AN ANALYSIS OF MEXICAN DERIVATIVES FUTURES MARKET: THE MEASURE OF THE IMPACT IN VOLATILITY AT THE INTRODUCTION AND THEIR MARKET EFFICIENCY

AN ABSTRACT
SUBMITTED ON THE FOURTEEN DAY OF DECEMBER 2009
TO THE DEPARTMENT OF FINANCE
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
OF THE A.B. FREEMAN SCHOOL OF BUSINESS
OF TULANE UNIVERSITY
FOR THE DEGREE
OF DOCTOR IN PHILOSOPHY

BY

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ABSTRACT

This dissertation studies the effects of the introduction of futures market in México in the spot price and the efficiency with the introduction of the electronic trading system. Mexican derivatives market (MEXDER) started operations in 1998 and has been showing an important growing. This research is based in the methodology followed in studies elaborated in Italy and United Kingdom.

In the first part I analyzed the impact on the spot price of stock index price quotations (IPC), with the introduction of futures contract on this underlying. As is used in this kind of investigations, I reviewed the performance of volatility after and before the introduction of futures. The results showed that the volatility of IPC diminishes before introduction of the future, but it was not possible to conclude that was caused by the future contract. Further investigation is required given important changes occurred at the same time, for example and may be the reason is the introduction of the electronic trading system in 1999.

For the second part, I tested the efficiency of three futures contracts: stock price index (IPC), short term interest rate (TIIE28) and dollar foreign exchange rate (DEUA). Three methods where used in order to robustness, the Augmented Dickey Fuller (ADF) unit root test, the KPSS test, and Variance-Ratio test. The results suggested that three contracts are efficient in a weak-form and the introduction of electronic trading system improved the efficiency in the interest future contract.
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In order to successfully conclude my doctorate thesis, tremendous effort and perseverance were needed throughout the whole process. At the end of the day, the satisfaction was worth all the sacrifices made through this long period of time.

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CHAPTER I. INTRODUCTION

1.1. Antecedents

The derivative market is one of the most important financial markets in terms of size and trading volume. It is widely used by investors expecting to obtain bigger gains and in other side risk managers worried for hedge operations in their companies. This market is operating in two forms, by private market named "over-the-counter" and by formal exchanges. The OTC market is greater than standardized exchanges in volume terms and operations.

This market is integrated by forwards, futures, options and swaps contracts. These agreements are essentially like insurance, providing protection against uncertain terms of trade on spot markets at the future date of delivery. However, these contracts serve different purposes.
A futures contract is an agreement between two parties to buy or sell an asset at a certain time in the future for a certain price. A forward contract is similar, with one important difference being that a futures contract is normally traded on an exchange, while a forward contract is operated by banks. An option is a contract that gives to the buyer the right, but not the obligation, to buy or sell an underlying asset in a certain period of time, at an agreed price, the strike price (exercise price). There are two types of options; a call option that gives the buyer the right to buy the underlying asset and a put option gives the buyer of the option the right to sell the underlying asset.

A swap is an agreement between two parties for exchange cash flows or another underlying asset. The advantage for this contract is that the benefit is shared between the involved parts.

To make trading possible in derivative market, the exchange specifies certain standardized features of the contract. As the two parties to the contract do not necessarily know each other, the exchange also provides a mechanism that gives the two parties a guarantee that the contract will be honored.

According to history, it is believed that futures trading may date back to India at about 2000 B.C., and that it subsequently appeared in Greco-Roman times. The trading methods of modern futures markets probably trace their origins to the medieval fairs of France and England, dating from the twelfth century. There were examples of organized forwards markets in Europe and Japan in the 17th and 18th centuries. Rice was traded for future delivery in Osaka, for example, beginning in the 1730s. The modern form of futures markets, however, originates in the mid-19th-century United States, especially in the grain markets of Chicago. The Chicago Board of trade (CBOT), established in 1848,
became an active exchange for trade of agricultural commodities, until 1865 the CBOT established its general rules. The organized trading of forwards contracts had become the first essential example of modern futures markets. Another important exchange is the Chicago Mercantile Exchange (CME), which from 1921 until 1947 specialized almost exclusively in foodstuffs.

The financial futures contracts were not introduced until 1970 in the CME (including International Monetary Market). By 1983, the CME no longer offered contracts in food group. After that, active financial futures markets have been introduced in different countries, notably England and Japan and recently the emerging markets.

The evolution of this market and actual size reach us to analyze the impact of futures trading in the spot market.

The objective of this research is to show the impact of futures trading on the Mexican Derivatives Market, following its introduction in August 1998, using different methodologies, as the Generalized Autoregressive Conditional Heteroscedastic (GARCH) family of statistical techniques. The model used in the second chapter had attempts to measure the impact of the introduction of futures market in Mexico, specifically in the volatility of spot stocks prices and the efficiency of the Mexican Market. In other hand, in third chapter the efficiency market of three Mexican futures contracts are measured.

1.2. Futures Contracts: an overview

To understand the behavior of the futures contracts it is important to define a few concepts. The spot price is the price of a good for immediate delivery, is also called the
cash price or the current price. The difference between the cash price and the futures price is called the basis. The basis receives a great amount of attention in futures trading. When the futures price expires, the futures price and the spot price of the underlying must be the same. The basis must be zero, again subject to the discrepancy due to transaction costs. This behavior of the basis over time is known as convergence.

The price difference for two futures contract expirations on the same commodity is an intracommodity spread. It indicates the relative price differentials for a commodity to be delivered at two points in time. It is known that the time spread can also be an economically important variable. Spread relationships are important for speculators. Much speculation involves some kind of spread position, if a trader hopes to use futures markets to earn speculative profits, an understanding of spread relationships is essential. Since most speculation uses spreads, the search for a profit turns on an ability to identify spread relationships that are economically unjustified. Is known that around 90% of the futures operations come from speculators trading.

Because futures contracts call for the delivery of some good at a particular time in the future, it is certain that the expectations of market participants help determine futures prices. The connection between futures prices and expected future spot prices is so strong that some market observers believe that they must be equal. Similarly, the price for storing the good underlying the futures contract helps determining the relationship among futures prices and the relationship between the futures price and the spot price.

All of these futures pricing issues are interconnected. The basis, the spreads, the expected future, spot price, and the cost of storage all form a system of related concepts. Another important issue is the open interest, that is, the number of futures contracts for
which delivery is currently obligated. When a contract is distant from maturity, it tends to have relatively little open interest. As the contract approaches maturity, the open interest increases. Most often, the contract closest to delivery, the nearby contract, has the highest level of open interest. As the nearby contract nears maturity, however, the open interest falls. This is due to the fact that traders close their positions to avoid actual delivery. When the futures contracts mature, all traders with remaining open interest must make or take delivery, and the open interest falls to zero.

There are two models of futures prices. The first of these is the cost-of-carry model. According to this model, futures prices depend on the cash price of a commodity and the cost of storing the underlying good from the present to the delivery date of the futures contract. The second model is the expectations model. According to this view, the futures price today equals the cash price that traders expect to prevail for the underlying good on the delivery date of the futures contract. For example, the futures price in April to September contract is the market's April estimates of what will be the underlying price in September when the futures contract expires.

To explore these models it is necessary to employ the concept of arbitrage. This concept assumes that prices in the market do not allow any arbitrage profits that are assuming the perfect markets.

1.2.1 Cost-of-Carry Model

Under this model, the cost of carry or carrying charge is the total cost to carry a good forward in time. These carrying charges fall into four basic categories: storage costs,
insurance costs, transporting costs and financing costs. While storage seems to apply most obviously to storing physical goods, such as corn or cotton, it is also possible to store financial instruments. It is important to mention that most participants in the futures markets face a financing charge on a short-term basis that is equal to the repo rate. The repo rate is defined like the interest rate on repurchase agreements. In a repurchase agreement a person sells securities at one point in time, with the understanding that they will be repurchased at a certain price at a later time.

Finally, there are three statistical characteristics of futures prices, the first being the distribution of futures prices. Most statistical tests of futures prices rely on the assumption that the underlying price changes are normally distributed. If futures prices changes are not normally distributed, then these tests become more difficult to conduct. Almost all studies in this area agree that changes in futures prices are not normally distributed, but that the distribution of percentage changes in futures price is leptokurtic (the tendency for a distribution to have too many extreme observations relative to a normal distribution). Many papers try to determine what distribution futures prices follow if they are not normal. Two candidates dominate. First, the distribution may be stable Pareto. In this case the distribution is symmetrical, like the normal distribution, but it is leptokurtic relative to a normal distribution. Second, some studies find that the distribution of futures changes seems to be similar to a mixture of two or more normal distributions. Thus, these studies find that the distribution is not normal, but that it can be approximated by a mixture of normal distributions. Both camps agree that this non-normally requires extra caution in making statistical inferences about futures prices.
Another characteristic of futures prices is autocorrelation, this means in addition to testing the distribution of futures price changes, several studies have examined whether the time series of futures price changes is autocorrelated. A time series is autocorrelated if the value of one observation in the series is statistically related to another.

Finally the futures prices can be described by their level of volatility. In a paper regarded as a classic, Samuelson (1973) argued that the volatility of futures prices should increase as the contract approaches expiration. This is the Samuelson hypothesis. In this analysis, Samuelson assumed that competitive forces in the futures market keep the futures price at a level to the expected future spot price at the contract's termination. Therefore, this conclusion implies that the futures price equals the expected future spot price.

