THE RELATIONSHIP BETWEEN STOCK PRICE INDEX AND TRADING VOLUME IN THE ISTANBUL STOCK EXCHANGE

M.B.A. THESIS

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THE RELATIONSHIP BETWEEN STOCK PRICE INDEX AND TRADING VOLUME IN THE ISTANBUL STOCK EXCHANGE

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ABSTRACT

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In this study, the long-term relationship and the short-term causality between stock price index and the trading volume and the direction of the causality is investigated in the context of a small stock market, the Istanbul Stock Exchange in Türkiye by using cointegration theory and Vector Error Correction Model. The data used includes daily closing values of ISE composite index and daily aggregate number of share units traded for the period 29/02/1988-30/09/1994. The emprical results reveal evidence of strong linear impact from lagged stock prices to current and future trading volume, which can be explained by both non-tax-related trading models and noise trading models, whereas weak evidence of a linear impact from lagged volume to current and future stock prices, which can be explained by sequential information arrival models and the mixture of distributions model.

Keywords: Granger Causality, Unit Root Test, Co-Integration Test, Vector Error Correction Model

ÖZET

İSTANBUL MENKUL KIYMETLER BORSASI'NDA FİYAT ENDEKSİ VE İŞLEM HACMİ ARASINDAKİ İLİŞKİ

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Bu çalışmada, İstanbul Menkul Kıymetler Borsası'nda (IMKB) fiyat endeksi ve işlem hacmi arasındaki uzun dönem ilişki, kısa dönem nedensellik ve nedenselliğin yönü kointegrasyon teorisi ve Vektör Hata Düzeltme Modeli kullanılarak araştırılmıştır. Testlerde, 29/02/1988 ve 30/09/1994 tarihleri arasındaki IMKB endeksi ve toplam işlem hacmi veri olarak kullanılmıştır. Bulgular, geçmiş endeks değerlerinin şu anki ve gelecekteki işlem hacmi üzerinde kuvvetli doğrusal etkisi olduğunu, ancak ters yöndeki etkinin zayıf olduğunu ortaya koymuştur. Kuvvetli fiyat etkisini vergi-dışı-yatırım güdüleri modeli ve hata yatırım modeli ile ve işlem hacmi etkisini de aralıklı bilgi akışı modeli ve dağılım karışımı modeli ile açıklamak mümkündür.

Anahtar terimler: Granger Nedensellik Testi, Birim Kök Testi, Kointegrasyon Testi, Vektör Hata Düzeltme Modeli

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I. INTRODUCTION

Financial media regularly reports trading volume data in stock markets. The information content of this data has received relatively little attention so far. However volume information can offer useful information for practitioners in investment decisions as well as researchers in testing the theories of financial economics.

This study intends to examine the long-term relationship and the short-term causality between trading volume and stock prices. There are at least four reasons why the price-volume relation is important. First, it provides insight into the structure of financial markets- the rate of information flow to the market, how the information is disseminated, the extent to which market prices convey the information, the size of the market and the existence of short sales constraints.

Second, the price-volume relation is important for event studies that use a combination of price and volume data from which to draw inferences. If price changes and volume are jointly determined, incorporating the price-volume relation will increase the power of these tests.

Third, the price-volume relation is critical to the debate over the empirical distribution of speculative prices. When sampled over fixed calendar intervals (e.g. days), rates of return appear leptocurtic compared to the normal distribution.

Fourth, price-volume relations have significant implications for research into futures markets. Price variability affects the volume of trade in futures contracts. This has bearing on the issue of whether speculation is a stabilising or destabilising factor on futures prices.

Most studies indicate that stock returns and trading volume are positively related to each other. It is shown that the volume that results when a previously uninformed trader interprets the news pessimistically is less than when the trader is an optimist. Since a price (marginally) decreases with a pessimist selling stocks and increases with an optimist buying stocks, a positive correlation between trading volume and stock prices can be assumed.

The main purpose of the present study is to investigate the long-term relationship and short-term linear causality between stock prices and trading volume and the direction of the causality in the context of a small stock market, the Istanbul Stock Exchange in Türkiye. The linear relationship will be investigated by means of Granger causality and the theory of cointegration and vector error correction model will be utilised to differentiate between short-run causality and long-run co-movements.

One of the main limitations of the earlier analyses on the stock price-trading volume relationship is that they are all performed on data from large stock markets. Meanwhile, the results from thin markets can be interesting because of several reasons. First, as spelled out by Lakonishok and Smith (1988) and Lo and MacKinlay (1990), evidence from new markets reduces the data snooping bias connected to financial models. They suggest that the best methodological approach for this type of data snooping is through the use of an independent sample. Furthermore, although the world's capital markets have integrated and developed in recent years, studies on thin security markets have been sparse quantitatively. Also, empirical results from small markets are of great importance to the increasing group of people, who are planning to operate in the international capital markets in the future.

II. LITERATURE REVIEW

II.1. Early Research

Academic treatment of a price-volume relation can be traced to Osborne (1959), who attempted to model the stock price change as a diffusion process with variance dependent on the number of transactions. This could imply a positive correlation between trading volume (V) and absolute value of price change ($|\Delta P|$), as later developed by Clark (1973), Tauchen and Pitts (1983), and Harris (1983). However, by assuming transactions are uniformly distributed in time, Osborne was able to reexpress the price process in terms of time intervals, and did not directly address the volume-price issue.

An early empirical examination of the volume-price relation was conducted by Granger and Morgenstern (1963). Using spectral analysis of weekly data from 1939-1961, they could discern no relation between movements in a Securities and Exchange Commission composite price index and the aggregate level of volume on the New York Stock Exchange. Data from two individual stocks also displayed no price-volume relation. In 1964, Godfrey, Granger and Morgenstern (1964) presented new evidence from several data series, daily and transaction data for individual stocks. But once again they could find no correlation between prices or the absolute values of price differences and volume.

Another finding by Godfrey, Granger and Morgenstern (1964) is that daily volume correlates positively with the difference between the daily high and daily low. This is supported by a later finding that daily volume correlates with the squared difference between the daily open and close. The authors attribute this correlation to institutional factors such as stop-loss and buy-above-market orders that increase the volume "as the price diverges from its current mean" (Godfrey, Granger and Morgenstern, 1964). However, Epps and Epps (1976) have suggested that volume moves with measures of within-day price variability because the distribution of the transaction price change is a function of volume.

The failure of Godfrey et al. (1964) to uncover a price-volume relation motivated the empirical tests of Ying (1966) and Crouch (1970). Ying applied a series of chi-squared tests, analysis of variance and cross-spectral methods to six-year, daily series of price and volume. Prices were measured by the Standard and Poors 500 composite index adjusted for dividend payouts and volume by the proportion of outstanding NYSE shares traded. The following list is Income Statement subset of his findings:

"(1) A small volume is usually accompanied by a fall in price.

(2) A large volume is usually accompanied by a rise in price.

(3) A large increase in volume is usually accompanied by either a large rise price or a large fall in price." (Ying, 1966, p. 676).

Ying's empirical methods are easily criticised, but it should be noted that items (1) and (2) suggest V and ΔP are positively correlated, and item (3) is consistent with a correlation between V and $|\Delta P|$. Each of these interpretations has been supported in subsequent tests. Thus, Ying (1966) was the first to document price-volume correlations in the same data set.

Former studies related with the relation between price changes and trading volume in financial markets are based on two empirical relations: 1) Volume (V) is positively related to the magnitude of the price change ($|\Delta P|$) 2) Volume (V) is positively related to the price change per se (ΔP).

II.2. Research on Volume and the Absolute Value of the Price Change

As an old Wall Street adage that "It takes volume to make prices move." Although one can question the asserted causality, numerous empirical findings support positive volume-absolute price change correlation. The summary of empirical studies from which inferences can be made about the correlation of the absolute value of price change (ΔP) with trading volume (V) can be seen on Table-1.

Crouch (1970 and 1970) found positive correlations between the absolute values of daily price changes and daily volumes for both market indices and individual stocks. Clark (1973) found a positive relation between the square of a measure of the price change and aggregated volume using daily data from the cotton futures markets. Using four-day interval and monthly data from a total of 51 stocks, Morgan (1976) found that in all cases the variance of price was positively related to trading volume. Westerfield (1977) found the same relation in a sample of daily price changes and volumes for 315 common stocks, as did Tauchen and Pitts (1983) using daily data from the Treasury bill features market.

TABLE 1

Summary of Emprical studies from which inferences can be made about the correlation of the Absolute Value of the Price Change (IΔPI) with trading volume (V)[a]

Author(s)	Year of Study	Sample Data	Sample Period	Differencing Interval	Support Positive (IΔpI, V) Correlation ?
Godfrey, Granger, and Morgenstern	1964	Stock market aggregates, 3 common stocks	1959-62 1951-53, 63	weekly, daily, transactions	No
Ying	1966	Stock market aggregates	1957-62	daily	Yes
Crouch	1970	5 common stocks	1963-67	daily	Yes
Crouch	1970	Stock market aggregates, 3 common stocks	1966-68	hourly and daily	Yes
Clark	1973	Cotton futures contracts	1945-58	daily	Yes
Epps and Epps	1976	20 common stocks	Jan., 1971	transactions	Yes
Morgan	1976	17 common stocks and 44 common stocks	1962-65, 1926-68	4-days monthly	Yes
Westerfield	1977	315 common stocks	1968-69	daily	Yes
Cornell	1981	Futures contracts for 17 commodities	1968-79	daily[b]	Yes
Harris	1983	16 common stocks	1968-69	daily	Yes
Tauchen and Pitts	1983	T-bill futures contracts	1976-79	daily	Yes
Comiskey, Walkling, and Weeks	1984	211 common stocks	1976-79	yearly	Yes
Harris	1984	50 common stocks	1981-83	transactions, daily	Yes
Rutledge	1984	Futures contracts for 13 commodities	1973-76	daily	Yes
Wood, Molnish and Ord	1985	946 common stocks, 1138 common stocks	1971-72, 1982	minutes	Yes
Grammatikos & Saunders	1986	Futures contracts for 5 foreign currencies	1978-83	daily	Yes
Harris	1986	479 common stocks	1976-77	daily	Yes
Jain & Joh	1986	Stocks market aggregates	1979-83	hourly	Yes
Richardson, Sefcik, and Thompson	1987	106 common stocks	1973-82	weekly	Yes

[a] This table summarizes the general conclusions of these studies about the correlation of IΔpI and V. Results that indicate no significant correlation are listed as not supporting a positive correlation. These studies employ various measures of the price change and trading volume.

[b] The daily data are transformed into a series of estimated average daily volumes and daily return variances for successive two-month intervals.

