase over the last years. But, their results are rather mixed and relay on the validity of the CAPM.

Other empirical studies have tested stock market comovements using cointegration tests and VAR models (Masih and Masih, 2001; Lim *et al.*, 2003: Wang and Nguyen, 2007; and Iwatsubo and Inagaki, 2007; Arouri and Jawadi, 2010, etc.). Their main result is that the US market is the most influential market. They also note strong evidence of significant comovements between the stock prices in the long-run. Nevertheless, the weakness of these studies consists on the fixation of the level of comovements. Indeed, as comovements between emerging and developed markets are governed by ongoing liberalization processes, regional and international factors, we can expect an unstable spillover effects between these markets and the world market yielding to a time-varying interdependency. However, this may escape linear modeling and usual cointegration tools, which can only test for two polar cases of comovements and absence of comovements.

In this study, we investigate comovements between Mexico and the world stock market in a nonlinear framework. More precisely, we make use of the nonlinear cointegration methodology to take into account time-varying aspects of comovements as well as potential asymmetries and nonlinearities. This enables to reproduce the different states of stock market comovements.

3. Nonlinear time-varying Adjustment Models

We briefly present in this section the nonlinear cointegration models we use to capture comovements between Mexico and the world market. Indeed, the cointegration methodology has the advantage to enable to capture stock price comovements in the short and long-terms. Furthermore, the introduction of nonlinearity and switching regime hypotheses extend the usual framework implemented in previous studies to reproduce the different regimes and states of stock market comovements.

Formally, we retain two Nonlinear Error Correction Models (NECMs): the Exponential Smooth Transition ECM (ESTECM) and the nonlinear ECM-Rational Polynomial (NECM-RP) in order to appropriately characterize the comovements for Mexico and the world stock market.[1] These models constitute a conjunction of two linear ECMs, while including two adjustment terms and a nonlinear function, which is bounded between zero and one, defining two different regimes, while the transition between these regimes is determined according to the statistical properties of this nonlinear function. To define this function, Escribano (1997) recommends to use the function that satisfies the stability conditions such as the rational polynomial function, smoothing functions, etc. In practice, there are several types of NECMs depending on the definition of the nonlinear function. In this paper, we propose using two specific kinds of NECMs: the ESTECM (equation (1)) and the NECM-RP (equation (2)).

[1] We briefly discuss these modeling, but we can refer to Escribano and Mira (2002) and Van Dijk *et al.* (2002) for more details about these models.

$$\Delta y_t = \alpha_0 + \lambda_1 z_{t-1} + \sum_{i=0}^{q} \beta_i \, \Delta x_{t-i} + \sum_{j=1}^{p} \delta_j \, \Delta y_{t-j} + \lambda_2 z_{t-1} \times \left[1 - \exp\left\{ -\gamma \left(z_{t-1} - c \right)^2 \right\} \right] + \varepsilon_t \qquad (1)$$

$$\Delta y_t = \alpha_0 + \lambda_1 z_{t-1} + \sum_{i=0}^{q} \beta_i \, \Delta x_{t-i} + \sum_{j=1}^{p} \delta_j \, \Delta y_{t-j} + \lambda_2 \times \frac{(z_{t-1} + a)^3 + b}{(z_{t-1} + c)^2 + d} + \mu_t \qquad (2)$$

where: y_t is the endogenous variable and x_t is a vector of K explanatory variables that are I(1). β'_i and δ'_j are vectors of parameters, λ_1 and λ_2 are the adjustment terms, z_t is the residual term of the linear cointegration relationship between the Mexican stock index and the world equity market. γ and c are respectively the transition speed between regimes and the threshold parameter of the exponential function, whereas a, b, c and d are real numbers, defining the rational polynomial function.

To investigate the nature of comovements between Mexico and the World market, we propose to test the mixing hypothesis applying two mixing tests: the KPSS test and Lo's test (1991): the *R/S* test. Then, we model the adjustment dynamics of stock market comovements by these above NECMs. Both models presented in equations (1) and (2) serve to apprehend the dynamic of stock market comovements, while capturing at each date the error correction and mean-reversion mechanisms between stock markets under consideration. In particular, the main advantage of the ESTECM is to capture smooth and gradual comovements while reproducing temporal paths governed by smooth-changing regimes and accounting for a slow adjustment mechanism. The NECM-RP can apprehend the adjustment dynamic of stock prices and the market response after an exogenous shock, while reproducing different sources of nonlinearity (*i.e.* abrupt changes in adjustment speeds, effects of negative and positive shocks on stock price adjustment, etc.).