1.3. Mexican Futures Market

In Mexico the Mexican Derivative Exchange (MexDer) started operations in December 15th 1998. This exchange operates only futures and options contracts with underlying financial assets.

In the organized derivative markets, there is necessary to have a Clearinghouse, who is the counterpart to every transaction performed on this market. This means it acts as a buyer vis-à-vis each seller and a seller vis-à-vis each buyer, looking to minimize the risk of default. In MexDer, Asigna Compensación y Liquidación is the Clearinghouse, whose safety net has been rated AAA by three of the leading rating agencies in the world (Moody's, Standard & Poor's and Fitch Ratings).
Table I.1: Futures and Options listed in Mexican Derivative Market

<table>
<thead>
<tr>
<th>Asset</th>
<th>Description</th>
<th>Ticker</th>
<th>Starting</th>
<th>Contract Period</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Foreign exchange</strong></td>
<td>Norteamerican dollar Euro</td>
<td>DEUA</td>
<td>Dec. 15, 1998</td>
<td>Monthly until 3 years</td>
</tr>
<tr>
<td></td>
<td>Euro</td>
<td>EURO</td>
<td>May 2005</td>
<td></td>
</tr>
<tr>
<td><strong>Index</strong></td>
<td>Mexican Index Price and Quotations</td>
<td>IPC</td>
<td>Apr. 15, 1999</td>
<td>Quarterly until 1 year</td>
</tr>
<tr>
<td><strong>Debt</strong></td>
<td>Equilibrium Interbank Rate (28 days)</td>
<td>TE28</td>
<td>May 26, 1999</td>
<td>Monthly until 5 years</td>
</tr>
<tr>
<td></td>
<td>Treasury Bills (91 days)</td>
<td>CE91</td>
<td></td>
<td>Monthly until 7 years</td>
</tr>
<tr>
<td></td>
<td>Federal Government Bonds of Development</td>
<td>M3</td>
<td>Oct. 12, 2001</td>
<td>Quarterly until 3 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M10</td>
<td>Sept. 12, 2003</td>
<td></td>
</tr>
<tr>
<td><strong>Stocks</strong></td>
<td>Cementos Mexicanos S.A.</td>
<td>CMXC</td>
<td>July 29, 1999</td>
<td>Quarterly until 1 year</td>
</tr>
<tr>
<td></td>
<td>Fomento Económico Mexicano S.A.</td>
<td>FEM</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grupo Carso S.A.</td>
<td>GCAA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Teléfonos de México S.A.</td>
<td>TMXL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>América Móvil L</td>
<td>AXL</td>
<td>March 22, 2004</td>
<td>Monthly until 4 years</td>
</tr>
<tr>
<td><strong>Inflation</strong></td>
<td>Investment units</td>
<td>UDI</td>
<td>Oct 13, 2003</td>
<td></td>
</tr>
</tbody>
</table>

The interest towards the Mexican Derivative Market has increased in the last few years, thanks to the rapid growth of the Mexican market (see Figure 1) to respect to another emerging market.
Mexder began operations with only futures contracts, but the strong success of this, convinced the Mexican Authorities to introduce an option market in March 2004, at first on single stocks and Mexican Index Price and Quotations (IPC). Given the rapid development of Mexican futures markets, lead to be ranked fifth in world at the end of 2004.

Actually, MexDer is an important competitor for the Chicago Mercantile Exchange (CME), given that many Mexican and North American investors require taking positions in American dollars (DEUA), Mexican Treasury Bill (Cetes), Mexican Interbank Offered Rate (TIIE), IPC or some shares listed in the Mexican market. At the end of 2004, the TIIE’s future contract was ranked on the third place world in terms of trading volume.

The market capitalization of Mexican Stock Exchange has increased from USD millions 153,488 at the end of 1999 to USD millions 300,932 in September 2009, with an absolute growth of 96%. This level of capitalization represents around 35% of GDP, against 20% in 1999. At the end of 2009 Mexican Stock Exchange has 373 listed companies, (125 domestic companies and 248 foreign companies). In terms of return, were ranked in third position in world, with lowest losses (-24% in local currency terms).
The best year in the last ten years was 2006, when got a return of 48.6% in terms of dollars, in third position for America’s Exchanges.

The IPC index is integrated for the 35 most liquid stocks in Mexican Stock Exchanges.

1.4. Purpose of the dissertation

The purpose of this study is analyzing the Mexican Futures Market, based on the Mexican Stock Exchange information. Two research lines were followed, at the first measuring the volatility impact in spot market of stock index and the efficiency of three futures contracts in the second part.

Figure 1.2: IPC Equity Index Futures

Source: Mexder • Beginning on April ** Until May
II. IMPACT OF FUTURES TRADING ON VOLATILITY OF IPC STOCK INDEX: THE CASE OF MEXICO

II.1. Introduction

The Mexican Derivative Market started operations in 1998 and has been growing in an important way to respect other emerging markets. Given this development, there is necessary to generate researches in order to analyze its performance. The purpose of this study is to analyze the effect of the introduction of stock index futures on the volatility of the Mexican Stock Exchange. The GARCH family of techniques is used in order to examine the relationship between information and volatility. This paper is focus in two issues: first if volatility diminishes in period after introduction of futures and two if their introduction was the reason. The results showed that volatility decreased after introduction of futures, suggesting that futures trading contribute to stabilizing the volatility of IPC Stock Index. But the results should be take with caution, because almost at the same time the Mexican Stock Exchange introduced the electronic trading system.

This chapter is organized as follows: Section two contains a literature review related with this topic; Section three describes the methodology and data; Section four explains the empirical results of the study.
II.2. Literature review

One of the most important studies in the topic of futures contracts is founded in Cox, Ingersoll and Ross (1981) paper. There the authors analyzed the difference between futures and forward prices, in theory these prices should be similar, but Cox, et al. proved the following conclusions: If the interest rates and futures prices are positively correlated, then the futures price should be greater than forward price. And if the interest rates and futures prices are negatively correlated, then the futures price should be less than forward price. According to Carlton (1984), one reason futures markets are attractive initially is the ability to hedge or reduce risks. Another reason is related with the liquidity of the markets. The futures market provides an almost instantaneous transaction, so it reduces the transaction costs more than forward markets do. A third reason is that in addition to the benefits stated above, market will produce a price that reflects some average of the beliefs of the market participants. In essence, the futures prices can be viewed as a manner for forecasting spot prices, based on the time value of money for example or expectations of the underlying asset, the future price represents the value that the market gives to this asset at a future time.

In the same study Carlton (1984) analyzed the growth in the number and use of futures markets and said that the 1970’s and early 1980’s were years filled with turbulent change, such as the oil shocks in 1973 and 1979, the first serious recession since 1950s, and the unprecedented inflation that coincided with uncertain nominal and real interest rates. The uncertainty in the economy was accomplished for an increase in number of participants in the derivative markets, industrial structure changes and value of transactions.
Another important issue in the derivatives markets is the theory about the relationship between futures markets and underlying spot markets. The presence of uniformed traders in these markets is, according with Cox (1976) the main cause of destabilization of the underlying cash market. Essentially the same argument has been proposed by Finglewski (1981), who asserted that a lower level of information of futures traders, compared with that of cash market participants results in increased cash market volatility. A similar conclusion comes from Stein (1987), who stated that futures markets attract uninformed traders because of their high degree of leverage; the activity of those traders reduces the information content of prices and increases spot market volatility. Cagan (1981) concludes similar by. In other words, the high volatility of futures markets, due to their high degree of leverage as well as to the presence of speculative uniformed traders, could be a major factor in increasing the volatility of spot markets.

On the hand, some researchers present arguments that futures markets have a beneficial effect on the underlying cash markets. Schwartz & Laatsch (1991) stated that futures markets are an important means of price discovery in spot markets. Stoll & Whaley (1988) claim futures markets enhance market efficiency. Danthine (1978) implies that futures trading increases market depth and reduces spot market volatility. Earlier studies on financial futures investigated the impact of Government National Mortgage Association (GNMA) futures on volatility of the GNMA cash market. Whereas Froewiss (1978) found that weekly spot price volatility was not affected by the introduction of futures, Finglewski (1981) concluded that GNMA futures’ trading has led to increased monthly volatility for the spot market. Simpson and Ireland (1982) proposed
similar results to Froewiss, in the sense that futures market did not affect spot market volatility.

Several studies by stock index futures and the relationship with spot markets have been developed. Santoni (1988) suggested that an increase in S&P500 futures contract trading volume does not increase the volatility of the underlying index. In Australia, Hodgson and Nicholls (1991) concludes that introduction of futures index and futures options index has not affected the long term volatility. Bessembinder and Seguin (1992) found evidence that unexpected S&P500 futures trading were positively related to spot market volatility, but the relationship between spot market volatility and expected futures volume was negative.

Antoniou and Holmes (1995) examine the impact of futures trading in the England Stock Exchange and they concluded that futures’ trading has led to increased volatility in spot market. Bologna (2002) concludes that at least for the Italian Stock Exchange, the existence of stock index futures, by reducing the underlying market volatility, contributes to increase market efficiency.

Illaueca and Lafuente (2003) concluded for Spanish Stock Exchange that there not exists evidence to support the hypothesis of transmission of volatility from futures to the spot market. Zavaleta (2006) investigates microstructures variables in Mexican Stock Exchange market and finds that the introduction of electronic trading system decreased the bid-ask spread, increasing volume and affecting volatility decreasing it. For Greek stock market, Drimbetas et al (2007) finds that the introduction of derivatives has induced a reduction of volatility and consequently it has increased the efficiency of the market.
II.3. Methodology and Data

II.3.1 Methodology

The objective of this research is to examine the relationship between stock index futures trading and spot price volatility for the IPC Index (Mexican Stock Exchange). Bologna’s (2002) and Antoniou’s (1995) methodology was used.

