E C O N O M I C S B U L L E T I N

An empirical analysis of structural changes in emerging market volatility

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Abstract

In this paper, two different stability tests in linear frameworks are used to examine the presence of structural changes in the GARCH-based conditional volatility of emerging market countries. We particularly relate this issue to the market liberalization reforms undertaken by these countries over the last three decades. Empirical results show that structural breaks detected in emerging market volatility do not happen together with official liberalization dates, but they rather coincide with dates of the first American Depository Receipt (ADR) and Country Fund introduction, and with dates of huge increases in the US capital flows into emerging countries. This leads to reinforce the findings of related literature on that emerging markets do react essentially to alternative events of official liberalizations.

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1. Introduction

Stock market liberalization has been one of the most important economic reforms conducted by many emerging countries since the early 1980s. Its objective was to create a more attractive environment for international investments and to increase the effectiveness of the internal capital markets. Much has been done specifically to gauge the impacts of the above reform on different aspects of emerging economies. Bekaert and Harvey (2003) present a very comprehensive review of the related literature. Overall, most studies find that market liberalization appeared to have a positive effects on emerging economies in that it increases the supply of foreign capital, improves international risk sharing between domestic and foreign investors, lowers the cost of capital leading to economic growth, and finally enhances informational efficiency of national markets as foreign participations require high transparency and appropriate accounting regulations. It is however worth noting that market liberalization could be costly to stock markets in newly liberalized countries because they might have to cope with the increased volatility and financial instability likely to cause economic turmoil such as the Tequila and Asian crises during the 1990s (see, e.g., Stiglitz, 2000 and references therein).

The impact that market liberalization exerts on emerging market volatility is, in this schema of things, of the utmost importance. There is now a vast literature that examines this issue using various sets of emerging countries and empirical methodologies. For example, the findings of past studies such as Bekaert and Harvey (1997, 2000), Kim and Signal (2000), and Cuñado *et al.* (2006) generally supported the proposition that market liberalization reduced the level of market volatility in emerging countries. By contrast, Levine and Zervos (1998), and Miles (2002) documented rather an increase of emerging market volatility following financial liberalization events. De Santis and Imrohoroglu (1997) found an insignificant impact of liberalization. In a related effort, Jayasuriya (2005) showed that the volatility in emerging countries can increase, decrease or remain unchanged over the post-liberalization period, and all according to the market's specific characteristics and the quality of financial institutions.

This paper contributes to the above literature in that it aims to test for structural breaks in the estimated conditional volatility of emerging markets over the pre- and post-liberalization period. If any structural breaks are present at the time of or near the initial liberalization date and its subsequent events, it is possible to interpret their presence as a significant impact of market reforms on the return variability. Using data from seven emerging countries, we find that the breakpoints detected by our testing procedure coincide mostly with alternative events of official liberalizations, indicating the importance of effective participation of foreign investors on the conditional volatility levels.

The remainder of this paper is organized as follows. Section 2 describes the empirical method and data used in this study. Section 3 reports and discusses the obtained results. Section 4 concludes the paper.

2. Empirical method and data

To achieve our objective, we proceed as follows. In the first step, we estimate the conditional volatility of emerging markets using a GARCH-type model introduced by Engle (1982) and extended by Bollerslev (1986). We test in the second step whether structural breaks occur in the time-paths of the volatility series (or also referred as indices) obtained from the first stage. Two different tests are employed for this purpose: the classical CUSUM test and the Bai-Perron's test (see, e.g., Brown *et al.*, 1975; Kramer *et al.*, 1988; and Bai and Perron, 1998, 2003).

In the existing literature, GARCH models have been successfully applied in describing the time-variations of emerging market returns (see, e.g., Bekaert and Harvey, 1997; and Kim and Singal, 2000). In particular, these models are found to be apt to capture the time-varying, persistent and clustering of return volatility. This fact naturally motivates the use of a GARCH model to measure emerging market volatility. However, instead of applying directly a standard GARCH(1,1) process, we specify a bivariate GARCH(1,1)-in-mean model which typically allows for the dynamic volatility transmissions between emerging and world stock markets as a result of increasing market integration after liberalization (see, e.g., Engle and Kroner, 1993 for further discussions about the econometric specification). Indeed, the conditional return on the world stock market index and that on the stock market index of an emerging country are modeled by a bivariate first-order autoregressive process. The "in-mean" factor is represented by the conditional variance. We also let the first-lag value of the world market return, and the conditional covariance between emerging and world stock markets to impact the expected returns of emerging market under consideration. Regarding the estimation procedure, we begin with the estimation of the conditional volatility of the world stock market using a standard univariate GARCH(1,1)-in-mean model and then use the estimated coefficients to generate the conditional volatility for each emerging market from estimating the bivariate model. By doing so, the influences of world market are set to be identical across emerging markets. All models are estimated by quasi-maximum likelihood method discussed in Bollerslev and Wooldridge (1992), which corrects for non Gaussian errors.