For our empirical investigation, y_t is the Mexican stock price and x_t the MSCI world market index in logarithms. Our empirical investigation is carried out in several steps. We test the integration order of the stock indices with the usual unit root tests (Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests). Then, we check for mixing and nonlinear cointegration hypotheses using KPSS and *R/S* tests on the residual term ($\hat{z}_t$). Under the mixing hypothesis, we test for the hypothesis of nonlinear cointegration between Mexican and the world stock markets. Finally, the NECMs are estimated by the Nonlinear Least Squares (NLS) method to apprehend the dynamics of comovements between the stock markets under consideration.

4. Empirical Results

4.1 Data

Our empirical investigation focuses on monthly Mexican stock index and the world market index over the period December 1987–January 2008 (242 observations). Both indices are expressed in US dollars and are obtained from Morgan Stanley Capital International (MSCI). From ADF and PP tests, the two series are I(1). The computation of the bilateral correlation between Mexican and world stock returns, while taking the Tequila effect into account, shows that the correlation is higher after the Mexican crisis (Table 1). It suggests an increase of comovements between stock markets after 1994. From table 2, we note that the normality is rejected suggesting significant asymmetry and a leptokurtic distribution. The negativity of the skewness is considered as a sign of nonlinearity in the stock price dynamics.

4.2 Nonlinear Adjustment Tests

From Table 3, we accept the hypothesis of linear cointegration between the Mexican and the world markets. It also implies that the Mexican mean-reverting dynamics may be reproduced via a linear ECM. However, linear modelling may not be appropriate to reproduce time-series that are generated by nonlinear processes because it fails to reproduce asymmetry inherent to time-varying comovements [Taylor and Sarno, 2001]. We test then the cointegration hypothesis using "mixing" tests, which are more powerful and robust than linear cointegration tests. Under the mixing and nonlinear cointegration hypotheses, we retain that may conclude that the Mexican stock market is nonlinearly mean-reverting toward the world market, indicating that the Mexican market is nonlinearly linked into the world market.

The two "mixing" tests: the KPSS and the *R/S* tests test the null hypothesis of "mixing" against its "non-mixing" alternative. For the KPSS, we retain Schwert' (1989) values given the following truncation parameter: $l_4 = \text{int}\left[4\left(\frac{T}{100}\right)^{\frac{1}{4}}\right]$ and $l_{12} = \text{int}\left[12\left(\frac{T}{100}\right)^{\frac{1}{4}}\right]$, where T is the number of observations.[2] For the choice of q for the *R/S* test, we have retained the value of Andrews (1991): $q_t = [K_T]$, where $K_T = \left(\frac{3T}{2}\right)^{\frac{1}{3}}\left(\frac{2\hat{\rho}}{1-\hat{\rho}^2}\right)^{\frac{2}{3}}$, $[K_T] = \text{int}(K_T)$ and $\hat{\rho}$ is the first-order autocorrelation coefficient. Our findings that are presented in Table 4 do not reject the mixing hypothesis and therefore the nonlinear cointegration hypothesis, implying strong evidence of time-varying and asymmetric comovements. In the next step, we estimate the NECMs: the ESTECM and the NECM-RP.

4.3 The NECMs Modeling

The NECMs presented in equations (1) and (2) are estimated according to Escribano and Mira (2002) and Van Dijk *et al.* (2002). The number of lags (p) for the NECMs is specified using autocorrelation functions and Ljung-Box tests. The results indicated q = 0, implying the absence of local time dependence for Mexico, and show that its dynamics depends only on current world markets. The empirical results reported in Table 5, imply several interesting findings. On the one hand, we point out significant nonlinear relationship between the MSCI world index and Mexican market. The parameters γ and c are statistically significant, confirming the choice of the preselected nonlinear form.