In previous empirical studies about this issue, the general methodology adopted is to examine spot price volatility prior to the onset of futures trading and to compare this with spot price volatility in post futures time. Analyzing the behavior of volatility, it is necessary to isolate influences not attributed to futures trading so that the impact futures trading make can be evaluated more readily. This is achieved including a proxy variable for which there is not related futures contract. After “market-wide” movements were isolated, the impact of futures trading is then captured by the introduction of a dummy variable.

One form to capture the time varying nature of volatility is to model the conditional variance as a GARCH process. The GARCH model was developed by Bollersev (1986) from the Autoregressive Conditional Heteroscedasticity (ARCH) model previously introduced by Engle (1982).

According to Gujarati (1995), researchers engaged in forecasting financial time series, such as interest rates, stock prices, inflations rates, and foreign exchanges rates; have observed that their ability to forecast such variables varies considerably from one time period to another. For some times periods the forecast errors are relatively small,
while for others they are relatively large, and then they are small again for another time period. This variability could very well be due to volatility in financial markets, sensitive as they are to rumors, political upheavals, changes in government monetary and fiscal policies, and the like. This would suggest that the variance of forecast errors is not constant but varies from period to period, that is, there is some kind of autocorrelation in the variance of forecast errors.

Since the behavior of forecast errors can be assumed to depend on the behavior of the (regression) disturbances $u_t$, one can make a case of autocorrelation on the variance of $u_t$. To capture this correlation, Engle (1992) developed the autoregressive conditional heteroscedasticity (ARCH) model. If ARCH is present, it is necessary to use generalized least squares (GLS). A generalization of the Arch model is the so-called GARCH, in which the conditional variance on $u$ at time $t$ is dependent not only on past squared disturbances but also on past conditional variances.

The GARCH process is defined as follows:

\[ y_t = \beta X_t + \varepsilon_t \]  \hspace{1cm} (1a)  
\[ \varepsilon_t \sim N(0, h_t) \]

\[ h_t = \alpha_0 + \Sigma \alpha_i \varepsilon_{t-i}^2 + \Sigma \beta_i \varepsilon_{t-i}^2 h_{t-i} + V_t \]  \hspace{1cm} (1b)  

or

\[ h_t = \alpha_0 + A(L)\varepsilon_t^2 + \beta(L)h_t + V_t \]  \hspace{1cm} (2)

Where: $A(L)$ and $\beta(L)$ are lag indicators and $V_t$ is white noise. According Bollersev (1987) among others, the GARCH (1,1) framework has been extensively found to be the most parsimonious representation of conditional variance that best fits many financial times series. In this work I tested alternative representation of volatility in order to find the best specification.
Then, we needed to test the impact of futures trading on volatility, amending the variance equation of the GARCH model with a dummy variable which takes a value of zero for the pre-futures period and a value of one for the post-futures period. Next, we tested the hypothesis that factors other than futures introduction may have affected market volatility. For this purpose we included the NYSE Composite index as a proxy for market factors in the mean equation of the model.

II.3.2 Data

Data used have been provided from Invertia Plus, daily returns of IPC from June 1995 until June 2005 were calculated, yielding a total of 2450 observations. Daily index information includes data from NYSE Composite in order to test whether the changes in volatility should be attributed to market factors rather than to the stock index futures introduction. The NYSE Index was chosen as representative of the behavior of the overall international market.

II.4. Results

As shown in Table 1 the standard deviation of daily returns for the IPC Index is higher for the pre-futures period. In contrast for NYSE index is lower in the same period. Therefore, while volatility in the market without futures is bigger in the previous period, the volatility of spot market underlying the futures contract has decreased on the basis of
this measure. However inferences cannot be drawn from these figures and further investigation is required.

### Table II.1: Mean and standard deviations of first differences of the log of the IPC and NYSE indexes.

<table>
<thead>
<tr>
<th>Period*</th>
<th>n</th>
<th>IPC Mean</th>
<th>IPC Standard Deviation</th>
<th>NYSE Mean</th>
<th>NYSE Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995-1999</td>
<td>2450</td>
<td>0.00068</td>
<td>0.01627</td>
<td>0.00026</td>
<td>0.01008</td>
</tr>
<tr>
<td>1995-Apr 1999</td>
<td>950</td>
<td>0.00094</td>
<td>0.01831</td>
<td>0.00072</td>
<td>0.00916</td>
</tr>
<tr>
<td>Apr 1999-2005</td>
<td>1500</td>
<td>0.00051</td>
<td>0.01484</td>
<td>-0.00003</td>
<td>0.01061</td>
</tr>
</tbody>
</table>

* Excluding Bank Holidays and other non-trading days

Following the Bologna's methodology, in order to identify the most appropriate GARCH model I compare a series of alternative specifications for both the mean and the variance equation. In the mean equation, I compare three different models, with one, two and three autoregressive terms respectively. In the case of Mexico, the IPC was highly impacted for the Russian Crisis in July 1998, so the effect of this was incorporated using a dummy variable in the mean equation. Table 2 reports the values of the Adjusted R-squared, the F-test and the Akaike Information Criterion for the three alternative specifications of the mean equation.
Table II. 2: Analysis of mean equation with different number of lags, for the dependent variable: “Price and Quotation Index (IPC) Return” and Russian Crisis.

<table>
<thead>
<tr>
<th>Number of lags</th>
<th>Adjusted R-squared</th>
<th>t-Statistic</th>
<th>F-Statistic</th>
<th>Akaike</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.019511</td>
<td>4.021408</td>
<td>24.33669</td>
<td>-5.417323</td>
</tr>
<tr>
<td>2</td>
<td>0.013487</td>
<td>-1.072048</td>
<td>16.71331</td>
<td>-5.410943</td>
</tr>
<tr>
<td>3</td>
<td>0.013353</td>
<td>-0.898092</td>
<td>16.53874</td>
<td>-5.410442</td>
</tr>
</tbody>
</table>

Statistics for the lags, significant at 1% level in one lag
Significance levels: *1%, **5%, ***10%

From the previous table, we can observe the lags increase insofar as the R-squared decreases; the same relationship occurs with the Akaike Information Criterion and the F-test. The equation with one lagged term has been chosen because it has the most statistic significant coefficient, as displayed through the T-test. So the best specification model in the mean equation is:

\[ IPC_t = \beta_0 + \beta_1 IPC_{t-1} + \beta_2 D_c + \epsilon_t \]  

(3)

Where \( IPC_t \) is the daily change in log prices for the IPC index, \( IPC_{t-1} \) is the previous return and \( D_c \) is the dummy for Russian Crisis.

GARCH (1,1) model has been found to be, at least within the GARCH class of models, the most convenient way to represent conditional variance for financial time series. I tested the consistency of this finding for the Mexican market using the likelihood ratio (LR) test. The restricted model of GARCH (1,1) was tested against the unrestricted model. To estimate the various GARCH models of table 4, maximum likelihood was used using the Berndt, Hall, Hall and Hausman (1974) algorithm and assuming that the errors follow a normal distribution. For every case the null hypothesis about the process of generation of returns follows GARCH (1,1) was not annulled. Results of the LR test are reported in Table 3.
Table II.3: Variable Exclusion Test for GARCH model.

<table>
<thead>
<tr>
<th></th>
<th>Log likelihood</th>
<th>Likelihood</th>
<th>Critical values at 5% significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unrestricted model</td>
<td>Restricted model</td>
<td>Ratio Test</td>
</tr>
<tr>
<td>GARCH (1,2) vs GARCH (1,1)</td>
<td>6928.1</td>
<td>6928.1</td>
<td>0.0000</td>
</tr>
<tr>
<td>GARCH (1,3) vs GARCH (1,1)</td>
<td>6936.8</td>
<td>6928.1</td>
<td>0.0025</td>
</tr>
<tr>
<td>GARCH (2,1) vs GARCH (1,1)</td>
<td>6928.1</td>
<td>6928.1</td>
<td>0.0000</td>
</tr>
<tr>
<td>GARCH (2,2) vs GARCH (1,1)</td>
<td>6928.5</td>
<td>6928.1</td>
<td>0.0001</td>
</tr>
<tr>
<td>GARCH (2,3) vs GARCH (1,1)</td>
<td>6937.5</td>
<td>6928.1</td>
<td>0.0027</td>
</tr>
<tr>
<td>GARCH (3,1) vs GARCH (1,1)</td>
<td>6935.1</td>
<td>6928.1</td>
<td>0.0020</td>
</tr>
<tr>
<td>GARCH (3,2) vs GARCH (1,1)</td>
<td>6943.1</td>
<td>6928.1</td>
<td>0.0043</td>
</tr>
<tr>
<td>GARCH (3,3) vs GARCH (1,1)</td>
<td>6937.8</td>
<td>6928.1</td>
<td>0.0028</td>
</tr>
</tbody>
</table>

Heteroskedasticity Consistent Covariance (Bollerslev-Wooldridge)
Optimization algorithm Marquardt

The best specification found is:

\[
IPC_t = \beta_0 + \beta_1 IPC_{t-1} + \beta_2 Dc + \varepsilon_t, \quad \varepsilon_t|\Phi_{t-1} \sim N(0, h_t) \quad (4a)
\]

\[
h_t = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \alpha_2 h_{t-1} + \gamma DUM_F \quad (4b)
\]

With \( \alpha_1 > 0, \alpha_2 > 0 \) and \( \beta_1 > 0 \). In equation (4a) \( IPC_t \) is the daily return on the IPC Index and \( IPC_{t-1} \) is a proxy for the mean of \( IPC_t \), conditional on past information, \( Dc \) is "dummy variable" which takes value of one for the period of July 1998 crash and zero otherwise. The conditional variance equation (4b) was increased to incorporate the \( DUM_F \) variable which represents the "dummy variable" and takes value zero for the pre-futures period and one for the post-futures period. This dummy allows us to determine whether exist any relationship between the IPC futures and the volatility of spot market.
Table II.4. Maximum likelihood estimates for the GARCH (1,1) model with dummy variable.