In what follows, we discuss the implementation of the stability tests used to detect the number and location of the structural breakpoints that might exist in the time-paths of conditional volatility indices when liberalization reforms took place. Let's consider the following single linear regression model:

$$y_t = \beta x_t^{\mathrm{T}} + \varepsilon_t \qquad (t = 1,\ldots,n) \tag{1}$$

where y_t refers to the estimated conditional volatility index (i.e., conditional variance) of an emerging market at the time *t*; $x_t = (1, y_{t-1})^{\mathrm{T}}$ is the (2×1) matrix of observations of the independent variables with the first component equal to unity; β is the (2×1) vector of regression coefficients; ε_t is an $iid(0,\sigma^2)$ error (or volatility innovations). Within this context, structural stability tests are concerned with testing the null hypothesis of '*no structural break*' (or stability of regression coefficients) against the alternative that the regression coefficients change over time. Therefore, if there are *m* breakpoints under the alternative hypothesis, the time-paths of the volatility index under consideration is split into *(m+1)* segments with constant regression coefficients. Accordingly, the model described by Equation (1) can be rewritten as:

$$\begin{aligned} y_t &= x_t^{\mathrm{T}}\beta_1 + u_t && (t = 1,\ldots,n_1) \\ y_t &= x_t^{\mathrm{T}}\beta_2 + u_t && (t = n_1+1,\ldots,n_2) \\ &\cdots\cdots\cdots\cdots\cdots\cdots \\ y_t &= x_t^{\mathrm{T}}\beta_{m+1} + u_t && (t = n_m+1,\ldots,n) \end{aligned} \tag{2}$$

where the vector $n_i = (n_1, n_2, \ldots, n_m)$ contains the *m* breakpoints and *m* is generally treated as unknown.

Based on this theoretical framework, the standard CUSUM test, initially proposed by Brown *et al.* (1975), can be implemented by defining the time-varying CUSUM (cumulative sums of recursive residuals) quantity as follows:

$$Wn(t) = \frac{1}{\tilde{\sigma}\sqrt{n-k}} \sum_{j=k+1}^{[k+t(n-k)]} u_j \qquad [0 \le t \le 1]$$

$$\text{with } \tilde{\sigma} = \sqrt{\frac{1}{n-r}\sum_{t=k+1}^{n}(u_t - \overline{u})^2}$$

where u_j are the estimated OLS recursive residuals from Equation (1) and k refers to the number of regressors (i.e., k equals 1 in our study). t refers to the time and is standardized to take values between 0 and 1. If there is a single structural break at fixed time $t_0 \prec 1$, the mean of the recursive residuals will be always equal to zero up to t_0 and different afterwards. In this case, the CUSUM path leaves its zero mean at t_0. Practically, the null hypothesis of coefficient constancy is rejected whenever the path of the CUSUM quantity crosses the critical boundaries estimated using a 95% level of confidence under the null. The drawback of such as test remains in the fact that we are not able to identify the exact date where the structural break takes place.

To by-pass the specific problem of the traditional CUSUM test, we follow the Bai and Perron (1998, 2003)'s OLS procedure to determine both the number and location of breaks in the coefficients of linear regression models. Assume that there exist m breaks $(n_1,...,n_m)$ in the time-path of the dependant variable (i.e., volatility index of an emerging market), the question of dating structural breaks turns to find the estimated breakpoints $(\tilde{n}_1,...,\tilde{n}_m)$ that minimize the objective function:

$$(\tilde{n}_1,...,\tilde{n}_m) = \arg\min_{(n_1,...,n_m)} RSS_n(n_1,...,n_m)$$

In this expression, RSS_n is the residual sum of squares issued from the estimation of the m regressions shown in Equation (2). The breakpoint selection procedure is based on the Bayesian Information Criteria (BIC). When performing the Bai-Perron's test, the maximum number of breaks is initially set to be 5. If the effective number of breaks is equal to 5, a higher number of breaks will be chosen so that the testing procedure captures all possible breakpoints.