Interestingly, the coefficient λ_1 is positive, but λ_2 is negative and significant. The sum $(\lambda_1 + \lambda_2)$ is negative, pointing out a significant nonlinear mean reversion in Mexican stock price. In the first regime (before the Mexican crisis)[3], Mexican stock price can deviate from the world market and its deviations approach a random walk; making the comovements inactive and the market segmented, which is opportune for investors to diversify while investing in Mexico. Nevertheless, for large deviations, a nonlinear mean-reversion mechanism is activated, ensuring the convergence of Mexican price toward the equilibrium and thus allowing for strong market links.

Besides, from graph 1, we note that the adjustment speed increases with the stock price deviation size. This result also provides strong evidence of nonlinearity in the adjustment. Indeed, from graph 1, the ESTECM seems reproducing the asymmetry and shows significant evidence of mean-reversion in the stock prices after 1994. From graph 2, the transition function reaches the unity and persists in the upper regime (regime of comovements), which is in line with confirming the findings of Adler and Qi (2003), who point out integration

[2] Int [.] denotes the interior part.

[3] The threshold parameter corresponds approximately to the Mexican deviation price of May 1993, indicating that the transition occurred around this date.

increase for Mexico in the recent years. By the way, this also suggests that today's Mexico market is progressively dependent on world market. This yields also an explanation of the spillover negative effect of the 2007-2009 international financial crisis in Mexico. However, by the end of the period, the transition function deviates from upper regime suggesting a relative segmentation and a weakness in the comovements. The nonlinear specification is *a priori* appropriate according to the different misspecification tests.

Under the restrictions: a = c = d =1 and b = 0, the second NECM was estimated also. Through the graph 3, our findings pint out the ability of this specification to capture several types of asymmetry, nonlinearity and smoothness inherent to stock price dynamics in Mexico. Indeed, the analysis of the histogram presented in graph 3 that is plotted in accordance with the estimated misalignment values ($\hat{z}_{t-1}$) provides the rejection of normality, and highlights a bimodal density with two modes of unequal. The existence of unequal modes indicates extreme stock price comovements between the different regimes. It is also an indication of potential nonlinear time-varying comovements.

5. Concluding Remarks

The aim of this study is to investigate stock market comovements between the Mexican and world stock markets in a nonlinear framework over the last three decades. Our approach allows to reproduce the dynamic evolution of stock price comovements for Mexico in relation to the world market while capturing the extreme cases of comovements (strong and weak comovements), as well a continuum of intermediate states of comovements. In particular, our results provide strong evidence of nonlinearity, structural breaks and switching regimes in comovements. They indicate asymmetric and nonlinear time-varying comovements that have increased after 1994. Our findings are of great interest for investment opportunity in Mexico. Finally, our nonlinear modeling approach can naturally be extended to other emerging and developed stock markets to investigate their dynamics.

References

Adler, M., and Qi, R. (2003) "Mexico's Integration into the North American Capital Market", *Emerging Economic Review*, **4**, 91-120.

Anderson H. M. (1997) "Transaction Costs and Nonlinear Adjustment Towards Equilibrium in The US Treasury Bill Markets", *Oxford Bulletin of Economics and Statistics*, **59**, 465-484.

Andrews, D. (1991) "Heteroscedasticity and Autocorrelation Consistent Covariance Matrix Estimation", *Econometrica*, **59**, 817-858.

Arouri, M., and Jawadi,F. (2010) Nonlinear Stock Market Linkages, in Barnett, W. and Jawadi, F. (Eds), *Nonlinear Modeling of Economic and Financial Time-Series*, Emerald Group, Publishing Limited, 205 pages.

Bekaert, G. and Harvey, C., (2003) "Emerging markets finance", *Journal of Empirical Finance*,**10**, 3-55.

Bekaert, G., and Harvey, C. (1995) "Time Varying World Market Integration", *Journal of Finance*, **50**(2), 403-44.

Bekaert, G., Harvey, C., and NG, A. (2005) "Market Integration and Contagion", *Journal of Business*, **78**, 39-69.

Boswijk H.P., Hommes C.H., Manzan S. (2007) "Behavioral Heterogeneity in Stock Prices", *Journal of Economic Dynamic and Control*, **31**(6), 1938-1970.

Carrieri, F., Errunza, V., and Hogan, K. (2006) "Characterizing World Market Integration Through Time", *Journal of Financial and Quantitative Analysis*, **42**, 915-941.

