Do the S&P CNX Nifty Index And Nifty Futures Really Lead/Lag?

Error Correction Model: A Co-integration Approach

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Ms. Shalini Bhatia
Lecturer
Deen Dayal Upadhyaya College
University Of Delhi
Email: shalini_bhatia@yahoo.com

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Shalini Bhatia*

Abstract

Applying the Co-Integration approach to study the long run relationship between Nifty futures and spot index and the Error Correction Model to examine the short-term adjustment process, using high frequency data, the study finds that, price discovery happens in both, the futures and the spot market. However the S&P CNX Nifty Futures Index is more efficient than the S&P CNX Nifty Index and leads the spot index by 10 to 25 minutes. Such a finding is consistent with similar studies in U.S and U.K markets.

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Keywords: lead-lag relationships, Co-integration Analysis, Error Correction Model and Granger Causality

Introduction*

When a security is traded in more than one market, investors have different avenues to trade and exploit information. An investor who wants to trade the S&P CNX Nifty index can do so in the spot market through basket trading[1] or in the futures market at the National Stock Exchange. Where frictionless and continuous information sharing across

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* The author is a senior lecturer in Deen Dayal Upadhyaya college, Delhi University. She is currently engaged in active research on financial derivatives in India.

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[1] Basket trading is an online order entry that enables a trading member to buy or sell Nifty index in one shot. Trading-members, participating in the NEAT F&O trading segment, can buy or sell the Nifty-50 stocks according to the existing weightage. As per this facility, a trading member, on defining the value of a portfolio to be transacted, can arrive at the quantity of each security in the portfolio to be bought or sold. This is arrived at as per the weightage (market capitalisation) of each security in the portfolio. The weightage is calculated using the latest traded price in the market thus minimising the errors caused due to price movement.

markets exists, trading should be considered as taking place in a single market with simultaneous price changes in stocks, stock indices and derivative instruments. In such a scenario an investor would be indifferent between trading in the spot or futures markets. However, if the markets were not frictionless, some markets would appear to be more attractive than others because of concerns relating to transaction costs, regulation and liquidity, leading to differences in price discovery across the different markets. In an efficient market, information processing should be expeditious and the most efficient market should lead the others. Hence, information transmission or price discovery is an indication of the relative market efficiencies of related assets. Therefore it is important to determine the nature and location of price discovery.

Stock index futures contracts are usually priced using the forward pricing model which, given perfect capital markets and non-stochastic interest rates and dividend yields, implies that contemporaneous rates of returns of the futures contract and the underlying index portfolio should be contemporaneously correlated. Relevant new information should be theoretically impounded simultaneously into both the futures and cash prices and therefore, price movements in one market should neither lead nor lag the prices in the other market. However, on small time intervals (high frequency) it is often noticed that some price series consistently lead other closely related prices. Such lead-lag relations indicate that one market processes new information faster than the other market. Due to arbitrage restrictions that link these markets, lead and lag correlation coefficients between price change series will generally be small although it is possible that one market consistently leads or lags the other. Several studies examine temporal relationships between futures and cash index returns.[2] The results frequently suggest that the futures returns lead the cash return and that this effect is stronger when there are more stocks included in the index. But the relationship is not completely unidirectional: the cash index may also affect the futures although this lead is almost always much shorter.

[2] Herbst (1987), Kawaller (1987), Stoll and Whaley (1990) Chan (1992), Tang, Mak and Choi (1992), Iihara, Kato and Tokunga (1996) , Abhyankar (1998) etc.

Research in this area is important for several reasons. Firstly it is important to determine the nature and location of price discovery and to find out which market is most efficient. Secondly, the lead lag relationship and its behaviour are of particular interest to arbitrageurs who are required to complete both legs of an index arbitrage transaction within a short time span. Thirdly existing research has concentrated largely on the U.S and U.K index futures markets. It is of interest to extend this work to a different market environment. The existing empirical works on the Indian market points towards a lead lag relationship between futures and spot markets, however, the direction of this relationship is inconclusive.

The purpose of the present research is to examine the robustness of the previous findings about the contribution of derivatives on the price discovery process involving index securities. The lead lag relationship between Nifty futures index and Nifty spot index will be investigated using high frequency data. Engle and Granger's Co-integration Analysis and Error Correction Model will be applied to study the interrelationship between the two markets The rest of the paper is organised in four sections. Section I explains the Cost of Carry model for pricing index futures and briefly reviews the existing literature on lead-lag relationship. It also covers the various issues because of which, there could be a lead-lag relationship, between the futures index and its corresponding underlying. Section II elaborates on the methodology and data used in the study. The empirical findings and their implications are discussed in section III. The last section gives the concluding observations.

Section I

Theoretical background

In a no-arbitrage world, the futures price and cash price reflect the value of the same underlying asset. The difference in prices is attributed to the cost-of-carry (COC Model) in the relationship. Any deviation from the relationship will be eliminated by arbitrage activities, wherein, investors would take offsetting positions in the two markets to earn an assured risk free return and in turn bringing the prices in the two markets in line with each other.

Stock index futures can be priced by using the COC Model given in equation (1).

$$F(t, T) = S(t)\, e^{r(T-t)} - D(t, T) \quad (1)$$

Where F(t, T) equals the futures price at time t, for a contract that matures at time T, S(t) is the spot index value at time t, r(T-t) is the risk-free interest rate compounded continuously[3] for the period T-t and D(t, T) is the value of dividends paid on the component stocks for the period from t to T.