* This table is taken from Karpoff (1987)

Tauchen and Pitts (1973), in their study were concerned with the relationship between the variability of the daily price change and the daily volume of trading on the speculative markets. Their work extended the theory of speculative markets in two ways. First, they derived from economic theory the joint probability distribution of the price change and the trading volume over any interval of time within the trading day. Second, they determined how this joint distribution changes as more traders enter (or exit from) the market. The model's parameters are estimated by FIML using daily data from the 90-day T-bills futures market. The results of the estimation can reconcile a conflict between the price variability-volume relationship for this market and the relationship obtained by previous investigators for other speculative markets.

Epps and Epps (1976) found a positive relation between the sample variances of price changes at given volume levels and the volume levels using transactions data from 20 stocks. Wood, McInish and Ord (1985) also report a positive correlation between volume and magnitude of the price change at the transactions level. Jain and Joh (1986) document a similar correlation over one-hour intervals, using data from market index.

Cornell (1981) found positive relations between changes in volume and changes in the variability of prices, each measured over two-month intervals, for each of 17 futures contracts. The relation was almost entirely contemporaneous, as most leading and lagged relations were statistically insignificant. Grammatikos and Saunders (1986) also found volume to be positively correlated with price variability, but for foreign currency futures. Rutledge (1984) found significant correlations between daily volume and the absolute value of daily price change for 113 out of 136 futures contracts analysed. Comiskey, Walking and Weeks (1984) found a similar correlation using yearly data on individual common stocks. Richardson, Sefcik and Thompson (1987) found that trading volume increases with the square of a measure of abnormal return around announcements of dividend changes. Harris (1983) found a positive correlation between volume and the square of the price change using daily data from 479 common stocks. The strength of the correlation varied across securities (Harris, 1986) and the correlation was also found to be stronger for daily than for transactions data. (Harris, 1984)

Haris and Gurel (1986), attempted to identify price pressure caused by large transactions may be inconclusive if the transactions convey new information to the market. This problem is addressed in an examination of prices and volume surrounding changes in the composition of the S&P 500 index. Since these changes cause some investors to adjust their holdings of the affected securities and since it is unlikely that the changes convey information about the future prospects of these securities, they provide an excellent opportunity to study price pressures. The results are consistent with the price-pressure hypothesis: immediately after an addition is announced, prices increase by more than 3 percent. This increase is nearly fully reversed after 2 weeks.

II.3. Research on Volume and the Price Change Per Se

The summary of empirical studies from which inferences can be made about the correlation of the price change (ΔP) with trading volume (V) can be seen in Table-2.

Another familiar Wall Street adage is that volume is relatively heavy in bull markets and light in bear markets. As support, Epps developed tests, first from the bond market (Epps, 1975) then from the stock market (Epps, 1977), which indicate that the ratio of V to $|\Delta P|$ is greater for transactions in which the price ticks up than for transactions on downticks. This was found to hold even when V and $|\Delta P|$ were measured over daily intervals and without regard for the general movement in prices. Conflicting evidence was found by Wood, McInish and Ord (1985) who found that the ratio of V to $|\Delta P|$ is higher for downticks. Smirlock and Starks (1985) found the relation to hold only during periods in which they could distinguish the arrival of information *ex ante*. In other periods, they found slight evidence that the ratio of V to $|\Delta P|$ is lower for upticks than for downticks, which they attribute to positive transaction costs and the lack of information arrival. However, using hourly data from a broad market index, Jain and Joh (1986) find that volume is positively related to the magnitude of price change, but that volume is more sensitive to positive than negative price changes.

TABLE 2

Summary of Empirical Studies drom which Inferences Can be Made about the Correlation of the Price Change (ΔP) with Trading Volume (V)[a]

Author(s)	Year of Study	Sample Data	Sample Period	Differencing Interval	Support Positive (Δp, V) Correlation?
Granger and Morgenstern	1963	Stock market aggregates 2 common stocks	1939-61	weekly	No
Godfrey, Granger and Morgenstern	1964	Stock market aggregates 3 common stocks	1959-62 1951-53,63	weekly, daily, transactions	No
Ying	1966	Stock market aggregates	1957-62	daily	Yes
Epps	1975	20 NYSE bonds	Jan. 1971	transactions	Yes
Morgan	1976	17 common stocks and 44 common stocks	1962-65, 1926-68	4 days, monthly	Yes
Epps	1977	20 common stocks	Jan. 1971	transactions, daily	Yes[b]
Hanna	1978	20 NYSE bonds	May. 1971	transactions	Yes
Bogalski	1978	10 common stocks and 10 associated warrants	1968-73	monthly	Yes
James and Edmister	1983	500 common stocks	1975, 77-79	daily[c]	No
Comiskey, Walkling, and Weeks	1984	211 common stocks	1976-79	yearly	Yes
Harris	1984	50 common stocks	1981-83	transactions, daily	Yes
Smirlock and Starks	1985	131 common stocks	1981	transactions	Yes[d]
Wood, Molnish and Ord	1985	946 common stocks 1138 common stocks	1971-72, 1982	minutes	No
Harris	1986	479 common stocks	1976-77	daily	Yes
Jain and Joh	1986	Stocks and aggregates	1979-83	hourly	Yes
Richardson, Sefcik, and Thopmson	1987	106 common stocks	1973-82	weekly	Yes

[a] This table summarizes the general conclusions of these studies about the correlation of Δp and V. Results that indicate no significant correlation are listed as not supporting a positive correlation. These studies employ various measures of the price change and trading volume.

[b] Support for a positive correlation between Δp and V at the transactions level depends on the treatment of volume over transactions with no price changes.

[c] Stocks are grouped into deciles ranked by average daily volume. Decile ranking is compared with mean daily return.

[d] The data are consistent with a positive correlation between Δp and V on days in which there is known information arrival. On other days the correlation appears insignificant or negative.

* This table is taken from Karpoff (1987)

The findings of Epps (1975), Hanna (1978), Jain and John (1986) and parts of Smirlock and Starks (1985) could imply a positive correlation between volume and the price change *per se* (ΔP). Such a correlation is implied by Ying's items (1) and (2), and several researchers have directly tested and found a positive correlation. Using monthly data from 10 stocks and 10 warrants, Rogalski (1978) found a contemporaneous correlation between price change and volume, but no lagged correlations. Morgan (1976) and Harris (1984, 1986) each found a positive correlation between price changes and volume even though it appears they were not looking for one, as did Richardson, Sefcik and Thompson (1986). Comiskey, Walkling and Weeks (1984) found positive cross-sectional correlations between annual measures of turnover and price change. However, James and Edmister (1983) found no such cross-sectional correlation.

In their study, James and Edmister (1983) examines the relation between common stock returns, trading activity and market value. In particular, the paper addresses the question of whether the firm size effect is explicable in terms of differences in trading activity between large and small firms because of either a liquidity premium associated with small firms or a misassessment of the risk of small firms. The results indicate that although firm size and trading activity are highly correlated, differences in risk adjusted returns across stocks of firms of different size.

Epps (1975), constructed a model of securities markets which predicts with some accuracy the behaviour of bond price changes and transaction volumes. The model regards all transactions as occurring between two groups of investors, the "bulls" and the "bears." Assuming that subjective probable outcomes of end-of-period value have constant coefficient of variation and that interpretations of new information typically reinforce existing opinions, the model implies that the ratio of transaction volume to price change on upticks exceeds the absolute value of this ratio on downticks. This hypothesis was strongly supported by an empirical test with individual transactions data from a sample of widely held, actively traded, high priced corporate bonds.

Smirlock and Starks (1985) investigated the empirical relationship between absolute stock price changes and trading volume by using the data of 300 firms from New York Stock Exchange for the 49 consecutive trading days from 15 June through 21 August 1981 . Using Granger causality tests, they found that there is a significant causal relationship between absolute price changes and volume at the firm level and that this relationship is stronger in periods surrounding earnings announcements. As a result, they suggested that information arrival follows a sequential rather than a simultaneous process, although the results do not support an extreme version of either information arrival model.

II.4. Recent Research

Campbell, Grossman and Wang (1993) investigate the relationship between aggregate stock market trading and the serial correlation of daily stock returns. For both, stock indices and individual large stocks, the first-order daily return autocorrelation tends to decline with volume, which means that it is lower on high-volume days than on low-volume days. The study explains this phenomenon using a model in which risk-averse "market makers" accommodate buying or selling pressure from "liquidity" or "noninformational" traders. Changing expected stock returns reward market makers for playing this role. The model implies that a stock price decline on a high-volume day is more likely than a stock price decline on a low-volume day.

Blume, Easley and O'Hara (1994), in their study on the informational role of volume and its applicability for technical analysis, showed that volume provides information on information quality that cannot be deduced from the price statistic. They developed a new equilibrium model in which aggregate supply is fixed and traders receive signals with differing quality. They showed how volume, information precision and price movements relate and demonstrated how sequences of volume and prices can be informative. They also showed that traders who use information contained in market statistics do better than traders who do not.

Hiemstra and Jones (1994) used linear and nonlinear Granger causality tests to examine the dynamic relation between aggregate daily stock prices and trading volume. They applied the tests to daily Dow Jones stock returns and percentage changes in New York Stock Exchange trading volume over the 1915 to 1946 and 1947 to 1990 periods. Granger tests can provide useful information on whether knowledge of past stock price movements improves short-run forecasts of current and future movements in trading volume and vice versa. They found evidence of significant bi-directional nonlinear causality between returns and volume in both sample periods.

Lamoureux and William (1993), in their study aiming to determine the ability of the joint distribution of returns and volume to explain salient features of stock return data, found out that there exists feedback effects between lagged volume and prices and contemporaneous order flow. They suggested that these would result if traders tended to rebalance portfolios only after large price shocks (as the result of transaction costs) or if traders use dynamic portfolio strategies, such as portfolio insurance. The tests are conducted on stock return and volume data for a sample of individual companies.

Martikainen, Puttonen, Luoma and Rothovius (1994) investigated the dynamic linkages between stock returns and trading volume in a small stock market, i. e. the Helsinki Stock Exchange in Finland during the period 1977-88. Both linear and non-linear dependence is investigated by using Granger causality tests and GARCH modelling. Consistent with earlier US results, their empirical evidence indicates significant bi-directional feedback between volume and stock prices in the period 1983-88. In the period 1977-82, however, no causality is observed. This significant variation in the results over time is explained by the development of Finnish financial market during the research period.

II.5. Explanations For a Causal Stock Price-Volume Relation

There are several explanations for the presence of a causal relation between stock prices and trading volume. First, the sequential information arrival models of Copeland (1976) and Jennings, Starks and Fellingham (1981) suggest a positive causal relation between stock prices and trading volume in either direction. In these asymmetric information models, new information flows into the market and is disseminated to investors one at a time. This pattern of information arrival produces a sequence of momentary equilibria consisting of various stock price-volume combinations before a final, complete information equilibrium is achieved. Due to the sequential information flow, lagged trading volume could have predictive power for current absolute stock returns and lagged absolute stock returns could have predictive power for current trading volume.