<table>
<thead>
<tr>
<th>$\beta_0$</th>
<th>$\beta_1$</th>
<th>$\beta_2$</th>
<th>$\alpha_0$</th>
<th>$\alpha_1$</th>
<th>$\alpha_2$</th>
<th>$\gamma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00112*</td>
<td>0.12694*</td>
<td>-0.01074*</td>
<td>8.00E-06*</td>
<td>1.33E-01*</td>
<td>0.847056*</td>
<td>-1.9E-06***</td>
</tr>
<tr>
<td>(0.00026)</td>
<td>(0.0225)</td>
<td>(0.002048)</td>
<td>(1.64E-06)</td>
<td>(8.62E-03)</td>
<td>(0.01067)</td>
<td>(1.24E-06)</td>
</tr>
<tr>
<td>0.001061</td>
<td>0.132304</td>
<td>-</td>
<td>7.67E-06</td>
<td>0.130833</td>
<td>0.850102</td>
<td>-1.84E-06</td>
</tr>
<tr>
<td>(0.00026)</td>
<td>(0.02246)</td>
<td>(1.60E-06)</td>
<td>(0.00851)</td>
<td>(0.01049)</td>
<td>(1.22E-06)</td>
<td></td>
</tr>
</tbody>
</table>

Significance levels. *1%, **5%, ••• 10%
Standard error is presented.

The results presented in Table 4 show that all the coefficients in the conditional variance equation are significant at 1%, except to the “dummy” variable, that is significant just around 10% level.

The negative coefficient is the expected for suggesting that the introduction of futures contract, contribute to diminish the stock market volatility in México, this results are similar to the Bologna’s (2002) study for Italy Stock Market, but are in contrast with the findings of Antoniou and Holmes (1995) for the London Stock Exchange where the introduction of futures index increase the volatility on spot market, and Hodgson and Des Nicholls(1991) find that futures contracts not affected the spot market in the Australian Stock Exchange.

The following step was taken to examine whether futures trading introduction is the only factor responsible for the reduction in the stock market volatility. To address this issue I including the daily returns of the NYSE Composite, as exogenous explanatory variable in the specification for the IPC Index returns series. The model estimated takes the following form:

$$IPC_t = \beta_0 + \beta_1 IPC_{t-1} + \beta_2 D_t + \beta_3 NYSE_t + \varepsilon_t, \quad \varepsilon_t | \phi_{t-1} \sim N(0, h_t) \quad (5a)$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \gamma DUM_F \quad (5b)$$
I tested the hypothesis that futures trading is the only cause for diminished volatility, testing the null hypothesis of $y = 0$ for the adjusted model.

Two GARCH (1,1) models were estimated, one for the pre-futures sub-period and other for the post-futures sub-period, in order to check how the estimates of the GARCH coefficients change from one period to another. This allowed to us to obtain more information about the effect of the introductions of index futures in Mexico. The model estimated was the same as used in equations (5a) to (56) with the exceptions that the variance equation does not contain the dummy variable $D_F$. The results are showed in Table 5.

Table II.5: Maximum likelihood estimates for the GARCH (1,1) model with NYSE variable in the mean equation and Russian Crisis.

<table>
<thead>
<tr>
<th></th>
<th>$\beta_0$</th>
<th>$\beta_1$</th>
<th>$\beta_2$</th>
<th>$\beta_3$</th>
<th>$\alpha_0$</th>
<th>$\alpha_1$</th>
<th>$\alpha_2$</th>
<th>$\gamma$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Estimates for the whole period</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.00066*</td>
<td>0.0967*</td>
<td>-0.00612*</td>
<td>0.76277*</td>
<td>0.000006*</td>
<td>0.10712*</td>
<td>0.87362*</td>
<td>-0.000003*</td>
</tr>
<tr>
<td></td>
<td>(.00022)</td>
<td>(0.0164)</td>
<td>(0.00175)</td>
<td>(0.01923)</td>
<td>(1.16E-06)</td>
<td>(9.29E-03)</td>
<td>(0.01051)</td>
<td>(0.0000089)</td>
</tr>
<tr>
<td><strong>Before the introduction stock futures index</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0004</td>
<td>0.1085*</td>
<td>0.00452**</td>
<td>0.8704*</td>
<td>1.18E-05*</td>
<td>0.1533*</td>
<td>0.8031*</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.0004)</td>
<td>(0.0279)</td>
<td>(0.00188)</td>
<td>(0.04546)</td>
<td>(0.000003)</td>
<td>(0.0193)</td>
<td>(0.0237)</td>
<td>-</td>
</tr>
<tr>
<td><strong>After the introduction stock futures index</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.00069*</td>
<td>0.089376*</td>
<td>-</td>
<td>0.7366*</td>
<td>5.00E-07*</td>
<td>0.0339*</td>
<td>0.96129*</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.000692)</td>
<td>(0.089376)</td>
<td>(0.022967)</td>
<td>(0.000000195)</td>
<td>(0.00577)</td>
<td>(0.006073)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Significance levels: * 1%, **5%, ***10%
Standard errors are presented in parentheses.
Results in Table 5 show that $\gamma$ dummy variable becomes more significative with the introduction of NYSE variable, suggesting that may be other factors affect volatility in México, is significative at 1*.

$\alpha_1$ is the coefficient relating to the lagged squared error term. In the context of this analysis, the lagged error term relates to changes in the spot price on the previous day which is attributable to market-specific factors.

According to Antoniou and Holmes (1995), assuming that market is efficient, these price changes are due to the arrival in the market of information specific to the pricing of the IPC. Hence, $\alpha_1$ relates to the impact of yesterday's market-specific price changes today. Because this relates to the arrival of information yesterday, $\alpha_1$ can thus be viewed as a "news" coefficient, with a higher value implying that recent news has a greater impact on price changes. Thus, $\alpha_2$ can be defined as "old news". $\alpha_2$ is the coefficient on the lagged variance term and as such is picking up the impact of price changes relating to days prior to the previous day and thus to news which arrived before yesterday.

In the case of México, it can be observed that the "news" impact diminishes in the post-futures period of the introduction of IPC futures contracts, given that the coefficient takes a value of 0.1533 in pre-futures period and 0.0339 then. Meanwhile the coefficient of "old news" increases from 0.8032 to 0.9613. These results, related to London and Italy are presented in the Table 6, where we can observe that they have opposite behavior to México.
Table II.6: Comparative estimates coefficients values of $\alpha_1$ and $\alpha_2$

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>London</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;News&quot;</td>
<td>0.0862</td>
<td>0.0991</td>
</tr>
<tr>
<td>&quot;Old News&quot;</td>
<td>0.8423</td>
<td>0.819</td>
</tr>
<tr>
<td><strong>Italy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;News&quot;</td>
<td>0.059</td>
<td>0.137</td>
</tr>
<tr>
<td>&quot;Old News&quot;</td>
<td>0.928</td>
<td>0.663</td>
</tr>
<tr>
<td><strong>Mexico</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;News&quot;</td>
<td>0.1533</td>
<td>0.0339</td>
</tr>
<tr>
<td>&quot;Old News&quot;</td>
<td>0.8032</td>
<td>0.9613</td>
</tr>
</tbody>
</table>

It would be reasonable to expect that the impact of recent incoming news would increase with the onset of stock index trading. In the case of Mexico however, this is not confirmed given the decrease of $\alpha_1$. The value of $\alpha_2$ is expected to decrease in the post-futures sub period, explaining for the increased rate of information flow reducing the uncertainty about previous news (reducing $\alpha_2$). In other words, in presence of stock index futures trading “old news” has less impact in determining the volatility of the stock market. This argument seems to confirm the expectation of increased market efficiency as a consequence of the activity in stock market futures (London and Italy). In the case of México, these results are not consistent with the theoretical arguments of Ross (1989) and the view that futures trading increase the flow of information to the spot market.

Interpreting the results for before and after periods of futures trading, a GARCH (1,1) representation is the most appropriate form of the model. The unconditional variance, given by $\alpha_0 / (1 - \alpha_1 - \alpha_2)$ is 0.000271 for pre-futures and 0.000105 for post-futures. This again seems to indicate lower market volatility after stock index futures introduction for the Mexican Stock Exchange.
The value of \( \alpha_1 \) decreases in post-futures period, suggesting a decrease in volatility. \( \alpha_1 \) is the coefficient related to the lagged squared error term. In the context of this analysis the lagged error term relates to changes in the spot price on the previous day, which is attributable to market-specific factors, i.e. non-market-wide factors.