The data used in this study consist of the S&P's IFCG total return indices for seven emerging markets (Argentina, Brazil, Chile, Colombia, Mexico, Malaysia and Thailand) and the MSCI World market index, sampled over the period January 1985 to January 2003. All the price data measured in US dollars were extracted from Datastream International and converted into log return. Though stochastic properties of monthly returns are intentionally not presented to conserve space, they are globally similar to the findings of previous studies. First, emerging market returns are significantly departed from normality according to the Jarque-Bera test for normality. Second, the Engle (1982)'s test for conditional heteroscedasticity reject the null hypothesis of no ARCH effects in monthly returns. Finally, the Dickey-Fuller augmented stationarity test with four lagged terms rejects the null hypothesis of non-stationary return series, implying that the treatment of integrated series is not necessary in our study.

Empirical results on the presence of structural breaks in the volatility dynamics of emerging markets will be discussed in the following section.

3. Results

For each emerging market, we report in Table 1 the summary statistics of the conditional volatility expressed in terms of conditional variance, obtained by estimating the bivariate GARCH-M model. It appears that Argentina is the most volatile market since this market averages out at about 7.7% per month. The lowest volatility level is observed in Colombian market with 0.8% per month.

We graph in Figures 1 and 2 the time-varying patterns of conditional volatility indices for two market groups: Latin American and Asian markets. As we can see, the evolution of emerging market volatility witnesses some periods of extreme movements during the period from 1985 to 2003, specifically in the early 1990s for Latin American markets and in the late 1990s for Asian markets. All markets responded largely to the market crash happened in October 1987. The Asian crisis equally induced a notable rise in conditional volatility in Thailand and Malaysia. It is interesting to note that large changes in emerging market volatility are often associated with major economic and political events. For example, the stock market in Argentina appeared to be greatly volatile just before its official liberalization. The same pattern is followed by the Colombian stock market when the government decided that it would allow the peso to devaluate at a faster rate in September, 2nd 1998.

Figure 3 depict the CUSUM paths of the Brown and *al.* (1975)'s stability test. We observe that, except for Malaysia, the null hypothesis of coefficient constancy is rejected in seven markets since the CUSUM trajectories crossed the 95% confidence interval at least one time over the study period, but the number and timing of the breakpoints remain unknown.

We now turn to discuss the results of the Bai-Perron's stability test. For this purpose, we report in Table 2 the optimal number of breakpoints (i.e., the one associated with the minimum BIC score) detected in the conditional volatility indices of sample emerging markets. The obtained results are globally consistent with the CUSUM test, the only exception being Malaysia. More precisely, the Bai-Perron's test identifies two breakpoints for this market while the CUSUM test provides evidence against the structural changes. The finding remains unchanged even when we perform the Bai-Perron's test without the first lag of the Malaysia's volatility index in the regression model. It is empirically not possible to make a clear conclusion on the structural change issue of Malaysian stock market volatility at this stage.

Table 2 also supplies the estimated break dates and their 95% confidence intervals. The comparison of these dates to different market liberalization dates for sample markets in Table 3 shows that the official liberalization dates fall into the 95% confidence intervals for the estimated break date in only two markets, Argentina and Chile. A straightforward intuition is that the official liberalization dates have less explanatory power regarding the changes in return volatility. By employing a GARCH methodology with structural breaks, Aggarwal and *al.* (1999) made the same conclusion. As regards other markets, the results indicate that the date of structural change in the US capital flows into Brazilian market is located within the 95% confidence interval of the first break date. In Colombia, the dates where the first ADR and Country Fund are introduced, and the date where a structural change in the US capital flows into this emerging market takes place are bounded by the 95% confidence interval of the first break date. The same pattern is observed in Mexico for the dates of the first Country Fund and ADR introduction. In Malaysia and Thailand, none of the estimated break dates is related to market liberalization events. It is nevertheless important to notice that the structural change in Thailand happens very close by the 1997 Asian financial crisis.