Tax-related and non-tax-related motives for trading are a second explanation. Tax-related motives are associated with the optimal timing of capital gains and losses realised during the calendar year. Non-tax-related motives include window dressing, portfolio rebalancing, and contrarian strategies. Lakonishok and Smidt (1989) show that current volume can be related to past stock price changes due to tax and non-tax-related trading motives. The dynamic relation is negative for tax-related trading motives and positive for certain non-tax-related trading motives.

A third explanation involves the mixture of distributions models of Clark (1973) and Epps and Epps (1976). These models provide differing explanations for a positive relation between current stock return variance and trading volume. In the mixture model of Epps and Epps (1976), trading volume is used to measure disagreement as traders revise their reservation prices based on the arrival of new information into the market. The greater the degree of disagreement among traders, the larger the level of trading volume. Their model suggests a positive causal relation running from trading volume to absolute stock returns. On the other hand, in Clark's (1973) mixture model, trading volume is a proxy for the speed of information flow, a latent common factor that affects contemporaneous stock returns and volume. There is no true causal relation from trading volume to stock returns in Clark's common-factor model.

Noise trader models provide a fourth explanation for a causal relation between stock returns and trading volume. These models can reconcile the difference between the short-run and long-run autocorrelation properties of aggregate stock returns. Aggregate stock returns are positively autocorrelated in the short-run, but negatively autocorrelated in the long-run. Since noise traders do not trade on the basis of economic fundamentals, they impart a transitory mispricing component to stock prices in the short-run. The temporary component disappears in the long-run, producing mean reversion in stock returns. A positive causal relation from volume to stock returns is consistent with the assumption made in these models that the trading strategies pursued by noise traders cause stock prices to move. A positive causal relation from stock returns to volume is consistent with the positive-feedback trading strategies of noise traders, for which the decision to trade is conditioned on past stock price movements.

Both non-tax-related trading models and noise trading models predict a significant causal relation from stock prices to volume, whereas causality from trading volume to stock returns is consistent with sequential information arrival models and the mixture of distributions model of Epps and Epps (1976).

III. METHODOLOGY

This study uses linear causality tests to examine the dynamic relation between stock price (daily aggregate stock prices) and trading volume in a small stock market, Istanbul Stock Exchange. Causality tests can provide useful information on whether knowledge of past stock prices movements improves short-run forecasts of current and future movements in trading volume, and vice versa. (Hiemstra and Jones, 1994)

As the standard Granger-causality tests are based on stationary variables, first of all the time series properties of the return and volume series are investigated. For this purpose, autocorrelation, stationarity and co-integration tests are performed. The autocorrelation analysis is done by the use of Ljung-Box Q-statistics and stationarity is tested by the use of Augmented Dickey-Fuller Unit Root test. Then, the co-integration test is performed. The standard Granger-causality tests are only valid if the original time series are not co-integrated. If the time series are co-integrated, then, as Granger (1988) argues, any causal inferences will be invalid. More precisely, Granger remarks: *"Thus, many of the papers discussing causality tests based on the traditional time series modelling techniques could have missed some of the forecastability and hence reached incorrect conclusions about non-causality in* *mean. On some occasions, causations could be present but would not be detected by the testing procedures used. This problem only arises when the series are I(1) and co-integrated.* (Bahmani-Oskooee and Alse, 1993)"

Therefore, it is necessary to check for the co-integration properties of the original series before using the simple Granger test. If co-integration is found, then the simple Granger test should be modified to include error correction mechanism and the model should be formulated in Vector Error-Correction Model.

If the price and trading volume series are found to be non-stationary, differencing would establish stationarity. However, using first differencing filters out low-frequency (long-run) information. The use of error-correction models enables to analyse causality between two variables after reintroducing the low frequency information (through the error-correction term) into analysis.

III.1. Time Series Properties of Data

Economic time series are covariance stationary, if the series have finite second moments, and the mean and covariance structure of the data do not change across observations. In other words, if the statistical properties of the time series do not change over time, it is stationary and one can model the process via an equation with fixed coefficients that can be estimated from past data.

Probably very few of the time series one meets in practice are stationary. Fortunately, however, many of the nonstationary time series encountered have the desirable property that if they are differenced one or more times, the resulting series will be stationary. Such nonstationary series is termed homogenous. The number of times that the original series must be differenced before a stationary series results is called the order of homogeneity.

We can decide whether a series is stationary or determine the appropriate number of times a homogenous nonstationary series should be differenced to arrive at stationary series by looking at its autocorrelations at lags (for this purpose Ljung-Box Q-statistics is used) and by performing Augmented Dickey-Fuller Unit Root tests.

III.1.1. Autocorrelation Analysis (Ljung-Box Q-Statistics)

The autocorrelation function for a stationary series drops off as k, the number of lags, becomes large, but this is usually not the case for a nonstationary series. Ljung-Box Q-statistics is used to test the joint hypothesis that all the autocorrelation coefficients are zero. The Q statistics composed of the first K sample autocorrelations is denoted as:

$$Q = N \; \Sigma pk^2 \qquad (1)$$

where

N : number of observations in the sample

p_k : sample autocorrelation coefficient

Q is (approximately) distributed as chi square with k degrees of freedom. Thus if the calculated value of Q is greater than, say, the critical 5 percent level, we can be 95 percent sure that the true autocorrelation coefficients $p_1, \ldots\ldots, p_k$ are not all zero. (Pindyck and Rubinfeld, 1991, pg:448)

III.1.2. Stationarity (Augmented Dickey-Fuller Unit Root Test)

This is a more formal test of nonstationarity. It is introduced by David Dickey and Wayne Fuller (1981). They have described a variable Pt, which has been growing over time, by the following equation:

$$P_t = A + BT + pP_{t-1} + e_t \qquad (2)$$

where

P_t : growing price series for time, t = 0 to last observation

A : drift variable

B : trend coefficient

p : coefficient on the lag variable

e_t : error term

One possibility is that P_t is growing because it has a positive trend (B>0), but would be stationary after detrending (i.e., p<1). In this case Pt could be used in a regression. Another possibility is that Pt has been growing because it follows a random walk (means it is nonstationary) with a positive drift (i.e., A>0, B=0, and p=1). In this case, one would want to work with backward first difference of Pt. Detrending would not make the series stationary, and inclusion of Pt in a regression (even if detrended) could lead to spurious results.

The test procedure of Dickey and Fuller (1981) is described as follows:

Test statistics can be based on the OLS estimation results from a suitably specified regression equation. For the time series P_t two forms of the un-restricted Augmented Dickey-Fuller regression equations are:

a) with-constant and no-trend

$$\Delta P_t = \alpha_0 + \alpha_1 P_{t-1} + \Sigma_j \ d_j \Delta P_{t-j} + e_t \tag{3}$$

b) with-constant and with-trend

$$\Delta P_t = \alpha_0 + \alpha_1 P_{t-1} + \alpha_2 T + \Sigma_j \ d_j \ \Delta P_{t-j} + e_t \tag{4}$$

The null hypothesis for a and b are:

a) Ho: P_t is a random walk plus drift, $\alpha_1=0$, $\alpha_0=0$

b) Ho: P_t is a random walk plus drift around a trend, $\alpha_1=0$, $\alpha_2=0$

We can define the restricted model for Pt for each case by the following equation, where the null hypothesis (α_1=0 and α_2=0) is true:

$$\Delta P_t = \alpha_0 + \Sigma_j \; d_j \, \Delta P_{t-j} + e_t \qquad (5)$$

Then we can compare the sum of squared errors of restricted and unrestricted models and construct the F-statistics to test whether the restrictions (α_1=0, α_2=0) jointly hold.

$$F = (N\text{-}k)\,(SSE_r\text{-}SSE_{ur}) \,/\, q\,(SSE_{ur}) \qquad (6)$$

where

SSE_r : sum of squared error residuals from restricted model

SSE_{ur} : sum of squared error residuals from unrestricted model

N : number of observations

k : number of estimated parameters in unrestricted model regression

q : number of parameter restrictions

This ratio, however, is not distributed as a standard F distribution under the null hypothesis. Instead, the distribution tabulated by Dickey and Fuller (1981) should be used. The critical values for this distribution (Pindyck and Rubinfeld, Econometric Models and Economic Forecasts, Third Edition, pg:319-333) are much larger than those in the standard F table.

Also, the t-test is conducted for testing whether the condition ($\alpha_1=0$) holds. For both of the cases and the determined lag order j, the following t-test statistic should be calculated:

$$t(P,j) = (P-1) / SE(P)$$

where

SE(P) standard error of parameter P

III.1.3. Cointegration Tests

If two variables follow random walks, but a *linear combination* of those variables are stationary, they are said to be co-integrated. For example it may be that the variables V_t and P_t are random walks (non-stationary), but the variable Z_t, i.e.,

$$Z_t = V_t - B_0 P_t \qquad (7)$$

$$Z_t = P_t - B_1 V_t \qquad (8)$$

is stationary. If this is the case, it is said that P_t and V_t are co-integrated, and B_0 and B_1 are called the co-integrating parameters.

More generally, if V_t and P_t are dth order homogenous nonstationary (integrated of order d), and $Z_t = V_t - B_0P_t$, is bth order homogenous nonstationary, with $b<d$, we say that V_t and P_t are co-integrated of order d,b and denoted $(V_t,P_t) \sim CI(d,b)$.

In testing for bivariate co-integration, one must first make sure that both series are integrated of the same order, i.e., $V_t \sim I(d)$ and $P_t \sim I(d)$. Next, the following co-integration equations should be estimated by OLSQ:

$$V_t = \gamma_O + B_0 P_t + \varepsilon_t \tag{9}$$

$$P_t = \gamma_1 + B_1 V_t + \varepsilon_t' \tag{10}$$

Then the value of Z_t and Z_t' should be calculated. Finally, the stationarity of Z_t and Z_t' should be tested to make sure that Z_t and $Z_t' \sim I(d\text{-}b)$, where $b>0$. For example, if $V_t \sim I(1)$ and $P_t \sim I(1)$, in order for V_t and P_t to be co-integrated, Z_t and Z_t' should be I(0). Specifically, the hypothesis that residuals, Z_t and Z_t', are nonstationary, i.e., the hypothesis of no co-integration is tested. For this purpose Augmented Dickey-Fuller Unit Root test is performed on the residual series.

Once, the co-integration is detected between two variables, the question that remains is which variable causes the other. Before the appearance of the error-correction models, the standard Granger or Sims tests were used to provide the answer, however as mentioned before, Granger (1988) argues that these tests are likely to provide invalid causal inferences when the time series are co-integrated. This is because the error-correction terms are not included in the standard Granger and Sims tests. The alternative test for Granger causality is based on error-correction models that incorporate information from the co-integrated properties of the variables involved.