De Grauwe, P., Grimaldi, M. (2006) "Heterogeneity of Agents, Transaction Costs and the Exchange Rate", *Journal* of *Economic Dynamics* and *Control*, **29**, 691-719.

De Santis, G., and Imrohoroglu, S. (1997) "Stock Returns and Volatility in Emerging Financial Markets", *Journal of International Money and Finance*, **16**(4), 561-579.
Dumas B. (1992) "Dynamic Equilibrium and the Real Exchange Rate in a Spatially Separated World", *Review of Financial Studies*, **5**, 153-180.
Escribano, A. (1997) "Nonlinear Error Correction: The Case of Money Demand in the U.K (1878-1970)", Working Paper, n°5, Universidad Carlos III, Madrid.
Escribano, A., and Mira, S. (2002) "Nonlinear Error Correction", *Journal of Time Series Analysis*, **23**, 509-522.
Gerard, B., Thanyalakpark, K., and Batten, J. (2003) "Are the East Asian markets integrated? Evidence from the ICAPM", *Journal of Economics and Business*, **55**, 585-607.
Iwatsubo, K., and Inagaki, K. (2007) "Measuring Financial Market Contagion Using Dually-Traded Stocks of Asian Firms ", *CEI Working Paper Series*, n°14, Institute of Economic Research, Hitotsubashi University.
Lim, K., Lee H., and Liew, K., (2003) "International diversification benefits in Asian stock markets: a revisit". *Mimeo*, Lebuan School of International Business and Finance, Universiti Malasya Sabbah y Faculty of Economics and Management, University Putera Malaysia.
Lo A., W. (1991) "Long-Term Memory in Stock Market Prices", *Econometrica*, **59**(5), 1279-1313.
Masih, A., and Masih, R. (2001) "Long and short term dynamic causal transmission amongst international stock markets", *Journal of International Money and Finance*, **20**, 563-587.
Phylaktis, K., and Ravazzolo, F. (2004) "Stock market linkages in emerging markets: implication for international portfolio diversification", *Journal of International Markets and Institutions*, Forthcoming.
Schwert, G., W. (1989) "Tests for Unit Roots: A Monte Carlo Investigation", *Journal of Business & Economic Statistics*, **7**, 147-159.
Taylor, M., P. and Sarno, L. (2001) "Real Exchange Rate Dynamics in Transition Economies: A Nonlinear Analysis, *Studies in Nonlinear Dynamics & Econometrics*, **5**(3), 153-177.
Van Dijk, D., Teräsvirta, T., and Franses, P., H., (2002) "Smooth Transition Autoregressive Models- A Survey of Recent Developments", *Econometric Reviews*, **21**, 1-47.
Wang, K. M., and Nguyen Thi, T., B. (2007) "Testing for contagion under asymmetric dynamics: Evidence from the stock markets between US and Taiwan", *Physica*, A **376**, 422-432.

Appendices

Table 1 : Bbilateral correlations

Series	RMSCI	RMEX	
Before Mexican Crisis: January 1988– November 1994			
RMEX	0.26	1.00	
RMSCI	1.00	0.26	
After Mexican Crisis: December 1994-January 2008			
RMEX	0.60	1.00	
RMSCI	1.00	0.60	
The whole period: January 1988- January 2008			
RMEX	0.47	1.00	
RMSCI	1.00	0.47	

Note: This table shows bilateral correlations between Mexican and World stock returns before and after the Mexican Crisis. RMSCI and RMEX are respectively the stock returns of the World and Mexican stock markets.

Table 2: Descriptive statistics

Series	Mean	Std. Dev.	Maximum	Minimum	Skewness	Kurtosis	Jarque-Bera (Probability)
Mexico	0.0169	0.0935	0.2540	-0.4195	-0.9425	6.1437	134.92 (0.00)
MSCI World Index	0.0053	0.0398	0.1055	-0.1444	-0.5733	3.8673	20.75 (0.00)

Note: This table presents the descriptive statistics of stock returns from the World and Mexican stock markets.

Table 3: Linear Cointegration Tests

Series	Constant	LMSCI	$\overline{R}^2$	ADF (p, model)
Mexico	-4.71 (-7.88)*	1.76 (19.85)*	0.62	-4.02 (1,a)

Note: This table reports the linear cointegration test. The values between brackets are the t-ratio.(*) and (a) designate respectively the significance at 5% and a model without a constant and linear trend.