Regarding the dummy variable, in the case of México and Italy, the sign of the coefficient obtained was negative, and the significance was at 10% respectively. This suggests that the introduction of futures contracts contributed to decreasing the market volatility per se, although for the case of México was much less registering a -3.19E-06 in the coefficient value, Italy an -0.01 and England 1.117E6.

Bologna`s results from this second estimation confirm that, in contrast to Antoniou and Holmes (1995) findings for the London Stock Exchange, without using any market factor in the mean equation, the overall volatility of the Italian stock market diminished after the introduction of stock index futures trading. This can be seen both from the sign of the coefficient \( \gamma \) of the dummy variable \( D_F \) and from the value of the unconditional variance for the two sub-periods. This result supports the hypothesis that index futures market reduced volatility, this result however has to be taken with caution, because the Mexican Stock Exchange had important change, it was the introduction of the electronic trading system at almost the same time of the introduction of futures index and Zavaleta (2006) finds that decrease in volatility of Mexican Stock Market is caused for less bid-ask spread and more volume. Hence, we can conclude that similarly to Italian Stock Exchanges, stock index futures introduction have a positive effect on the underlying market volatility, by decreasing it.
II.5. Conclusions

In this paper the GARCH technique was used to analyze the relationship between stock index futures and corresponding stock market volatility for the Mexican Stock Exchange. The results obtained shows that after futures market introduction, the volatility of IPC was diminishing. This argument is also supported by the finding that unconditional volatility in the post-futures period was lower than that in the pre-future period considered. However, the results have to be taken with caution because Mexican Stock Exchanges had important changes in the same time, the most relevant was the introduction of the electronic trading system, Zavaleta (2006) finds that this issue impact on a lower volatility on the Mexican Market and less spread in general terms. Further investigation is required in order to isolate the effect of introduction futures in the spot market if there exits.
CHAPTER III. EFFICIENCY TEST OF THE MEXICAN FINANCIAL FUTURES MARKETS AND THE IMPACT OF ELECTRONIC TRADING SYSTEMS

III.1. Introduction

In finance one of the most topics studied by researchers over the past four decades is market efficiency, mainly focused on stock markets. There are no many studies about efficiency market derivatives though this market has been growing around the world. Efficiency knowledge is very important in order more informed investors can outperform less knowledgeable ones. Characteristics of securities and types of operators can affect the degree of the market efficiency. The simplest definition of market efficiency is that the price already reflects the available information and thus buying or selling the stock should, on average, return to the investors only a "fair" measure of return (after transaction costs) for the associated risk.

According to Fama (1970) there are three forms of efficiency: weak-form in which the information subset of interest is just past price (or returns) histories; semi-strong form in which the concern is the speed of price adjustments of stock splits, annual reports, new securities issues, among others and finally strong-form in which the concern is whether any investor or groups (e.g., managements of mutual funds) have monopolistic
access to any information relevant for the formation of prices have recently appeared. These forms of efficiency are summarized in the Efficient Market Hypothesis (EMH) by Fama (1965, 1970).

The efficient market hypothesis is associated with the concept of “random walk”, term widely used in finance literature to characterize a price series where all subsequent price changes represent random departures from previous price. Malkiel (2003) stated that the logic of the random walk idea is that if the flow of information is unimpeded and information is immediately reflected in stock prices, then tomorrow’s price change will reflect only tomorrow’s news and will be independent of the price changes today. But news is by definition unpredictable and, thus, resulting price changes must be unpredictable and random. A fully efficient market will have completely random and unpredictable price changes.

When we have confirmed a random walk in a research, is considered sufficient condition of market efficiency. But is important to establish the rejection of a random walk does not necessarily imply market inefficiency.

This study aims to investigate the efficiency of futures trading by examining three Mexican financial futures contracts: IPC futures, TIIE and DEUA (or stock index futures, interest rate futures and foreign exchange rate futures respectively). In May of 2000 the electronic trading system was introduced in to the futures markets with the aim of improving speed, ease and transparency in Mexican Derivatives Market (MEXDER) trading. This study also examines whether the trading system automation has any significant impact on the efficiency of the contracts under investigation. Similar research comes from Evans (2006), who analyzes the UK derivatives market.
For robustness, three testing methods are employed to examine the weak form efficiency of the markets via the observation of randomness of their price processes. Mexican Derivative Market was created in 1998 and had shown an important performance, as similar emerging countries, some years has been ranked in the top ten exchanges in a world, in terms of increments of volume traded. At this time there are limited studies about this market, so there is important contributing to develop research on this field.

This chapter is organized as follows: Section two reviews previous studies on the efficiency of financial markets. Data and methodology used for the testing procedures are explained in Section three, followed by the report of empirical results in Section four and finally Section five presents the conclusion.

III.2. Literature Review

An important number of investigations have examined the efficiency of various financial markets. Earlier work on the US stock markets (i.e. Working, 1934, 1960; Fama, 1965; Samuelson, 1965), all report random fluctuation of security prices. Fama (1965) found that successive runs of stock price changes validated the Random Walk Hypothesis (RWH). Kho (1996) examines the efficiency of foreign currency markets and confirm previous studies that have found that the technical rules generate statistically significant measured profits in foreign exchange markets. Several other studies have examined market efficiency via the measure of the security prices autocorrelation and considered significant non-zero autocorrelation as the indicator of market weak-form inefficiency.
Gwilym and Stucliffe (1999) summarize the findings of 36 empirical studies, using high frequency data, on the dependence in returns of stock index futures, interest rate futures, spot equities and spot foreign exchange rates, the majority of which found negative first-order autocorrelation in the price returns of the financial instruments under their research. For the UK, ap Gwilym and Stucliffe (1999) found a non-linear dependence (Arch effects) in price returns of the FTSE100 futures, Long Gilt (bond futures) and Short Sterling contracts.

As for the randomness of the security prices, the empirical results are mixed. A number of more recent empirical studies find that security prices do not follow a random walk process. Ayadi and Pyun (1994) find no conclusive evidence of a random walk in South Korean equity prices. Similarly, Madhusoodanan (1998) also reports no random walk process in the BSE national indices on the Indian market. Grieb and Reyes (1999) find non-random walk in the Mexican market but a random walk in the Brazilian market. Chang and Ting (2000) find that the random walk hypothesis cannot be rejected with monthly, quarterly and annually value-weighted market indices of the Taiwanese stock prices. Huber (1997) does not find randomness in the daily stock returns in the Vienna Stock Exchange either but suggests that, as the market becomes institutionally more mature and more liquid, stock returns approach a random walk.

On the other hand, Li and Zu (2002) examines the Efficient Market Hypothesis using four New Zealand Stock Exchange indices within the random walk, cointegration and Granger causality test framework and find that small-firm stock market is semi-strong

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form efficient to a certain degree. The share market of the top ten companies is not even weak-form efficient; while the share markets covering the top 30 and 40 large companies are weak-form efficient but not semi-strong form efficient. Smith et al. (2002), as well as Magnusson and Wydick (2002), report the randomness of stock prices of various African markets. Ryoo and Smith (2002) finds that the price limit system prevents the security prices of Korean Stock Exchange from following a random walk process, resulting in the market being inefficient but the stock market as a whole approaches a random walk as price limits are relaxed. Majnoni and Massa (2001) find that most of the reforms introduced by the Italian Stock Exchange, i.e. the specialized intermediaries, an obligation to trade on the official markets and screen-based trading have increased market efficiency over the sample period. Only the cash settlement appears to have substantially reduced it.

Freund and Pagano (2002) measure the degree of market efficiency before and after automation at the New York and Toronto Stock Exchanges. Overall, the results show that the level of informational efficiency remains effectively unchanged during the automation period. Despite several deviations from a random walk process, the returns for stocks on these exchanges do not appear to exhibit consistent patterns that investors can exploit to generate abnormal returns. Automation coincides with an improvement in market efficiency at the Toronto Stock Exchange when compared with the New York Stock Exchange. Zavaleta (2006) find that once electronic trading system was implemented in Mexican Stock Exchanges, a decrease of 1 peso in the spread increases the relative volume traded in 0.008119%. He concluded that the introduction of the electronic trading system decreased volatility in the Mexican market.
There have been relatively very few papers examining the efficiency of the financial futures markets and, particularly, the impact of automation on the efficiency of the futures markets. Lee and Mathur (1999) carried out efficiency tests for six Spanish futures markets: Spanish stock index futures (IBEX 35), interest rate futures MIBOR (90 day), MIBOR (360 day), national bond (10 year), national bond (3 year) and Foreign exchange rate (Deutsche Mark: Spanish Peseta). Their results show a strong evidence of weak-form market efficiency for these six Spanish futures markets.

In the case of Mexico Gurrola and Herrerias (2007) reviewed nonstationary in the Mexican interest rate futures market and find that exists a weekend effect where rate changes tend to be positive on Mondays and negative on Friday, together with a higher volatility at expiration dates in short term contracts and induces to nonstationary patterns.