To sum up, structural changes in the time-varying volatility of sample emerging markets do not appear at the time of official liberalization, but rather occur when financial instruments like Country Fund and ADR are firstly launched and also when the US capital flows into emerging markets increase largely. This typically indicates that emerging market volatility responds less to the official liberalization than to its subsequent events.

4. Conclusion

In this paper, we examined whether structural changes have taken place in the volatility dynamics of seven emerging markets. We further relate this issue to market liberalization reforms as policymakers in emerging countries might hope to know the outcomes of their economic policies. Our empirical results from a bivariate GARCH-in-mean model for conditional volatility and stability tests reinforce previous findings, especially those of Aggarwal and *al.* (1999), in the sense that none of the estimated break dates in the conditional volatility indices are directly linked to the official liberalization dates. This also implies that the announcements of official liberalization on return volatility are generally insignificant.

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Table 1 - Summary statistics of conditional volatility series

Conditional volatility of sample emerging markets is estimated using a bivariate GARCH(1,1)-in-Mean model combined with a bivariate AR(1) process. Q-statistics are the Ljung-Box test for serial correlation applied to both returns in level and square returns up to 12 lags. ADF refers to the Augmented Dickey-Fuller test for stationarity (no trend with constant and four additional autoregressive components). $^{+}$ and $^{++}$ indicate rejection of the null hypothesis (no autocorrelation and non-stationarity) at the 5% and 1% levels of significance respectively for statistical tests.

	Argentina	*Brazil*	*Chile*	*Colombia*	*Malaysia*	*Mexico*	**Thailand**
Mean	0.077	0.034	0.011	0.008	0.012	0.018	0.015
Minimum	0.012	0.013	0.009	0.005	0.004	0.012	0.005
Maximum	0.570	0.168	0.034	0.027	0.073	0.069	0.116
Q(12)	304.854^{++}	224.852^{++}	35.335^{++}	82.800^{++}	388.440^{++}	85.469^{++}	669.827^{++}
ADF(4)	-5.336^{++}	-4.669^{++}	-5.850^{++}	-4.629^{++}	- 2.976^{++}	-6.061^{++}	- 3.589^{++}

Table 2 - Results of the Bai-Perron's test for multiple structural breakpoints

The breakpoint selection procedure in the works of Bai and Perron (1998, 2003) is based on the Bayesian Information Criteria (BIC). First, we arbitrarily set the maximum number of breaks to be 5. If the effective number of breaks is equal to 5, a higher number of breaks will be chosen so that the testing procedure captures all possible breakpoints. In principle, the optimal number of breakpoints is the one associated with the minimum BIC. For the countries considered in this present study, none of the volatility series has more than 5 breakpoints.

Market	**Number of breakpoints**	**Estimated break dates**	**95% confidence intervals for break dates**
Argentina	1	1989:06	[1988:02 - 1991:03]
Brazil	3	1987:03 1991:07 1998:07	[1985:02 - 1987:04] [1991:06 - 1993:02] [1996:01 - 1998:09]
Chile	1	1992:04	[1991:07 - 1998:03]
Colombia	2	1992:11 1997:08	[1992:10 - 1995:08] [1996:03 - 1997:09]
Malaysia	2	1997:06 2000:02	[1996:07 - 1997:07] [2000:01 - 2001:02]
Mexico	2	1982:07 1991:07	[1979:07 - 1982:10] [1990:08 - 1996:03]
Thailand	1	1997:08	[1996:01 - 1997:09]

Table 3 - Stock market liberalization dates

All the dates reported in this table are derived from Bekaert and Harvey (2000).

Market	**Official dates of liberalization**	**Date of the first ADR introduction**	**Date of the first Country Fund introduction**	**Date of the structural break in the US capital flows**
Argentina	11-1989	08-1991	10-1991	04-1993
Brazil	05-1991	01-1992	10-1987	06-1986
Chile	01-1992	03-1990	09-1989	01-1988
Colombia	02-1991	12-1992	05-1992	08-1993
Malaysia	12-1988	08-1992	12-1987	04-1992
Mexico	05-1989	01-1989	06-1981	05-1990
Thailand	09-1987	01-1991	07-1985	07-1988