III.2. Standard Granger Causality

Granger causality tests investigate the dynamic relationship of two stationary time series, in this case stock prices, {Pt} and trading volume {Vt}, which can be formulated as follows assuming stationary at level:

$$P_t = ao + \Sigma_i \, c_{0i} \, V_{(t-i)} + \Sigma_j \, d_{0j} \, P_{(t-j)} + e_t \quad (11)$$

$$V_t = a_1 + \Sigma_i \, c_{1i} \, P_{(t-i)} + \Sigma_j \, d_{1j} \, V_{(t-j)} + e_t' \quad (12)$$

The standard Granger causality examines whether past values in one variable, P, help to explain current values in another variable, V, over and above the explanation provided by past changes in V. To determine whether causality runs in the other direction, the experiment will be repeated by interchanging P and V as in Equation (12).

The test depends on the following null hypothesis:

H_O: $c_{0i} = 0$ for all i's and

H_O: $c_{1i} = 0$ for all i's

Specifically, V is said to Granger-cause P, if at least one of the c_{0i}'s is significantly different from zero (Ho is rejected). Similarly, P is said to Granger-cause V, if one of the c_{1i} 's is significantly different from zero. If both of these conditions hold, then we can say that there exists feedback, i.e. bi-directional causality between price and trading volume. The test for causality is based on F-statistic which can be calculated as in equation (6). In the calculation of F-statistics, the above models are referred to as full models, while the ones excluding c_{0i}'s and c_{1i}'s are referred to as reduced models.

It should be noted that, if we find that the series are non-stationary and there is co-integration between them, then the above Granger causality would not be valid, but it should be modified to include error-correction terms, more specifically vector-error correction model should be used.

III.2.1. Vector Error Correction Model

Vector error correction allows long-run components of variables to obey equilibrium constraints while short-run components have a flexible dynamic specification when there is cointegration between two series.

The error-correction models are formulated by the following equations. (Bahmani-Oskooee and Alse, 1993) In these equations, the variables are defined in terms of their first differences and the error-correction terms are introduced.

$$(1\text{-}L)V_t = a_o + b_o Z_{t-1} + \Sigma_{i=1,..M}\ c_{oi}(1\text{-}L)V_{t-1} + \Sigma_{i=1,..N}\ d_{oi}(1\text{-}L)P_{t-1} + e_t \quad (13)$$

$$(1\text{-}L)P_t = a_1 + b_1 Z_{t-1}' + \Sigma_{i=1,..M}\ c_{1i}(1\text{-}L)P_{t-1} + \Sigma_{i=1,..N}\ d_{1i}(1\text{-}L)V_{t-1} + e_t' \quad (14)$$

where L is the lag operator and the error-correction terms Z_{t-1} and Z_{t-1}' are the stationary residuals from co-integration equations (7) and (8) respectively which are used with lags (one period). By including the error-correction terms in (13) and (14), the error-correction models introduce an additional channel through which Granger causality could be detected. For example, concentrating on equation 13, P is said to Granger cause V not only if the d_{oi} 's are jointly significant, but also if b_o is significant. Therefore, in contrast to the standard Granger test, the error-correction model allows for finding that P Granger causes V, as long as the error-correction term carries a significant coefficient even if the d_{oi} 's are not jointly significant.

The coefficient of the error-correction terms show the speed of adjustment by providing the proportion of deviation that is corrected within one unit of time (in our case one day).

As Oskooee and Alse (1993) states, an issue pertaining to the error-correction models that has not been settled yet is whether long-run causality can be distinguished from short-run. Granger (1988) concludes that the error-correction models should produce better short-run forecasts and provide the short-run dynamics necessary to obtain long-run equilibrium.

A possible interpretation offered by Jones and Joulfaian (1991) is that the lagged changes in the independent variable represent the short-run causal impact, while the error-correction term gives the long-run impact. According to this interpretation, the series V_t and P_t exhibit long-run comovements, when at least one of the coefficients b_0 and b_1 is different from zero. Similarly, there is a short-term relationship between the series V_t and P_t, when at least one of the coefficients c_0 and c_1 is different from zero.

IV. DATA

Daily data, stock market index and trading volume, from the Istanbul Stock Exchange (ISE) is used in this study. Stock market index series, Pt, is composed of daily closing value of ISE composite index and it will be referred as price during the study. Regarding trading volume series, Vt, daily aggregate figures in the share units is used. The data is transformed by taking natural logarithm.

Data is collected for the period 29/02/1988-30/09/1994. Sample period is divided into three sub-periods according to the important shifts in trading volume. Tests are conducted separately for each three sub-period as well as for the whole period. The sub-periods can be seen in Table-3.

Table-3 Test Periods

PERIOD	COVERS:	TRADING VOLUME
1988-1994 (Whole period)	29/02/1988 - 30/09/1994	115-23203
1988-1989 (Period-1)	29/02/1988 - 29/12/1989	115-751.6
1990-1992 (Period-2)	02/01/1990 - 31/12/1992	5226.1-8378.2
1993-1994 (Period-3)	04/01/1993 - 30/09/1994	21287.1-23203

V. EMPIRICAL RESULTS

In this chapter, the findings related with the time series properties of the data and the Granger causality will be reported for every test period.

V.1. Time Series Properties of Data

In this part, first of all, the volume and price series for the whole test period are plotted in Figures 1 and 2. Then the basic statistical properties of the logarithmic price and the volume series are analysed. The results can be seen in Table-4.

Table-4: Statistical Properties of Logarithmic Price and Volume Series (1988-1994)

	PRICE	**TRADING VOLUME**
Mean	5835.163469	384470791895
Standard Error	157.4162272	17075005578
Median	3840.1242	105772713850
Standard Deviation	6388.461752	692959182137
Variance	40812443.56	4.80192E+23
Kurtosis	1.841418359	11
Skewness	1.661359017	3
Range	28521.59	5328261705900
Minimum	362.02	110920400
Maximum	28883.61	5328372626300
Count	1647	1647

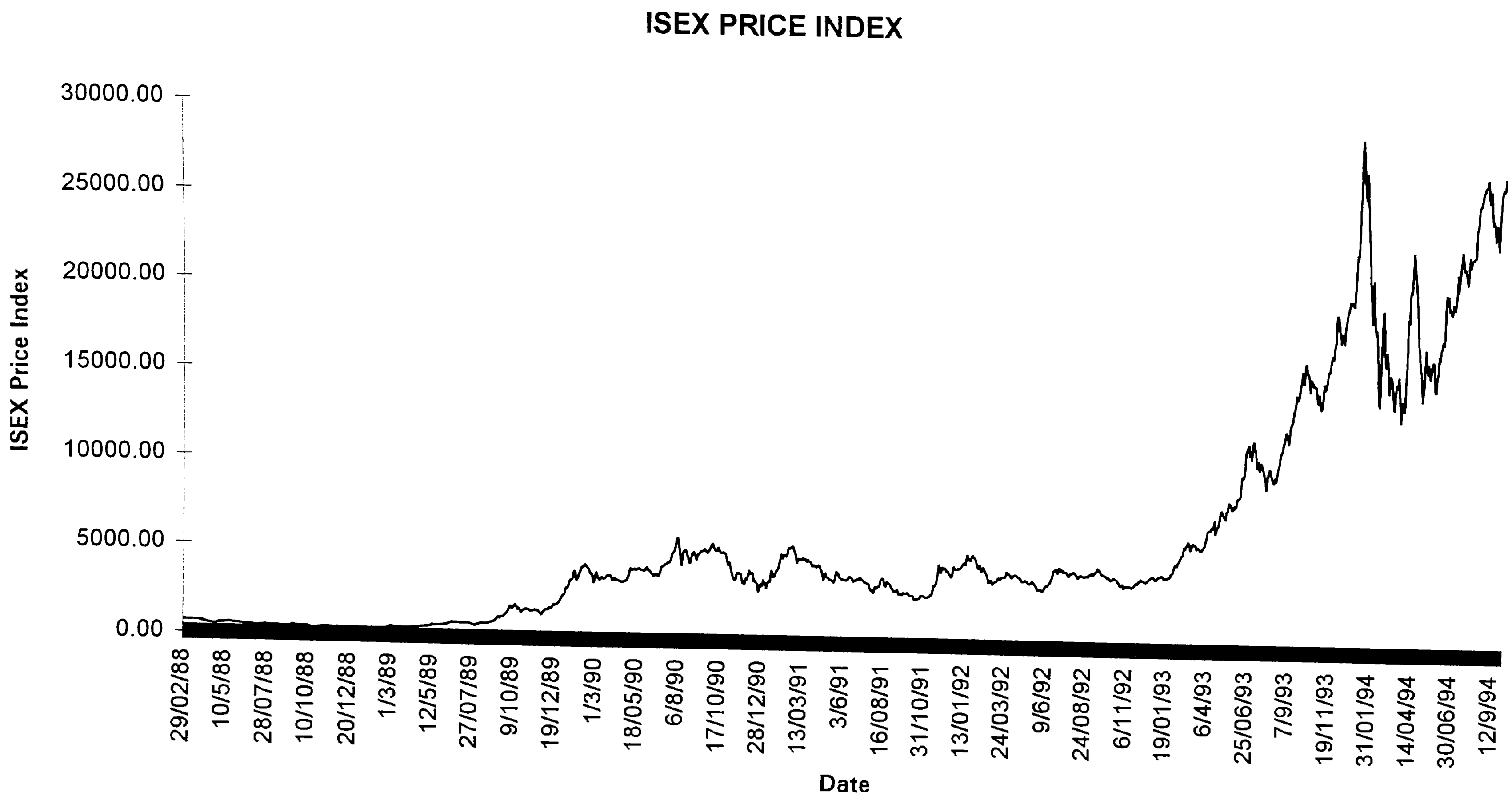
ISEX PRICE INDEX
30000.00
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
ISEX Price Index
29/02/88
10/5/88
28/07/88
10/10/88
20/12/88
1/3/89
12/5/89
27/07/89
9/10/89
19/12/89
1/3/90
18/05/90
6/8/90
17/10/90
28/12/90
13/03/91
3/6/91
16/08/91
31/10/91
13/01/92
24/03/92
9/6/92
24/08/92
6/11/92
19/01/93
6/4/93
25/06/93
7/9/93
19/11/93
31/01/94
14/04/94
30/06/94
12/9/94
Date