III.3. Data and Methodology

III.3.1. Data

The data used in this study are daily closing returns of the nearby contracts of three Mexican financial futures contracts: IPC (stock index futures), TIIE28 (interest rate futures) and DEUA (northeastern dollar exchange rate future). The data are obtained from Infosel and Bloomberg, a private data services with information of Mexican Derivatives Market (MEXDER). The sample period covers an 8 years from January 1999 to June 2007.
III.3.2. Methodology

Following Evan's (2006) methodology, the testing process employs three different methods: (1) Augmented Dickey-Fuller (ADF) unit-root test. (2) KPSS test and (3) Lo-MacKinlay Variance Ratio test. Using three tests should provide more robust evidence of the nonstationarity or randomness of the price series under investigation. In addition, the ADF unit-root test is documented to have a shortcoming in failing to distinguish between a unit root and weakly stationary series. To overcome this lack of power of rejection the null hypothesis of a unit root, one needs to test for stationarity in addition to test of the null hypothesis of a unit root (nonstationarity). This is achieved here by using the KPSS test, devised by Kwiatkowski et al. (1992). The KPSS test is specifically designed to perform a test that has stationarity as the null hypothesis and a unit root (nonstationarity) as the alternative hypothesis. The combined results from both the ADF and KPSS tests which is the acceptance of the ADF unit root null hypothesis and the rejection of stationarity from the KPSS test, will provide firmer evidence of the nonstationarity of the price series. However, the unit root tests also fail to detect some important departures from the random walk. I therefore employ the Variance-Ratio test of LO-MacKinlay (1988), which is considered a better alternative, to test for a random walk process.
III.3.2.1. Augmented Dickey-Fuller (ADF) unit-root test.

The Augmented Dickey-Fuller (ADF) test has been a popular test for stationarity of time-series data. The ADF test has a control for higher-order correlation by adding lagged difference terms of the dependent variable in the regression equation as follows:

$$
\Delta Y_t = \mu + \beta T + \gamma Y_{t-1} + \sum_{i=1}^{L} \alpha_i \Delta Y_{t-i} + \epsilon_t, 
$$

The null hypothesis $H_0$ of a unit root (or nonstationarity), when $\gamma = 0$, is tested against the alternative hypothesis $H_1$ or (stationarity), when $\gamma > 0$. The trend time variable $T$ is optional.

In general the ADF test can be performed with an inclusion of a constant, a constant and linear trend, or neither in the test regression. The choice is important since the distribution of the test statistic under the null hypothesis differs among these three cases. As trend is typically one of the inherent characteristics of time series data, particularly financial prices, a constant and a linear trend are therefore included in the test regressions of the analysis.

The null hypothesis of a unit root is rejected (accepted) if the ADF test statistic is less (more) than the critical value at 1%, 5% and 10% level of significance. Here the critical values used are from MacKinnon (1991), a much larger set simulations that allows for any sample size and number of independent variables in the test regression.
III.3.2.2. KPSS test.

Kwiatkowski et al. (1992) proposed the KPSS test, to examine the stationarity of time series. They pointed out that the standard unit root test fail to reject the null hypothesis of a unit root for many economic time series. Nelson and Plosser (1982) report that the unit root tests performed by using three Dickey-Fuller type tests (1976, 1979) gave a false rejection of a unit root null hypothesis of all, except one, of 14 annual US time series data. They believe that the way the classical unit-root hypothesis testing is carried out ensures that the null hypothesis is rejected only if there is strong evidence against it.

However, as most economic time series are not very informative about existence (or absence) of a unit root, the standard unit root tests are, as a result, not very powerful against the alternative hypothesis. This observation has also been supported by the empirical research of DeJong et al. (1989), who found that DF tests had low power against stable autoregressive alternatives with roots near unity. Diebold and Rudebush (1990) also reported that DF tests had low power against fractionally integrated alternatives.

In contrast to the ADF unit root (nonstationarity) tests, the KPSS method sets the stationarity around a deterministic trend of the series under investigation as the null hypothesis (H₀) and nonstationarity (unit root) as the alternative hypothesis (H₁). The series is expressed as the sum of the deterministic trend, random walk and stationary error. The test is the LM test of the hypothesis that the random walk has a zero variance. Based on Kwiatkowsky et al. (1992) the test statistic is calculated as follows:

\[ \eta_u = T^{-2} \sum_{t=1}^{T} S_t^2 / S^2(L), \]  

(2)
Where $L$ is the lag parameter, is the cumulative sum of the residuals ($e_t$) from a regression of the series on a constant and a linear trend variable ($t$).

\[ P_t = \alpha + \beta t + e_t , \]  
(3)

\[ S_t = \sum_{i=1}^{t} e_i; \ t = 1,2, \ldots, T , \]  
(4)

And

\[ S^2(L) = T^{-1} \sum_{t=1}^{T} e_t^2 + 2T^{-1} \sum_{s=1}^{L} \left( 1 - \frac{s}{L+1} \right) \sum_{t=s+1}^{T} e_t e_{t-s} , \]  
(5)

III. 3.2.3. Variance-ratio test.

Lo and MacKinlay (1988) stated that the variance ratio can be used as an alternative test of random walk hypothesis, based on the fact that the variance of random walk increments in a finite sample increased linearly with the sampling interval. For example, the variance of monthly sample series must be four times as large as the variance of weekly data or the variance of weekly sample series must be five times as large as the variance of daily data. This test involves testing whether the ratio of variances of different intervals weighted by their length is one.

Let $p_t$ be the natural logarithm of price series and according with random walk hypothesis, follows the form:

\[ p_t = \alpha + p_{t-1} + \epsilon , \]  
(6)

And the variance of its $q$-differenced series, $(p_t - p_{t-q})$, would be $q$ times the variance of its first-differenced series, $(p_t - p_{t-1})$. Therefore, given $nq + 1$ observations of the price series $p0, p1, p2, \ldots, p_{nq}$ where $q$ is any integer greater than 1.
The variance-ratio VR(q) of q-differenced series is defined as:

\[ VR(q) = \frac{\sigma_h^2(q)}{\sigma_a^2} \], \quad Z^*(q) = \frac{VR(q) - 1}{\sqrt{\phi(q)}} , \quad (7) \]

Where the \( \sum \sigma_e^2(q) \) is an unbiased estimator of 1/q of the variance of the q-differenced series and \( \sum \sigma_a^2 \) is an unbiased estimator of the variance of the first-differenced series.

Most detailed,

\[ \sigma_h^2(q) = \frac{1}{m} \sum_{t=q}^{mq}(p_t - p_{t-q} - q\mu)^2 , \quad (8) \]

where

\[ m = q(nq + 1 - q) \left( 1 - \frac{q}{nq} \right) ; \quad \mu = \frac{1}{nq} (p_{mq} + 1 - p_0) , \quad (9) \]

And

\[ \sigma_a^2 = \frac{1}{nq - 1} \sum_{t=1}^{mq}(p_t - p_{t-1} - \mu)^2 , \quad (10) \]

The standard Z test statistic is

\[ Z(q) = \frac{VR(q) - 1}{\sqrt{\phi(q)}} , \quad (11) \]

Where

\[ \phi(q) = \frac{2(2q-1)(q-1)}{3q(nq)} , \quad (12) \]

To adjust for heteroscedasticity, an inherent characteristic of financial times series, Lo and MacKinlay proposed a modified test statistic, called \( Z^*(q) \) as shown bellow:

\[ Z^*(q) = \frac{VR(q) - 1}{\sqrt{\phi^*(q)}} , \quad (13) \]
where

$$\phi^*(q) = \sum_{j=1}^{q-1} \left[ \frac{2(q-j)}{q} \right] \delta(j),$$  \hspace{1cm} (14)

and

$$\delta(j) = \frac{\sum_{t=j+1}^{nq} (p_t - p_{t-1} - \mu)^2 (p_{t+j} - p_{t+j-1} - \mu)^2}{\left[ \sum_{t=1}^{nq} (p_t - p_{t-1} - \mu)^2 \right]^2},$$  \hspace{1cm} (15)

Both $Z(q)$ and $Z^*(q)$ are asymptotically normally distributed with zero mean and a standard deviation of 1.

### III.4. Empirical results

Table 1 presents the descriptive statistics of the daily price returns of IPC, TIIE28 and DEUA futures contracts during the period 1999-2007. Price returns is the difference of natural logarithms of two successive daily closing prices.

**Table III.1: Descriptive statistics of futures price returns**

<table>
<thead>
<tr>
<th></th>
<th>IPC</th>
<th>TIIE 28</th>
<th>DEUA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.000802</td>
<td>-0.000546</td>
<td>1.56E-05</td>
</tr>
<tr>
<td>($t$-statistic)</td>
<td>(1.775009)</td>
<td>(-1.273019)</td>
<td>(0.010036)</td>
</tr>
<tr>
<td>(Prob.)</td>
<td>0.076</td>
<td>0.2032</td>
<td>0.992</td>
</tr>
<tr>
<td>Median</td>
<td>0.000836</td>
<td>0</td>
<td>0.003666</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.157315</td>
<td>0.201637</td>
<td>0.35977</td>
</tr>
<tr>
<td>Minimum</td>
<td>-0.087894</td>
<td>-0.250132</td>
<td>-0.36853</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.020459</td>
<td>0.019256</td>
<td>0.091474</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.856998</td>
<td>0.216934</td>
<td>-0.7466</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>15.1776</td>
<td>29.86557</td>
<td>2.436616</td>
</tr>
</tbody>
</table>

Notes: Price return is the difference of the natural logarithm of daily closing prices. The observation period covers from 4 January 1999 to 25 June 2007.
The average returns of IPC, TIIE and DEUA futures prices are 0.000802, -0.000546 and 0.000015 respectively. The corresponding t-statistic value of the mean test with the null hypothesis of zero mean are 1.77, -1.27 and 0.01 indicating that none of these futures prices series has its mean different from zero. For symmetry, the standard normal distribution should have zero skewness. The three contracts appear to have its distribution closer to normality. For peakedness, the conventional normality statistic requires the kurtosis to be 3. With the kurtosis level of 15.17 for IPC, 29.86 for TIIE and 2.44 for DEUA, these estimates indicates that both IPC and TIIE price returns have a high peak while that of DEUA is very close to the standard normal distribution. It is in contrast to the finding of Evans (2006), where FTSE100 (stock index futures) is the lower kurtosis in UK.