Table 4: Mixing Tests

KPSS		R/S
l_4	l_{12}	Andrews
0.45	0.12	1.1

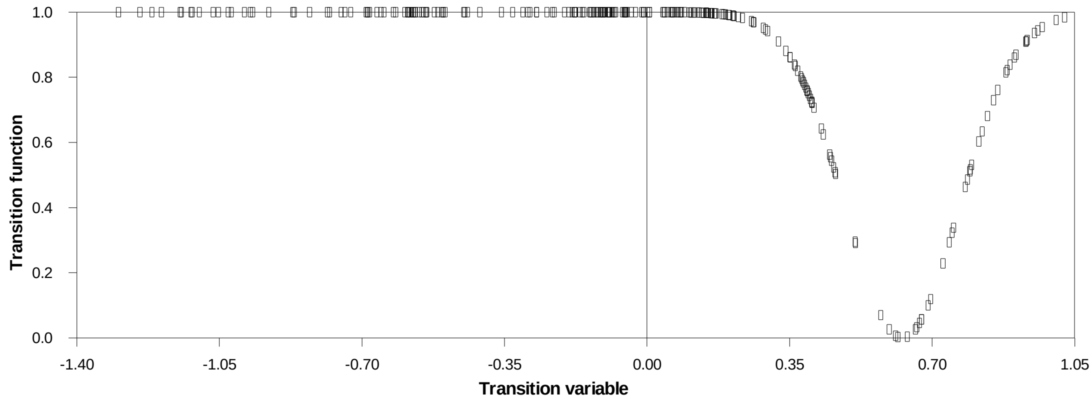
Note: This table presents the results of mixing tests. (*) denotes the rejection of the null hypothesis at the 5% significance level.

Table 5: NECM Estimation Results for Mexico

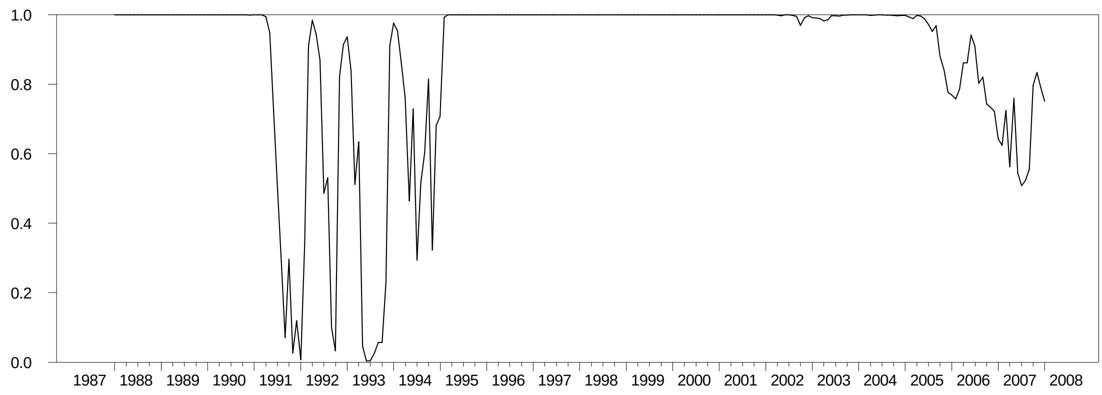
Coefficients	ESTECM (0,1)	NECM-RP
α_0	0.0045 (1.04)	0.0094 (1.36)
ρ_1	0.0994^* (2.36)	-0.032 (-1.11)
ρ_2	-0.1315^* (-3.05)	0.0054 (0.36)
β_0	1.105^* (8.52)	1.11^* (8.38)
γ	26.06^* (2.04)	-
$\gamma \times \sigma_{z_{t-d}}$	7.64	-
c	0.6268^* (16.979)	-
ADF^{GLS}	-9.83	-9.79
R/S	1.4	1.5
$\sigma_{NECM} / \sigma_{LECM}$	0.73	0.88

<u>Note:</u> This table presents the estimation results of NECM for Mexico. The values in brackets are the t-statistic of nonlinear estimators. (*) denotes the significance at 5%.

Graph 1: Exponential Transition Function



Graph 2: Evolution of the Exponential Transition Function



Graph 3: Histogram of the Rational Polynomial Function for Mexico