FIGURE 1

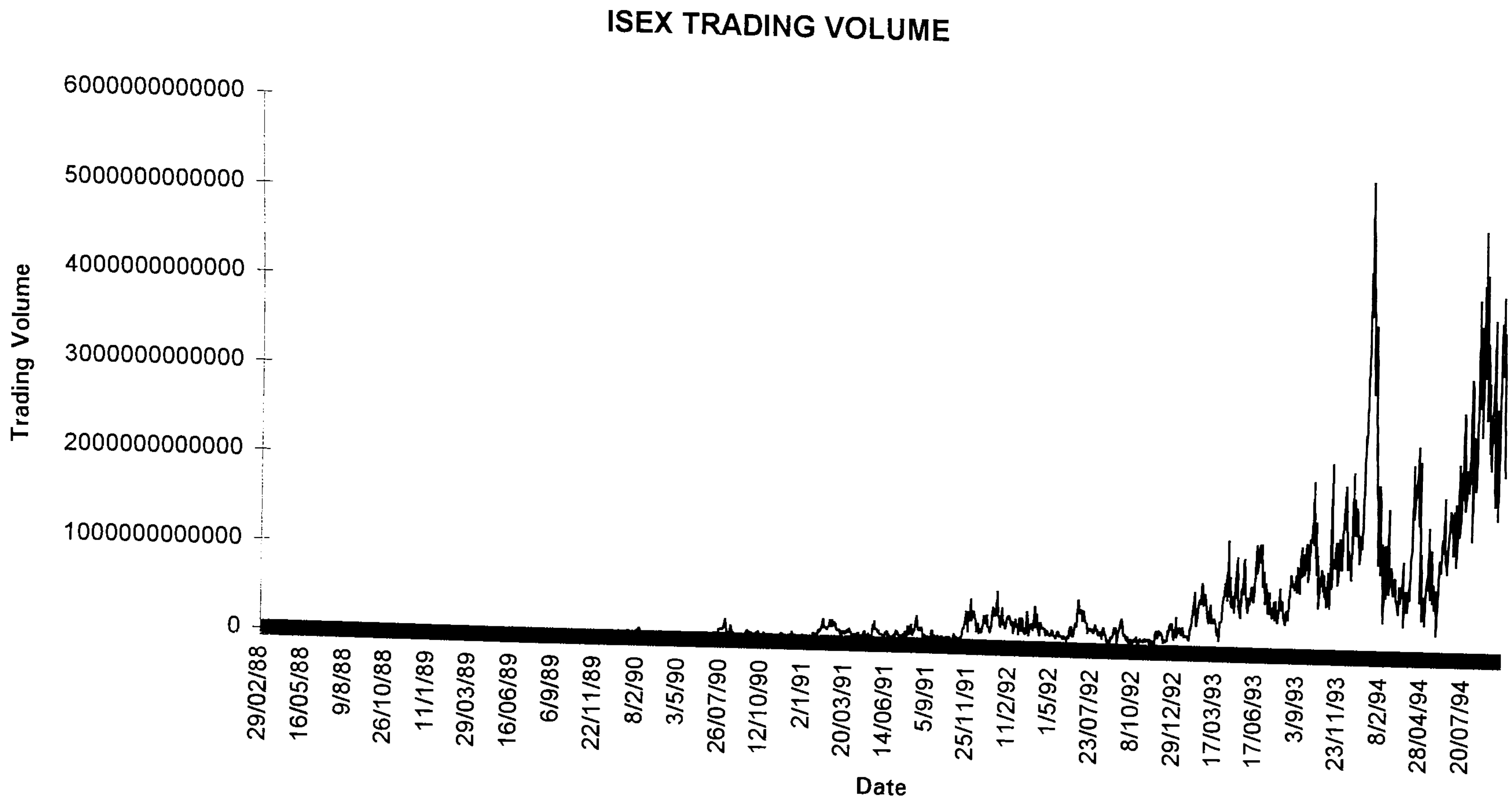
ISEX TRADING VOLUME
6000000000000
5000000000000
4000000000000
3000000000000
2000000000000
1000000000000
0
Trading Volume
29/02/88
16/05/88
9/8/88
26/10/88
11/1/89
29/03/89
16/06/89
6/9/89
22/11/89
8/2/90
3/5/90
26/07/90
12/10/90
2/1/91
20/03/91
14/06/91
5/9/91
25/11/91
11/2/92
1/5/92
23/07/92
8/10/92
29/12/92
17/03/93
17/06/93
3/9/93
23/11/93
8/2/94
28/04/94
20/07/94
Date

FIGURE 2

V.1.1. Autocorrelation Analysis

The autocorrelations for the level and the first differenced logarithmic price and volume data for each period are submitted in Appendix-1. As an example, we can look at the autocorrelation coefficients and Ljung Box Q-Statistics of the logarithmic price series for the 1988-1994 period in Table-5a.

Table-5a: Autocorrelation Analysis for Logarithmic

Price Series for the Period 1988-1994

Lag	Autocorrelation	Ljung Box Q-Statistic
1	1.00	1614.66*
2	1.00	3223.37*
3	0.99	4825.99*
4	0.99	6422.68*
5	0.99	8013.34*
6	0.99	9597.89*
7	0.98	11176.31*
8	0.98	12748.63*
9	0.98	14314.83*
10	0.98	15874.99*
11	0.98	17428.91*
12	0.97	18976.40*

* indicates the coefficients which are significant at 5% level

Significant autocorrelation is obvious. The first-order autocorrelation, 1.00, reveals that about 100% of the price figures are predictable by using only the preceding day's price. The autocorrelation figures do not die out as the number of lags increases. Also, when we look at the Ljung Box Q-statistic, we see that all of them are significant at the 5% level, indicating that the joint hypothesis of all the autocorrelation coefficients are zero can be rejected. These indicate that the level price series are not stationary.

As differencing can transform a non-stationary series to a stationary one, we should look at the autocorrelations at the first difference of the logarithmic price data.

Table-5b: Autocorrelation Analysis for First Differenced Logarithmic Price Series for the Period 1988-1994

Lag	Autocorrelation	Ljung Box Q-Statistic
1	0.28	108.13*
2	-0.03	109.26*
3	-0.01	109.56*
4	0.05	113.04*
5	0.04	115.42*
6	0.00	115.43*
7	0.03	116.47*
8	0.01	116.68*
9	0.00	116.70*
10	0.06	122.65*
11	0.05	127.46*
12	0.00	127.46*

* indicates the coefficients which are significant at 5% level

As it is seen, for the first differenced logarithmic series, the autocorrelations are smaller and die out at higher orders of lags. Also, it is obvious that lags are still useful in predicting the future prices, because we still reject the null hypothesis that all autocorrelation coefficients are zero.

V.1.2. Stationarity

Before conducting the Augmented Dickey-Fuller Unit Root test, we have to decide on the number of lags that will be included in the model for both of price and volume series.

V.1.2.1. Lag Determination

First the following regression equation is constructed for the price series including 10 lags due to the limitations of the software used..

$$P_t = a_0 + \Sigma(j=1,.12)\ b_j P_{t-j} + e_t$$

Then the significance of the lag coefficients are investigated by using t-statistics. The lags which have insignificant coefficients are excluded from the model. This procedure is continued until all the lag coefficients in the model are found to be significant. The lags in the final model are the ones which are useful in predicting the future price. As the Augmented Dickey-Fuller Unit Root test was formulated for a continuos number of lags, for example for first five lags or first seven lags, the last significant lag is chosen as the lag number to be used in the test.

As an example, lag determination procedure for logarithmic price series for the 1988-1994 period is described below:

Table-6a: T-test for Lag Determination for the 1988-1994 Price Series

Variable Name	**Estimated Coefficient**	**T-Ratio**
Lag1	1.3748	54.890*
Lag2	-0.4847	-11.380*
Lag3	0.1208	2.737*
Lag4	0.0891	2.015
Lag5	-0.1378	-3.111*
Lag6	0.0252	0.570
Lag7	0.1001	2.263
Lag8	-0.1249	-2.822*
Lag9	0.0114	0.268
Lag10	0.0263	1.042

* indicates the coefficients which are significant at 1% level.

After the first run the lags 4, 6, 7, 9, 10 are found to be insignificant in prediction and excluded from the regression equation. Then the reduced model is regressed. The results can be seen in the following table.

Table-6b: T-test for Lag Determination for the 1988-1994 Price Series

Variable Name	Estimated Coefficient	T-Ratio
Lag1	1.3722	55.280*
Lag2	-0.4973	-12.120*
Lag3	0.1775	5.541*
Lag5	-0.0423	-2.131*
Lag8	-0.0096	-0.846

* indicates the coefficients which are significant at 1% level.

This time only the coefficient of lag 8 is found to be insignificant and it is excluded from the regression equation and the new model is regressed again and the result can be seen in Table-6c.

Table-6c: T-test for Lag Determination for the 1988-1995 Price Series

Variable Name	Estimated Coefficient	T-Ratio
Lag1	1.3731	55.36*
Lag2	-0.4978	-12.13*
Lag3	0.1789	5.591*
Lag5	-0.0536	-3.637*

* indicates the coefficients which are significant at 1% level.

In this run, all the coefficients are found to be significant, so that the number of lags to be included in the Augmented Dickey-Fuller Unit Root test for logarithmic price series is 5. The same procedure is repeated for both series in each period. The results are summarised in Table-7.

Table-7: Number of Lags to be Used in Augmented Dickey-Fuller Unit Root Tests

Period	Number of Lags For Price Series	Number of Lags For Volume Series
1988-1994	5	10
1988-1989	2	1
1990-1992	2	3
1993-1994	3	3

In Augmented Dickey-Fuller Unit Root tests for periods, in addition to the lag orders determined above, lag order 5 is used which is a convenient lag order which absorbs week effect.

V.1.2.2. Augmented Dickey-Fuller Unit Root Test

The Augmented Dickey-Fuller Unit Root tests are performed for both forms of unrestricted models; with-constant and no-trend and with-constant and with-trend. In these tests, the natural logarithmic transformed data and the lag orders determined before are used . The results are summarised in Table-8.

Table-8 Results of Augmented Dickey-Fuller Unit Root Tests on Ln(P) and Ln(V)

		constant, no trend		**constant, trend**	
Period	**Lag Order**	**t-statistics**	**F-statistics**	**t-statistics**	**F-statistics**
		Critical Value= -3.43	Critical Value= 6.43	Critical Value= -3.96	Critical Value= 8.27
1988-1994					
Ln(P)	5	-0.11481	2.528	-1.1290	1.8225
Ln(V)	10	-1.8041	1.8512	-2.6769	3.6022
1988-1989					
Ln(P)	2	1.6814	2.8540	-1.0467	6.4228
	5	1.2670	1.7936	-1.2830	5.6707
Ln(V)	1	-1.4863	1.3450	-3.6613	7.0567
	5	-0.1222	0.5943	-2.2171	3.4907
1990-1992					
Ln(P)	2	-3.0728	4.7460	-3.1008	4.8428
	5	-2.9885	4.4676	-2.9963	4.4888
Ln(V)	3	-3.3629	5.6932	-5.1141*	13.078*
	5	-2.9555	4.4022	-4.6539*	10.830*
1993-1994					
Ln(P)	2	-2.0150	4.1299	-2.6477	3.9758
	5	-2.0349	4.1172	-2.6840	4.0804
Ln(V)	3	-3.0172	4.8352	-4.0166*	8.1513
	5	-3.5000*	6.4153*	-4.6604*	11.005*

*indicates the statistics which are significant at 1% level

In case of logarithmic transformed price series in all periods and logarithmic transformed volume series in the whole period and the first sub-period, the null hypothesis of a unit root cannot be rejected at the 1% significance level. In all cases, the t-test statistics exceed the critical values and similarly F-test statistics are smaller than the critical values which are necessary conditions for not rejecting the null hypothesis. Then, we conclude that these series are non-stationary at level. However, in case of the logarithmic transformed volume series for second and third periods, the null hypothesis of a unit root can be rejected at 1% significance level, which means that they are stationary at level.