III.4.1. Augmented Dickey-Fuller (ADF) test.

First the ADF unit root test is used to determine whether the price series under investigation contain a unit root. The results from this test provide evidence of the absence or existence of a unit root for the series examined. Table 2 reports the statistical results of the ADF tests on the returns of IPC, TIIE and DEUA futures contracts. Similarly to Evans (2006) for UK research, an ADF test is conducted on both the level and the first difference of the data series. The tests are also undertaken at various lag lengths, from 0 to 6. The null hypothesis of a unit root is rejected (or accepted) against the one-sided alternative if the $t$-statistic is less (or greater) than the conventional critical values. Here the critical values at 1%, 5% and 10% level of significance are -3.9664, -
3.4139 and -3.1287 respectively.

At levels and the choice of lag 1, the ADF test statistic of the IPC, TIIE and DEUA futures prices series are 0.529, -1.988, and -29.159. For the price first differences (price returns) the ADF test statistics are -30.58, -31.42 and -242.679 respectively. As first differences become larger, the ADF test statistics are decreasing. In the same way of Evans (2006) the ADF tests statistics at levels are all greater than critical values, except for DEUA in lag 1 and 2. Whereas the ADF test statistics at first-difference are all less than the critical values at 1%, 5% and 10%. As a result, the ADF tests fail to reject the null hypothesis of a unit root (H0) in levels, but reject first differences for these three contracts. This implies that the time series of the futures prices under investigation contains one unit root, as similar in UK research of Evans (2006).

The test results are quite robust to the lag length specification and inclusion of the time trend in the regression. The ADF tests therefore provide supporting evidence of nonstationarity for the price series of IPC, TIIE and DEUA futures contracts.
Table III. 2. Augmented Dickey Fuller (ADF) test results of future prices

<table>
<thead>
<tr>
<th>IPC Futures</th>
<th>TIIE 28 Futures</th>
<th>DEUA Futures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level ADF lag</td>
<td></td>
</tr>
<tr>
<td></td>
<td>W/O Trend</td>
<td>With Trend</td>
</tr>
<tr>
<td>1</td>
<td>3.178867</td>
<td>0.529425</td>
</tr>
<tr>
<td>2</td>
<td>2.788007</td>
<td>0.285585</td>
</tr>
<tr>
<td>3</td>
<td>3.429934</td>
<td>0.741742</td>
</tr>
<tr>
<td>4</td>
<td>3.072107</td>
<td>0.539528</td>
</tr>
<tr>
<td>5</td>
<td>3.521544</td>
<td>0.819867</td>
</tr>
<tr>
<td>6</td>
<td>3.167137</td>
<td>0.584665</td>
</tr>
<tr>
<td></td>
<td>First-difference ADF Lag</td>
<td></td>
</tr>
<tr>
<td></td>
<td>W/O Trend</td>
<td>With Trend</td>
</tr>
<tr>
<td></td>
<td>Critical values</td>
<td>Critical values</td>
</tr>
<tr>
<td></td>
<td>W/O Trend</td>
<td>With Trend</td>
</tr>
<tr>
<td>1% level</td>
<td>-3.433343</td>
<td>-3.962526</td>
</tr>
<tr>
<td>5% level</td>
<td>-2.862748</td>
<td>-3.412002</td>
</tr>
</tbody>
</table>
III.4.2. KPSS test.

The KPSS test has stationarity of the time series as the null hypothesis ($H_0$) and a unit root (nonstationarity) as the alternative hypothesis ($H_1$). In this test the null hypothesis of stationarity is rejected in favour of the unit root alternative if the calculated test statistic exceeds the critical values estimated in Kwiatkowski et al. (1992).

This test has the stationarity as the null hypothesis ($H_0$) and nonstationarity (or unit root) as the alternative hypothesis ($H_1$). Critical values are 0.119, 0.146 and 0.216 at the 10%, 5% and 1% significant levels, respectively. The null hypothesis of stationarity is rejected if the test statistic is greater than critical values.

Table 3 reports the KPSS test statistics up to 20 lag lengths for the three futures contracts. The KPSS test statistic value with the choice of lag 1 is 22.02, 19.38 and 12.16 for the IPC, TIIE and DEUA contracts, respectively. The KPSS decline monotonically as the lag length $L$ increases up to around 8. For the three futures price series under investigation, these estimates are much larger than the critical values at all significant levels. Even when the choice of lag ($L$) increases, the magnitude of the decreased KPSS test statistic is still considerably larger than the critical values at all significant levels. In this study, at $L=8$, the KPSS test statistic value has dropped to 4.94, 4.35 and 3.44 for the IPC, TIIE and DEUA contracts respectively. The KPSS simulated critical values are 0.216, 0.146 and 0.119 at the 1%, 5% and 10% levels of significance. Kwiatkowski et al. (1992) considered the value of the lag truncation parameter $L$, used in the estimation of the long-term variance $S^2(L)$ from 0 to 8. Their choice of 8 as the maximal value of lag length ($L$) is based in two considerations. First, the long-term run variance estimate
settled down reasonably well when reaching L=8 for most data series. Second, based on their simulations, L=8 is the compromise between the large size distortions under the null (for L=4) and the very low power under the alternative (L=12). They reported that the values of KPSS test statistics were unfortunately sensitive to the choice of L. Specifically, the value of the test statistics decreases as L increases. This occurs because $S^2(L)$ increases as L increases, and is a reflection of large and persistent positive autocorrelations in the data series.

I therefore conclude that using the simulated critical values in Kwiatkowski et al. (1992) (Table 1, pp. 166), the null hypothesis of stationarity is rejected for the three futures contracts under investigation by the KPSS test at conventional significant levels, i.e. 1%, 5% and 10%. This finding supports the results from the unit root ADF tests and is further evidence of nonstationarity of futures prices of IPC, TIIE and DEUA contracts.

Table III.3: KPSS test results

<table>
<thead>
<tr>
<th>Lag L</th>
<th>IPC</th>
<th>TIIE 28</th>
<th>DEUA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22.0218</td>
<td>19.3833</td>
<td>12.1628</td>
</tr>
<tr>
<td>2</td>
<td>14.7042</td>
<td>12.9408</td>
<td>10.0848</td>
</tr>
<tr>
<td>3</td>
<td>11.0447</td>
<td>9.7186</td>
<td>7.2124</td>
</tr>
<tr>
<td>4</td>
<td>8.8484</td>
<td>7.7850</td>
<td>5.8873</td>
</tr>
<tr>
<td>5</td>
<td>7.3841</td>
<td>6.4958</td>
<td>5.1376</td>
</tr>
<tr>
<td>6</td>
<td>6.3381</td>
<td>5.5748</td>
<td>4.3135</td>
</tr>
<tr>
<td>7</td>
<td>5.5537</td>
<td>4.8840</td>
<td>3.8079</td>
</tr>
<tr>
<td>8</td>
<td>4.9435</td>
<td>4.3466</td>
<td>3.4414</td>
</tr>
<tr>
<td>9</td>
<td>4.4554</td>
<td>3.9166</td>
<td>3.0756</td>
</tr>
<tr>
<td>10</td>
<td>4.0560</td>
<td>3.5647</td>
<td>2.8041</td>
</tr>
<tr>
<td>11</td>
<td>3.7232</td>
<td>3.2714</td>
<td>2.5995</td>
</tr>
<tr>
<td>12</td>
<td>3.4416</td>
<td>3.0233</td>
<td>2.3882</td>
</tr>
<tr>
<td>13</td>
<td>3.2002</td>
<td>2.8105</td>
<td>2.2251</td>
</tr>
<tr>
<td>14</td>
<td>2.9909</td>
<td>2.6262</td>
<td>2.0909</td>
</tr>
</tbody>
</table>
III.4.3. Variance Ratio test.

As was mentioned earlier, the unit root test has been questioned for not being a fully efficient method in testing the non-stationarity of price behavior. For this case, Lo and MacKinlay (1988) proposed the variance ratio test as an alternative for measuring unit root. Around one year later of the beginning of the sample period used in this study, an electronic trading system was introduced in 08 May 2000 for the three financial futures contracts. To observe its impact on futures market efficiency, the variance-ratio test is performed on two observation sets. The first set includes the observations before the introduction of electronic trading system (labeled “Before ET”). The second set includes all observations, both before and after automation (labeled “Incl. ET”). If the series follows a random walk process its variance ratio should be equal to 1. The closeness to 1 of the variance ratios can be used to identify the efficiency level of particular financial market. A decrease in the absolute deviation of the variance ratio from 1 is employed here as an indication of an improvement in the futures market efficiency as a result of the introduction of electronic trading system.

Following the asymptotically standard normal distribution, the critical value of Z and Z* statistics is 2.567, 1.960 and 1.645 at 1%, 5% and 10% significant level, respectively.

Price series used here are in natural logarithm form. The null hypothesis of unit variance
(random walk) is rejected if the test statistic is greater than the critical values, or accepted otherwise.