Figure 1 - Volatility dynamics in Latin American markets

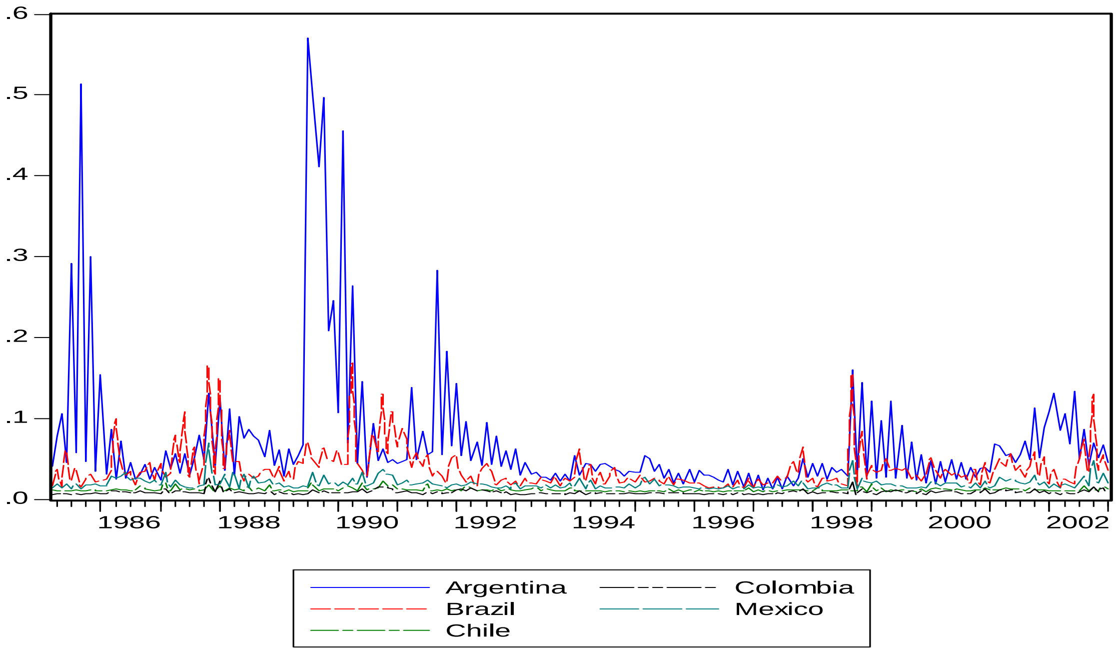


Figure 2 - Volatility dynamics in Asian markets

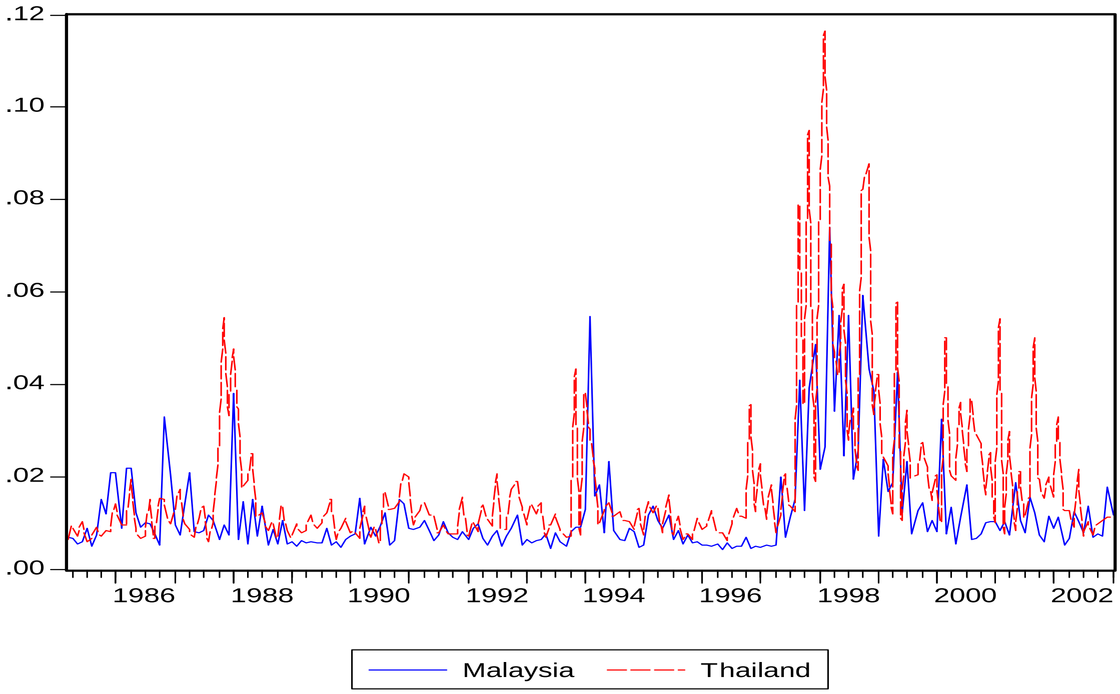
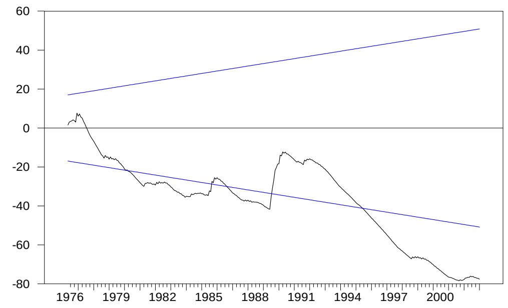
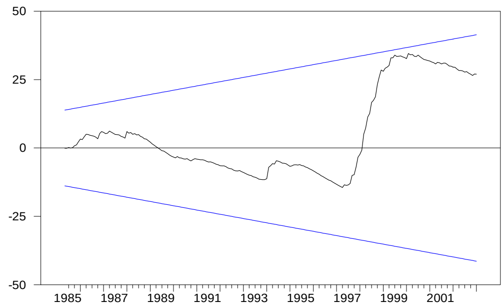