Now, one should investigate whether the Augmented Dickey-Fuller Unit Root tests on the first differences of non-stationary series show stationarity, such that whether the series are I(1) or not. For this purpose, the natural logarithmic transformed series are differenced and Augmented Dickey-Fuller Unit Root tests are performed again. The results are summarised in Table-9.

Table-9 Results of Augmented Dickey-Fuller Unit Root Tests on dLn(P) and dLn(V)

		constant, no trend		**constant, trend**	
Period	**Lag Order**	**t-statistics**	**F-statistics**	**t-statistics**	**F-statistics**
		Critical Value= -3.43	Critical Value= 6.43	Critical Value= -3.96	Critical Value= 8.27
1988-1994					
Ln(P)	5	-15.364*	118.02*	-15.374*	78.783*
Ln(V)	10	-16.807*	141.24*	-16.802*	141.16*
1988-1989					
Ln(P)	2	-11.377*	64.731*	-11.980*	71.770*
	5	-6.9521*	24.179*	-7.5808*	28.760*
Ln(V)	1	-21.223*	225.20*	-21.245*	225.68*
	5	-11.977*	71.726*	-12.120*	73.513*
1990-1992					
Ln(P)	2	-13.444*	90.373*	-13.434*	90.249*
	5	-11.655*	67.925*	-11.646*	67.826*
1993-1994					
Ln(P)	2	-9.1548*	41.906*	-9.2063*	42.378*
	5	-7.7748*	30.224*	-7.8284*	30.647*

*indicates the statistics which are significant at 1% level

According to the test results, we can reject the null hypothesis of unit root at 1% significance level in each case, because the t-test statistics are smaller than the critical values and the F-test statistics are greater than the critical values. Then, we can conclude that the price series for all periods and the volume series for the whole and first sub-periods are I(1) at 1% significance level, which means that differenced natural logarithmic transformed series for these periods are stationary. The following table summarises the results of stationarity (Dickey Fuller Unit Root) tests

Table-10 Summary of Augmented Dickey-Fuller Unit Root Tests

	PRICE SERIES **Stationary at:**	**VOLUME SERIES** **Stationary at:**
1988-94	1st difference	1st difference
1988-89	1st difference	1st difference
1990-92	1st difference	Level
1993-94	1st difference	Level

Now the existence of cointegration between the price and volume series in the whole and first sub-periods should be investigated.

V.1.3. Co-integration Test

After determining that the price and the volume series are integrated of the same order, i.e. $V_t \sim I(1)$ and $P_t \sim I(1)$ in the whole and the first sub periods, the bivariate co-integration is tested between them.

V.1.3.2. Co-integration Test Results

In this part of the study, it is examined whether the index and the volume series are cointegrated in the mentioned periods by using lag order 5. The test results can be seen in Table-11.

Table-11 Co-integration Test Results

	constant, no trend	constant, trend
Dependent Variable	**t-statistics**	**t-statistics**
	Critical Value= -3.34	Critical Value= -3.78
1988-1994		
Ln(P)	-3.8234*	-1.7784
Ln(V)	-4.9316*	-7.2312*
1988-1989		
Ln(P)	-3.9891*	-4.4762*
Ln(V)	-4.4215*	-5.5982*

* indicates the cases where null hypothesis of no co-integration can be rejected at 5% significance level

According to the test results, the null hypothesis of no co-integration between the price and volume series can be rejected at 5% significance level in each period. These results suggest that there is link between stock market index and the trading volume in the long-run for the whole and the first sub-periods.

Table-12 Summary of Co-integration Tests

	Dependent Variable: PRICE	**Dependent Variable: VOLUME**
1988-94	Cointegrated	Cointegrated
1988-89	Cointegrated	Cointegrated

V.2. Granger Causality

V.2.1. Vector Error Correction Model

In this part, the causality between the volume and price series and its direction will be investigated by using vector error correction model which takes into account the co-integration between the series and do not generate invalid causal inferences in such cases. For this purpose, first the vector error correction equations (14) and (15) are estimated for each period by using 5 lags for each variable. Z_{t-1} and Z_{t-1}' in these equations are obtained from equation (11) after the estimation of B_0 and B_1 from OLS estimation of the equations (12) and (13). The B_0 and B_1 coefficients for each period are summarised in Table-13.

Table-13 The B_0 and B_1 Coefficients For Periods

PERIOD	B_0	B_1
1988-1994	0.82934E-13	0.85234E+13
1988-1989	0.42832E-07	0.14872E+08
1990-1992	0.19148E-08	0.48746E+08
1993-1994	0.57580E-08	0.11983E+09

The estimated coefficients of vector error correction equation for each period can be seen in Tables 14 and 15.

Table-14 Vector Error Correction Model Results
Dependent Variable = Price

$$(1\text{-}L)P_t = a_1 + b_1 Z_{t-1}' + \Sigma_{i=1,..M}\, c_{1i}(1\text{-}L)P_{t-1} + \Sigma_{i=1,..N}\, d_{1i}(1\text{-}L)V_{t-1} + e_t'$$

Coefficient	1988-1994	1988-1989	1990-1992	1993-1994
b_1	-0.53E-17	-0.232E-09	0.449E-09*	0.554E-10
c_{11}	0.244*	0.376*	0.221*	0.292*
c_{12}	-0.097*	-0.144*	-0.068	-0.163*
c_{13}	0.011	-0.017	-0.054	0.0163
c_{14}	0.025	0.045	-0.003	0.0008
c_{15}	0.040	0.037	0.065	-0.025
d_{11}	-0.664E-05	-0.004	-0.0002	0.0102
d_{12}	0.360E-03	0.005	-0.00009	0.0092
d_{13}	0.515E-03	0.004	0.013*	0.014
d_{14}	0.352E-03	0.003	0.0029	0.010
d_{15}	-0.113E-03	-0.0003	-0.0057	0.001
F-statistics for $\Sigma c_{1i}=0$	18.312**	13.263**	7.822**	7.315**
F-statistics for $\Sigma d_{1i}=0$	0.832	1.386	2.792**	0.941

* indicates the coefficients which have significant t-ratios at 5% level

**indicates the F-statistics which are significant at 5% level

Table-15 Vector Error Correction Model Results

Dependent Variable = Volume

$(1\text{-}L)V_t = a_o + b_o Z_{t-1} + \Sigma_{i=1,..M}\ c_{oi}(1\text{-}L)V_{t-1} + \Sigma_{i=1,..N}\ d_{oi}(1\text{-}L)P_{t-1} + e_t$

Coefficient	**1988-1994**	**1988-1989**	**1990-1992**	**1993-1994**
$\mathbf{b_0}$	-0.0157	-0.0149	-0.1516*	-0.0189
$\mathbf{c_{01}}$	-0.552*	-0.479*	-0.459*	-0.619*
$\mathbf{c_{02}}$	-0.430*	-0.369*	-0.309*	-0.332*
$\mathbf{c_{03}}$	-0.264*	-0.287*	-0.051*	-0.135*
$\mathbf{c_{04}}$	-0.209*	-0.172*	-0.138*	-0.0067
$\mathbf{c_{05}}$	-0.078*	-0.119*	-0.116*	-0.0118
$\mathbf{d_{01}}$	16.727*	3.577*	3.485*	4.038*
$\mathbf{d_{02}}$	0.247	0.641	-0.064	-0.553
$\mathbf{d_{03}}$	-2.931	1.194	-0.862*	-0.103
$\mathbf{d_{04}}$	2.479	-0.350	0.290	0.794
$\mathbf{d_{05}}$	-1.168	0.704	0.455	-0.696
F-statistics for $\mathbf{\Sigma c_{0i}=0}$	92.422**	22.741**	29.591**	28.112**
F-statistics for $\mathbf{\Sigma d_{0i}=0}$	10.733**	7.295**	21.344**	20.230**

* indicates the coefficients which have significant t-ratios at 5% level

**indicates the F-statistics which are significant at 5% level

As co-integration reveals long-term relationship, one would expect to find statistically significant coefficients for the lagged error-correction coefficients for the cointegrated series in causality equations. However, this is not observed in all cases. This would be due that, when we are conducting the causality tests we are assuming linear relationship between price and volume series, however this may not be the case. Because of this, it is normal to observe some conradictory results.

In the case when price series is the dependent variable, significant vector-error correction term coefficient is observed in second sub-period. This means that, there is significant positive causality from volume to price series in second sub-period, resulting from long-run equilibrium adjustment process. On the other hand, no statistically significant lagged volume coefficient, except one in the second sub-period, is observed. The null hypothesis that all lagged volume coefficients are jointly significantly different from zero cannot be rejected in all periods, except in second sub-period, which reveal that volume Granger causes price in the short-term movements in only second sub-period. So, in case of price, indirect causality through long-run adjustment and direct causality is observed in only second sub-period.

In the case when volume series is the dependent variable, significant vector-error correction term coefficient is again observed only in second sub-period. There is significant positive indirect causality from volume to price series in second sub-period due to long-run equilibrium adjustment process. Also, in all periods direct causality is observed from price series to volume series, such that the null hypothesis that all lagged price coefficients are jointly significantly different from zero can be rejected in all periods. Almost all volume lags included in the model are useful in determining the future volume.

There is bi-directional causality between price and volume in second sub-period. In all other periods, bi-directional causality is not observed, but it is found that, price Granger causes volume.

VI. CONCLUSION

In this study, the long-term relationship and the short-term causality between stock price index and the trading volume and the direction of the causality is investigated in the context of a small stock market, the Istanbul Stock Exchange in Türkiye by using cointegration theory and Vector Error Correction Model. The data used includes daily closing values of ISE composite index and daily aggregate number of share units traded for the period 29/02/1988-30/09/1994. Sample period is divided into three sub-periods according to the important shifts in trading volume and tests are conducted separately for each three sub-period as well as for the whole period.

The linear relationship between two variables is investigated by means of Granger causality and as the standard Granger-causality tests are based on stationary variables, first of all the time series properties of the return and volume series are investigated. For this purpose, autocorrelation, stationarity and co-integration tests are performed. It is found that, price series in all periods and volume series in the whole and first sub-periods are stationary at their first-differences and volume series for the last two periods are stationary at level. As cointegration should be tested between two series which are both stationary at their first differences, cointegration tests are conducted for only the whole and the first sub-periods. Significant cointegration is observed in both periods, which reveals that there may be long-term co-movement between two series.