The variance-ratio statistics for the three futures contracts over the period before the introduction of electronic trading are presented in Table 4 Panel A. For the lag length=2, the statistics are 0.60, 0.40 and 0.56 for three contracts respectively. Their heteroscedasticity-adjusted Z* test statistics are -4.92, -3.76 and -2.99, which are much lower than the critical values. The Z and Z* statistic values follow an asymptotically standard normal distribution, whose critical value at 1%, 5% and 10% is 2.56, 1.96 and 1.645 respectively. As a result none of the Z* statistics of IPC, TIIE and DEUA contracts are significantly different from zero, and hence the VR test fails to reject the null hypothesis of unit-variance, giving supporting evidence of futures prices following a random walk process. In results of Table 4 (Panel C), the variance ratios (at level) of all contracts are close to zero and proved to be statistically indifferent from zero (or having a unit-variance, VR(q)=1), implying randomness in the futures price series. In general form, if traders have knowledge about that market prices follow a random walk they get benefit, but also from the knowledge of the degree of efficiency or inefficiency of the markets. The examination of the absolute deviation of the variance ratio from 1 (as VR(q)=1 indicates a random walk process), rather than its level. According to reported in Panel C, the IPC contract has the lower absolute deviation at 0.40, followed by DEUA (0.45) and TIIE (0.60), indicating that the Mexican stock exchange index futures market is relatively the most efficient (before electronic system), followed by DEUA and TIIE. Among the three Mexican futures contracts, interest rate (TIIE) has shown the largest improvement in market efficiency after the introduction of an electronic trading system.
This is indicated by the smallest absolute deviation of VR from 1 (q=2) at 0.54 as compared with 0.60 before automation.

### Table III.4: Variance-ratio test results of VR (q) and test statistics Z(q) and Z*(q)

<table>
<thead>
<tr>
<th>Lag (q)</th>
<th>IPC VR (q)</th>
<th>Z(q)</th>
<th>Z* (Q)</th>
<th>TIIE VR (q)</th>
<th>Z(q)</th>
<th>Z* (Q)</th>
<th>DEUA VR (q)</th>
<th>Z(q)</th>
<th>Z* (Q)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A: Before electronic trading system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.60</td>
<td>-6.45</td>
<td>-4.92</td>
<td>0.40</td>
<td>-9.16</td>
<td>-3.76</td>
<td>0.56</td>
<td>-8.16</td>
<td>-2.99</td>
</tr>
<tr>
<td>4</td>
<td>0.31</td>
<td>-5.94</td>
<td>-4.77</td>
<td>0.21</td>
<td>-6.47</td>
<td>-3.15</td>
<td>0.29</td>
<td>-6.98</td>
<td>-3.03</td>
</tr>
<tr>
<td>8</td>
<td>0.16</td>
<td>-4.58</td>
<td>-3.98</td>
<td>0.11</td>
<td>-4.58</td>
<td>-2.75</td>
<td>0.13</td>
<td>-5.41</td>
<td>-2.96</td>
</tr>
<tr>
<td>16</td>
<td>0.07</td>
<td>-3.40</td>
<td>-3.18</td>
<td>0.05</td>
<td>-3.28</td>
<td>-2.30</td>
<td>0.07</td>
<td>-3.89</td>
<td>-2.71</td>
</tr>
<tr>
<td><strong>Panel B: Including electronic trading system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.26</td>
<td>-33.33</td>
<td>-8.32</td>
<td>0.46</td>
<td>-24.19</td>
<td>-5.04</td>
<td>0.41</td>
<td>-34.59</td>
<td>-29.12</td>
</tr>
<tr>
<td>4</td>
<td>0.13</td>
<td>-21.15</td>
<td>-5.53</td>
<td>0.26</td>
<td>-17.79</td>
<td>-4.43</td>
<td>0.21</td>
<td>-24.95</td>
<td>-20.72</td>
</tr>
<tr>
<td>8</td>
<td>0.07</td>
<td>-14.26</td>
<td>-3.76</td>
<td>0.13</td>
<td>-13.18</td>
<td>-4.18</td>
<td>0.10</td>
<td>-17.84</td>
<td>-14.34</td>
</tr>
<tr>
<td>16</td>
<td>0.03</td>
<td>-9.93</td>
<td>-2.67</td>
<td>0.06</td>
<td>-9.58</td>
<td>-3.81</td>
<td>0.05</td>
<td>-12.68</td>
<td>-10.07</td>
</tr>
<tr>
<td><strong>Panel C: Absolute deviation of variance ratio from 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.40</td>
<td>0.74</td>
<td>0.60</td>
<td>0.54</td>
<td>0.45</td>
<td>0.59</td>
<td>0.45</td>
<td>0.59</td>
<td>0.59</td>
</tr>
<tr>
<td>4</td>
<td>0.69</td>
<td>0.87</td>
<td>0.80</td>
<td>0.74</td>
<td>0.71</td>
<td>0.79</td>
<td>0.71</td>
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<td>0.79</td>
</tr>
<tr>
<td>8</td>
<td>0.84</td>
<td>0.93</td>
<td>0.89</td>
<td>0.87</td>
<td>0.87</td>
<td>0.90</td>
<td>0.87</td>
<td>0.90</td>
<td>0.90</td>
</tr>
<tr>
<td>16</td>
<td>0.93</td>
<td>0.97</td>
<td>0.95</td>
<td>0.94</td>
<td>0.93</td>
<td>0.95</td>
<td>0.93</td>
<td>0.95</td>
<td>0.95</td>
</tr>
</tbody>
</table>

The Z* statistics are required for statistical inference in case the homoscedasticity assumption of error terms is violated. For the IPC futures market, the variance ratio of the Mexican stock index futures has decreased from 0.60 (q=2) to 0.31, 0.16 and 0.07 as the lag length increases to 4, 8 and 16. The corresponding Z* statistics values are -4.92,
4.77, -3.98 and -3.18. None of the rest statistics are different from zero and therefore I fail to reject the random walk null hypothesis of IPC futures price series. This result indicates that the Mexican stock index futures prices follow a random walk process.

After the introduction of the electronic trading system, the variance ratios \( q^2 \) have decreased to 0.26 for IPC, and DEUA to 0.41; but increased for TIIE (similar to UK interest rate market). A more accurate indication of any improvement in market efficiency after automation can be obtained via the examination of the absolute deviations of their variance ratios (VR) from 1. As reported in Panel C, the Mexican interest rate futures, shows an improvement in its market efficiency as indicated by a smaller absolute deviation than before the introduction of an electronic trading system, i.e. 0.60 and 0.54, and remains at the rest lags. But in the case of IPC and DEUA, the performance was different, because the VR increased with the automation.

In the case of Mexican interest futures market, the value of \( Z \) and \( Z^* \) statistics of TIIE for any lag length \( q \) are less than the common critical values at 1%, 5% and 10%. None of the \( Z^* \) statistics are significantly different from zero and, similarly to the foreign exchange contract (DEUA), fails to reject the null hypothesis of unit variance (or random walk). At \( q=2 \) the variance ratio of TIIE is 0.40, which decreases to 0.21, 0.11 and 0.02 when the lag length \( q \) increases to 4, 8 and 16 respectively. In the case of DEUA, at \( q=2 \) the variance ratio is 0.56, which decreases to 0.29, 0.13 and 0.07. This implies that the interest rate and foreign exchange futures market are efficient at its price series appear follow a random walk process.
III.5. Conclusions

This study examines the efficiency of Mexican futures market in three contracts: stock index futures (IPC), interest rate futures (TIIE) and foreign exchange futures (DEUA). The analytical framework of this study has been based on the concept of weak-form informational efficiency of the Efficient Market Hypothesis (EMH), which states that the market is weakly efficient if the information in past prices cannot be used to forecast future prices and continuously generate superior profits. If this is true, the price path of such financial instruments should follow a random walk hypothesis.

Using daily closing prices over the period of 1999-2007, the study employed three different testing methods to research the price performance of the futures contracts. These are the Augmented Dickey-Fuller (ADF) unit root test, the KPSS test and the Lo-MacKinlay Variance Ratio test.

The results showed that, for all conventional significance levels, the ADF fails to reject the null hypothesis of unit root (or nonstationarity) at level, but rejects the unit root null hypothesis at the first-differences of daily prices of IPC futures, interest rate and foreign exchange contracts. This implies that the price series of these three Mexican futures contracts contain a unit root and are integrated of order one, $I(1)$. This test is robust to the lag length, specification and inclusion of a time trend in the test regression. The ADF test results indicate that the price series of these three Mexican contracts have a unit root and are all significantly nonstationary. As for the KPSS method, the test results have rejected the null hypothesis of stationarity of futures prices series of IPC, TIIE and DEUA all significant levels. This provides further supporting evidence that all three
futures contracts have a nonstationary price generating process. For robustness, the Variance-Ratio test developed by Lo and MacKinlay (1989) was also used for validating evidence of the randomness, or otherwise, of the price series. That is because the first test used has been known to fail to detect certain departures from a random walk. In this analysis, the Variance Ratio tests fail to reject (accept) the unit-variance null hypothesis, the condition for a random walk, for all three futures contracts, implying that the price series of IPC futures, interest rate and foreign exchange rate all follow a random walk process. These results showed weak-form efficiency in the three futures markets under investigation. In order to examine the impact of the introduction of electronic trading system on the market efficiency of futures Mexican market, a measure for relative efficiency is devised and applied to two observation sets, called pre-automation and post-automation. Before the introduction of an electronic trading system, the Mexican stock exchange index futures market is relatively the most efficient, followed by DEUA and TIIE. After automation, the results show that interest rate future (TIIE) contract has the largest improvement in market efficiency.
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BIOGRAPHY

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