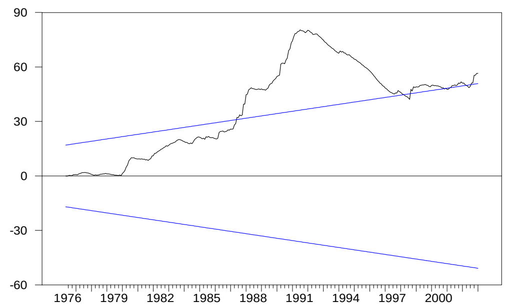
Figure 3 - CUSUM paths for the conditional volatility indices



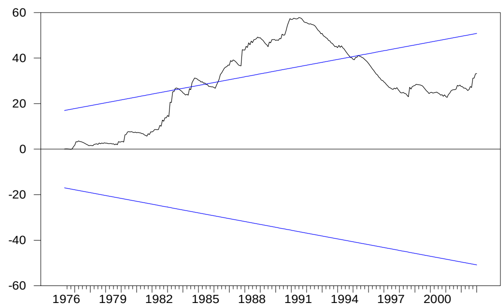
Argentina



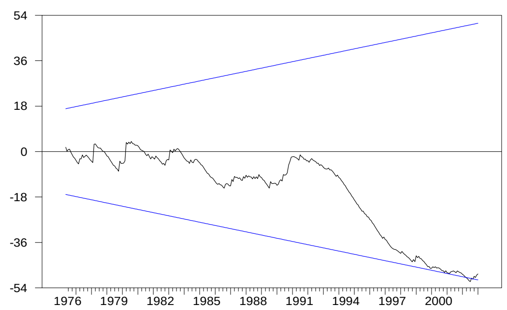
Malaysia



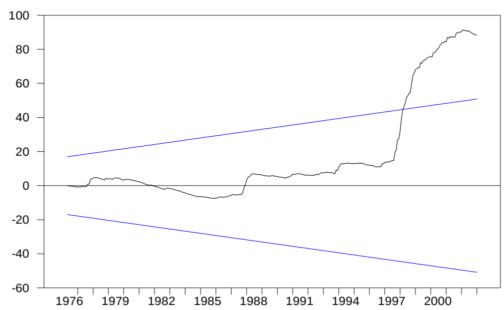
Brazil



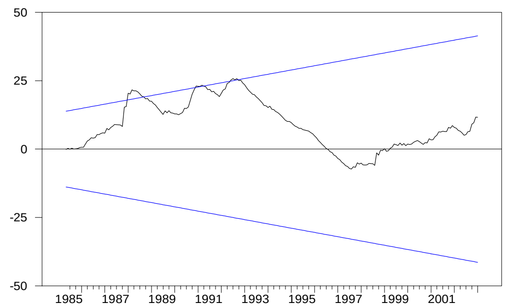
Mexico



Chile



Thailand



Colombia