As co-integration is found, the simple Granger test is modified to include error correction mechanism and formulated in Vector Error-Correction Model. Results of Vector Error Correction Model revealed that, there is bi-directional direct and indirect causality between stock price index and trading volume in only second sub-period, where indirect causality results from long-run equilibrium adjustment process. In other words, there is short-term relationship and long-term co-movement between price and volume in second sub-period. In all other periods, positive short-term causality from price to volume is found, but no causality from volume to price series and no long-term co-movement are observed.

In this study, evidence of strong linear impact from lagged stock prices to current and future trading volume and weak evidence of a linear impact from lagged volume to current and future stock prices are detected. The significant casual relation from stock prices to trading volume in all periods can be explained by both non-tax-related trading models and noise trading models, whereas significant causal relation from trading volume to stock prices can be explained by sequential information arrival models and the mixture of distributions model of Epps and Epps (1976). It can be concluded that most traders in Istanbul Stock Exchange (ISE) are noise traders, not information traders and non-tax related motives, such as window dressing and portfolio rebalancing are dominant in case of ISE. The information disseminated by trading volume is not so much effective in determining the final, complete information equilibrium, except in period January 1990-December 1992.

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APPENDIX

AUTOCORRELATION ANALYSIS

A. AUTOCORRELATION ANALYSIS FOR THE PERIOD 1988-1994

1. Ln(P)

LAGS	AUTOCORRELATIONS												STD ERR
1 -12	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.02
13 -24	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.12

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VAL	LAG	Q	DF	P-VALUE
1	1644.22	1	.000	13	20954.53	13	.000
2	3283.13	2	.000	14	22527.80	14	.000
3	4916.74	3	.000	15	24095.34	15	.000
4	6545.00	4	.000	16	25657.19	16	.000
5	8167.87	5	.000	17	27213.46	17	.000
6	9785.25	6	.000	18	28764.13	18	.000
7	11397.16	7	.000	19	30308.95	19	.000
8	13003.66	8	.000	20	31847.90	20	.000
9	14604.78	9	.000	21	33380.96	21	.000
10	16200.64	10	.000	22	34908.01	22	.000
11	17790.98	11	.000	23	36428.96	23	.000
12	19375.61	12	.000	24	37943.93	24	.000

LAGS	PARTIAL AUTOCORRELATIONS												STD ERR
1 -12	1.00	-.05	0.00	-.01	-.01	-.01	0.00	0.00	0.00	0.01	-.02	-.02	0.02

2. dLn(P)

LAGS	AUTOCORRELATIONS												STD ERR
1 -12	0.26	-.02	-.01	0.05	0.04	0.00	0.03	0.01	0.01	0.06	0.05	0.00	0.02
13 -24	0.00	-.01	-.02	-.05	-.01	0.01	0.02	0.03	0.01	-.03	-.04	0.00	0.03

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VAL	LAG	Q	DF	P-VALUE
1	110.18	1	.000	13	130.79	13	.000
2	111.18	2	.000	14	130.85	14	.000
3	111.38	3	.000	15	131.30	15	.000
4	115.23	4	.000	16	135.27	16	.000
5	118.12	5	.000	17	135.44	17	.000
6	118.15	6	.000	18	135.66	18	.000
7	119.19	7	.000	19	136.41	19	.000
8	119.50	8	.000	20	137.75	20	.000
9	119.61	9	.000	21	137.84	21	.000
10	125.94	10	.000	22	139.21	22	.000
11	130.77	11	.000	23	142.40	23	.000
12	130.78	12	.000	24	142.43	24	.000

LAGS	PARTIAL AUTOCORRELATIONS												STD ERR
1 -12	0.26	-.10	0.02	0.05	0.02	-.01	0.03	0.00	0.01	0.06	0.02	-.02	0.02

3. Ln(V)

LAGS	AUTOCORRELATIONS												STD ERR
1 -12	0.94	0.92	0.92	0.91	0.91	0.90	0.90	0.89	0.89	0.89	0.88	0.88	0.02
13 -24	0.88	0.87	0.87	0.87	0.87	0.86	0.86	0.86	0.86	0.86	0.85	0.85	0.11

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VAL	LAG	Q	DF	P-VALUE
1	1453.83	1	.000	13	17432.25	13	.000
2	2852.78	2	.000	14	18699.78	14	.000
3	4241.48	3	.000	15	19949.55	15	.000
4	5606.37	4	.000	16	21211.52	16	.000
5	6964.57	5	.000	17	22465.51	17	.000
6	8302.36	6	.000	18	23709.72	18	.000
7	9628.98	7	.000	19	24943.96	19	.000
8	10954.15	8	.000	20	26173.34	20	.000
9	12274.39	9	.000	21	27405.83	21	.000
10	13583.14	10	.000	22	28640.34	22	.000
11	14860.88	11	.000	23	29854.35	23	.000
12	16141.14	12	.000	24	31050.87	24	.000

4. dLn(V)

LAGS	AUTOCORRELATIONS												STD ERR
1 -12	-.36	-.12	0.04	-.05	0.04	-.03	-.03	0.01	0.02	0.05	-.09	-.03	0.02
13 -24	0.10	-.02	-.08	0.06	0.00	0.00	-.01	-.02	0.00	0.06	-.01	-.08	0.03

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VAL	LAG	Q	DF	P-VALUE
1	208.66	1	.000	13	279.77	13	.000
2	232.46	2	.000	14	280.19	14	.000
3	234.76	3	.000	15	291.52	15	.000
4	238.16	4	.000	16	296.53	16	.000
5	240.56	5	.000	17	296.56	17	.000
6	241.79	6	.000	18	296.57	18	.000
7	242.99	7	.000	19	296.93	19	.000
8	243.16	8	.000	20	297.82	20	.000
9	243.72	9	.000	21	297.84	21	.000
10	248.67	10	.000	22	304.79	22	.000
11	262.96	11	.000	23	304.90	23	.000
12	264.00	12	.000	24	315.71	24	.000

LAGS	PARTIAL AUTOCORRELATIONS												STD ERR
1 -12	-.36	-.28	-.15	-.16	-.07	-.09	-.10	-.08	-.05	0.04	-.07	-.10	0.02

B. AUTOCORRELATION FOR THE PERIOD 1988-1989

1. Ln(P)

LAGS	AUTOCORRELATIONS												STD ERR
1 -12	0.99	0.98	0.97	0.96	0.95	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.05
13 -24	0.88	0.88	0.87	0.86	0.85	0.84	0.83	0.83	0.82	0.81	0.80	0.80	0.22

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VAL	LAG	Q	DF	P-VALUE
1	462.46	1	.000	13	5446.20	13	.000
2	916.85	2	.000	14	5817.90	14	.000
3	1363.83	3	.000	15	6182.99	15	.000
4	1803.70	4	.000	16	6541.91	16	.000
5	2236.40	5	.000	17	6894.79	17	.000
6	2661.93	6	.000	18	7241.62	18	.000
7	3080.36	7	.000	19	7582.19	19	.000
8	3491.62	8	.000	20	7916.96	20	.000
9	3895.59	9	.000	21	8246.24	21	.000
10	4292.67	10	.000	22	8570.15	22	.000
11	4683.44	11	.000	23	8889.19	23	.000
12	5067.93	12	.000	24	9203.88	24	.000

LAGS	PARTIAL AUTOCORRELATIONS												STD ERR
1 -12	0.99	-.04	0.03	0.01	-.01	0.00	-.01	-.01	-.02	0.02	0.03	-.01	0.05

2. dLn(P)

LAGS	AUTOCORRELATIONS												STD ERR
1 -12	0.33	-.02	-.02	0.07	0.10	0.09	0.00	-.02	-.01	0.02	0.13	0.05	0.05
13 -24	0.01	0.02	0.01	0.03	0.04	0.01	-.03	0.01	0.06	0.05	0.01	0.00	0.05

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VAL	LAG	Q	DF	P-VALUE
1	50.24	1	.000	13	71.87	13	.000
2	50.42	2	.000	14	72.04	14	.000
3	50.69	3	.000	15	72.10	15	.000
4	53.32	4	.000	16	72.49	16	.000
5	57.88	5	.000	17	73.14	17	.000
6	62.11	6	.000	18	73.20	18	.000
7	62.11	7	.000	19	73.58	19	.000
8	62.34	8	.000	20	73.62	20	.000
9	62.43	9	.000	21	75.41	21	.000
10	62.70	10	.000	22	76.64	22	.000
11	70.43	11	.000	23	76.72	23	.000
12	71.84	12	.000	24	76.72	24	.000

LAGS	PARTIAL AUTOCORRELATIONS												STD ERR
1 -12	0.33	-.14	0.03	0.08	0.05	0.06	-.05	0.01	-.02	0.02	0.12	-.04	0.05

3. Ln(V)

LAGS	AUTOCORRELATIONS												STD ERR
1 -12	0.96	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.86	0.85	0.83	0.05
13 -24	0.82	0.82	0.81	0.80	0.79	0.79	0.78	0.78	0.77	0.76	0.75	0.75	0.21

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VAL	LAG	Q	DF	P-VALUE
1	429.82	1	.000	13	4842.90	13	.000
2	838.03	2	.000	14	5166.55	14	.000
3	1237.00	3	.000	15	5485.33	15	.000
4	1629.82	4	.000	16	5795.14	16	.000
5	2014.20	5	.000	17	6102.17	17	.000
6	2390.83	6	.000	18	6408.20	18	.000
7	2761.59	7	.000	19	6708.73	19	.000
8	3124.83	8	.000	20	7006.42	20	.000
9	3481.35	9	.000	21	7296.49	21	.000
10	3833.88	10	.000	22	7578.23	22	.000
11	4181.08	11	.000	23	7855.44	23	.000
12	4515.29	12	.000	24	8131.91	24	.000

LAGS	PARTIAL AUTOCORRELATIONS												STD ERR
1 -12	0.96	0.20	0.20	0.13	0.05	0.04	0.05	0.00	0.02	0.05	0.01	-.10	0.05

4. dLn(V)

LAGS	AUTOCORRELATIONS												STD ERR
1 -12	-.29	-.12	-.05	0.02	0.00	-.02	0.02	-.02	-.03	0.05	0.03	-.09	0.05
13 -24	0.01	0.01	0.09	-.10	-.04	0.04	-.02	0.07	0.02	-.06	-.07	0.06	0.05

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VA	LAG	Q	DF	P-VALUE
1	38.54	1	.000	13	52.47	13	.000
2	44.76	2	.000	14	52.54	14	.000
3	45.88	3	.000	15	56.60	15	.000
4	46.17	4	.000	16	61.14	16	.000
5	46.18	5	.000	17	61.80	17	.000
6	46.47	6	.000	18	62.51	18	.000
7	46.67	7	.000	19	62.64	19	.000
8	46.79	8	.000	20	65.22	20	.000
9	47.20	9	.000	21	65.49	21	.000
10	48.31	10	.000	22	67.17	22	.000
11	48.86	11	.000	23	69.71	23	.000
12	52.42	12	.000	24	71.67	24	.000

LAGS	PARTIAL AUTOCORRELATIONS												STD ERR
1 -12	-.29	-.21	-.17	-.09	-.07	-.07	-.03	-.04	-.07	0.01	0.04	-.06	0.05

C. AUTOCORRELATION ANALYSIS FOR THE PERIOD1990-1992

1.Ln(P)

LAGS	AUTOCORRELATIONS												STD ERR
1 -12	0.98	0.94	0.92	0.89	0.86	0.83	0.81	0.78	0.76	0.74	0.71	0.68	0.04
13 -24	0.66	0.63	0.60	0.58	0.55	0.53	0.51	0.48	0.45	0.43	0.41	0.39	0.15

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VAL	LAG	Q	DF	P-VALUE
1	711.41	1	.000	13	6545.93	13	.000
2	1379.47	2	.000	14	6847.95	14	.000
3	2008.43	3	.000	15	7125.59	15	.000
4	2600.89	4	.000	16	7380.42	16	.000
5	3157.67	5	.000	17	7615.84	17	.000
6	3680.48	6	.000	18	7832.77	18	.000
7	4174.26	7	.000	19	8029.76	19	.000
8	4638.73	8	.000	20	8207.22	20	.000
9	5074.80	9	.000	21	8365.89	21	.000
10	5484.32	10	.000	22	8507.99	22	.000
11	5865.89	11	.000	23	8636.14	23	.000
12	6218.98	12	.000	24	8752.95	24	.000

LAGS	PARTIAL AUTOCORRELATIONS												STD ERR
1 -12	0.98	-.14	0.04	0.00	-.02	0.00	0.05	-.05	0.00	0.00	-.06	-.03	0.04

2. dLn(P)

LAGS	AUTOCORRELATIONS												STD ERR
1 -12	0.20	-.05	-.04	0.02	0.03	-.05	0.00	0.03	0.01	0.10	0.04	-.05	0.04
13 -24	0.02	0.05	0.01	-.07	-.04	0.01	0.03	0.03	-.02	-.05	-.07	-.02	0.04

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VAL	LAG	Q	DF	P-VALUE
1	29.61	1	.000	13	46.18	13	.000
2	31.21	2	.000	14	48.13	14	.000
3	32.27	3	.000	15	48.28	15	.000
4	32.68	4	.000	16	51.94	16	.000
5	33.52	5	.000	17	53.27	17	.000
6	35.06	6	.000	18	53.44	18	.000
7	35.06	7	.000	19	54.17	19	.000
8	35.90	8	.000	20	54.79	20	.000
9	35.94	9	.000	21	55.04	21	.000
10	42.85	10	.000	22	57.26	22	.000
11	44.15	11	.000	23	61.31	23	.000
12	45.92	12	.000	24	61.69	24	.000

LAGS	PARTIAL AUTOCORRELATIONS												STD ERR
1 -12	0.20	-.09	-.01	0.03	0.02	-.06	0.03	0.02	-.01	0.11	0.00	-.06	0.04

3. Ln(V)

LAGS	AUTOCORRELATIONS												STD ERR
1 -12	0.91	0.86	0.84	0.82	0.80	0.78	0.77	0.75	0.74	0.73	0.72	0.71	0.04
13 -24	0.70	0.68	0.67	0.65	0.64	0.62	0.61	0.61	0.59	0.59	0.58	0.56	0.15

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VAL	LAG	Q	DF	P-VALUE
1	617.92	1	.000	13	5964.88	13	.000
2	1171.03	2	.000	14	6321.95	14	.000
3	1699.33	3	.000	15	6664.11	15	.000
4	2202.65	4	.000	16	6989.36	16	.000
5	2678.68	5	.000	17	7300.56	17	.000
6	3134.04	6	.000	18	7598.13	18	.000
7	3578.65	7	.000	19	7883.60	19	.000
8	4003.06	8	.000	20	8165.66	20	.000
9	4418.96	9	.000	21	8433.76	21	.000
10	4827.44	10	.000	22	8698.51	22	.000
11	5215.64	11	.000	23	8955.34	23	.000
12	5593.88	12	.000	24	9201.42	24	.000

LAGS	PARTIAL AUTOCORRELATIONS												STD ERR
1 -12	0.91	0.19	0.20	0.09	0.04	0.05	0.07	0.00	0.07	0.04	-.03	0.04	0.04

4. dLn(V)

LAGS	AUTOCORRELATIONS	STD ERR
1 -12	-.23 -.15 -.02 0.02 -.03 -.04 0.04 -.06 0.00 0.07 -.05 -.03	0.04
13 -24	0.05 0.00 0.03 -.02 0.00 -.03 -.05 0.08 -.07 0.03 0.01 -.05	0.04

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VAL	LAG	Q	DF	P-VALUE
1	40.43	1	.000	13	73.31	13	.000
2	58.30	2	.000	14	73.31	14	.000
3	58.48	3	.000	15	73.92	15	.000
4	58.86	4	.000	16	74.31	16	.000
5	59.41	5	.000	17	74.31	17	.000
6	60.67	6	.000	18	74.89	18	.000
7	62.15	7	.000	19	76.47	19	.000
8	64.85	8	.000	20	81.36	20	.000
9	64.85	9	.000	21	85.14	21	.000
10	69.02	10	.000	22	85.76	22	.000
11	71.05	11	.000	23	85.87	23	.000
12	71.61	12	.000	24	87.90	24	.000

LAGS	PARTIAL AUTOCORRELATIONS	STD ERR
1 -12	-.23 -.22 -.12 -.06 -.07 -.08 -.01 -.09 -.05 0.03 -.05 -.04	0.04

D. AUTOCORRELATION ANALYSIS FOR THE PERIOD 1993-1994

1. Ln(P)

LAGS	AUTOCORRELATIONS												STD ERR
1 -12	0.99	0.98	0.97	0.96	0.94	0.93	0.92	0.91	0.90	0.89	0.87	0.86	0.05
13 -24	0.85	0.84	0.83	0.82	0.81	0.80	0.79	0.77	0.76	0.75	0.74	0.73	0.22

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VAL	LAG	Q	DF	P-VALUE
1	428.18	1	.000	13	4894.10	13	.000
2	847.61	2	.000	14	5211.21	14	.000
3	1258.48	3	.000	15	5520.45	15	.000
4	1660.64	4	.000	16	5822.25	16	.000
5	2054.07	5	.000	17	6117.17	17	.000
6	2438.91	6	.000	18	6405.31	18	.000
7	2815.26	7	.000	19	6686.34	19	.000
8	3182.93	8	.000	20	6960.41	20	.000
9	3541.99	9	.000	21	7227.84	21	.000
10	3892.85	10	.000	22	7488.95	22	.000
11	4235.18	11	.000	23	7743.83	23	.000
12	4568.90	12	.000	24	7992.76	24	.000

LAGS	PARTIAL AUTOCORRELATIONS												STD ERR
1 -12	0.99	-.06	0.00	-.02	-.01	0.00	0.00	-.02	0.00	0.01	-.03	-.01	0.05

2. dLn(P)

LAGS	AUTOCORRELATIONS	STD ERR
1 -12	0.29 -.01 0.02 0.05 -.01 -.01 0.06 -.01 0.00 0.01 -.01 0.02	0.05
13 -24	-.04 -.13 -.12 -.10 0.00 0.01 0.03 0.01 -.02 -.06 -.07 -.02	0.05

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VAL	LAG	Q	DF	P-VALUE
1	36.78	1	.000	13	40.69	13	.000
2	36.85	2	.000	14	48.59	14	.000
3	37.06	3	.000	15	55.17	15	.000
4	38.10	4	.000	16	59.56	16	.000
5	38.12	5	.000	17	59.56	17	.000
6	38.14	6	.000	18	59.58	18	.000
7	39.76	7	.000	19	60.01	19	.000
8	39.81	8	.000	20	60.04	20	.000
9	39.81	9	.000	21	60.20	21	.000
10	39.84	10	.000	22	61.73	22	.000
11	39.85	11	.000	23	63.75	23	.000
12	39.96	12	.000	24	63.97	24	.000

LAGS	PARTIAL AUTOCORRELATIONS	STD ERR
1 -12	0.29 -.11 0.06 0.02 -.03 0.01 0.06 -.06 0.04 -.01 -.01 0.03	0.05

3.Ln(V)

LAGS	AUTOCORRELATIONS	STD ERR
1 -12	0.90 0.87 0.84 0.81 0.77 0.73 0.70 0.68 0.65 0.64 0.61 0.59	0.05
13 -24	0.57 0.55 0.53 0.51 0.49 0.47 0.45 0.45 0.43 0.41 0.40 0.41	0.18

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VAL	LAG	Q	DF	P-VALUE
1	355.22	1	.000	13	056.80	13	.000
2	686.66	2	.000	14	3192.01	14	.000
3	998.80	3	.000	15	3317.73	15	.000
4	1290.92	4	.000	16	3434.73	16	.000
5	1551.13	5	.000	17	3541.73	17	.000
6	1787.97	6	.000	18	3641.56	18	.000
7	2006.66	7	.000	19	3735.01	19	.000
8	2214.28	8	.000	20	3829.03	20	.000
9	2404.95	9	.000	21	3912.99	21	.000
10	2587.15	10	.000	22	3991.69	22	.000
11	2755.64	11	.000	23	4065.75	23	.000
12	2910.38	12	.000	24	4141.79	24	.000

LAGS	PARTIAL AUTOCORRELATIONS	STD ERR
1 -12	0.90 0.30 0.14 0.05 -.10 -.03 0.02 0.08 0.01 0.06 -.03 -.05	0.05

4. dLn(V)

LAGS	AUTOCORRELATIONS												STD ERR
1 -12	-.36	-.04	0.02	0.08	-.06	-.03	-.05	0.05	-.06	0.04	0.00	-.05	0.05
13 -24	0.04	-.02	-.02	0.04	-.02	0.00	-.08	0.15	-.06	0.00	-.11	0.08	0.06

MODIFIED BOX-PIERCE (LJUNG-BOX-PIERCE) STATISTICS (CHI-SQUARE)

LAG	Q	DF	P-VAL	LAG	Q	DF	P-VALUE
1	57.23	1	.000	13	69.36	13	.000
2	57.83	2	.000	14	69.63	14	.000
3	58.01	3	.000	15	69.91	15	.000
4	61.17	4	.000	16	70.67	16	.000
5	62.66	5	.000	17	70.89	17	.000
6	63.19	6	.000	18	70.89	18	.000
7	64.17	7	.000	19	73.74	19	.000
8	65.12	8	.000	20	83.57	20	.000
9	66.79	9	.000	21	85.07	21	.000
10	67.49	10	.000	22	85.07	22	.000
11	67.49	11	.000	23	90.24	23	.000
12	68.54	12	.000	24	93.23	24	.000

LAGS	PARTIAL AUTOCORRELATIONS												STD ERR
1 -12	-.36	-.19	-.08	0.07	0.01	-.04	-.11	-.04	-.08	0.00	0.02	-.05	0.05