The above cost-of-carry relationship will hold good, as long as, the markets are perfect, interest rates are non-stochastic and the dividends paid by the underlying basket of shares are known with certainty. Hence, if the futures price (F) and the cash price (S) share the same (stochastic) trend in their price dynamics, i.e. they move together, they are regarded as co-integrated. If this relationship holds good then there would be no lead-lag relationship between the two markets.

An assumption of the COC model is that the two markets are perfectly efficient, frictionless and act as perfect substitutes. Accordingly profitable arbitrage opportunities should not exist because new information arrives simultaneously to both the markets and is reflected immediately in both futures and spot prices. However, numerous empirical studies, in the international markets, have established the existence of lead-lag relationship between price changes in spot and futures markets.

Herbst, McCormick, and West (1987) find that futures prices for Value Line and S&P 500 tend to lead their corresponding spot prices. Even though there are indications of

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[3] There are two reasons why continuous compounding is preferable to discrete compounding. First, it is computationally easier in a spreadsheet. Second, it is internally consistent. For example, interest rate is always quoted on an annual basis but the compounding frequency may be different in different markets. Bond markets use half-yearly compounding; banks use quarterly compounding for deposits and loans; and money markets may use overnight or weekly or monthly intervals for compounding. With continuous compounding, we do not have to specify the frequency of compounding. This is the reason why academics prefer continuous compounding to discrete compounding.

significant lead at longer time spans, the spot index reacts initially in less than one minute. Consequently, knowledge of lead-lag relationship is unlikely to provide profitable trading advantage. Kawaller, Koch and Koch (1987) document that S&P 500 futures price and its spot price are mostly simultaneously related throughout the trading day, with futures price leading the spot price at times by as much as twenty minutes. However the lead from spot price to futures price does not last for more than one minute. They attribute this futures leading spot relationship to infrequent trading in the stock market**.** Stoll and Whaley (1990) find that index futures lead their spot prices by about five to ten minutes, even after purging microstructure effects such as infrequent trading. They also find some evidence that spot returns lead futures returns in early inception period of futures trading. Chan (1992) and Ghosh (1993) further report the dominant role of S&P 500 futures index in the price discovery process. However using a Cointegration approach, Wahab and Lashgari (1993) finds that error correcting price adjustments occur significantly in both the S&P 500 futures and cash markets in price discovery.

Abhyankar (1995) investigates the lead lag relationship in return and volatilities between FTSE 100 stock index futures and underlying cash markets, utilizing hourly intra day data. The author finds a strong contemporaneous relationship between futures and cash prices along with some significant evidence that futures markets lead spot market during times of high volatility. Abhyankar (1998) revisited the relationship using 5-minute returns by regressing spot returns on lagged spot and futures returns, and futures returns on lagged spot and futures returns using Exponential Generalised Auto Regressive Conditional Heteroskedasticity (EGARCH). It was found that the futures returns led the spot returns by 15-20 minutes. Min and Najand (1999) used intraday data from the Korean market, found that the futures market leads the cash market by as long as 30 minutes.

In India, little work has been done in this area. The lead-lag analysis by Thenmozhi (2002) showed that the returns on futures lead the spot market returns. The study lent credence to the belief that the futures market tends to lead spot market and the index futures market serves as a primary market of price discovery. The study also showed that the cash index does not lead the futures returns. Though the futures lead the spot market returns by one day, the exact time by which the futures lead the spot market returns was not identified as the study was conducted using daily returns due to lack of data in terms of minute -by-minute or hourly returns.

Mukherjee and Mishra (2006) used intraday data from April to September 2004 to investigate the lead lag relationship between Nifty spot index and Nifty futures. They found that there was a strong bidirectional relationship among returns in the futures and the spot markets. The spot market was found to play a comparatively stronger leading role in disseminating information available to the market and therefore said to be more efficient. The results relating to the informational effect on the lead-lag relationship exhibit that though the leading role of the futures market wouldn't strengthen even for major market-wide information releases, the role of the futures market in the matter of price discovery tends to weaken and sometimes disappear after the release of major firm-specific announcements.

The two studies on the lead lag relationship in the Indian market have come up with diametrically opposing views. According to Thenmozhi, futures markets lead the spot market. Whereas, according to Mukherjee and Mishra the spot market had a major role to play in price discovery and leads over the futures market. The general conclusion of previous research is that the returns in the futures market seem to lead cash market returns and there is some evidence of the predictive ability from cash to futures returns.

It has been argued that the persistence in the lead-lag relationship between index futures and spot index prices can be traced to one or more market imperfections, such as transaction costs, liquidity differences between the two markets, non-synchronous trading effects, the automation of one or the other market, short selling restrictions, different taxation regimes, dividend uncertainties and non-stochastic interest rates. In the following are reviewed some of the market imperfections that have been demonstrated in the literature to have had a major impact on the lead-lag relationship between spot and futures index price changes.

One of the reasons for persistence of lead-lag relationship between spot and futures market is the difference in transaction costs. The Trading Cost Hypothesis [4] predicts that the market with the lowest transaction costs will react more quickly to new information and will lead price changes in the other markets. Transaction costs are substantially lower when trading a futures contract against a basket of spot index stocks. When market-wide information suggests a need to hedge portfolios, the futures contract trade can be executed at lower cost, leading to an asymmetric price relationship with the underlying index in the cash market lagging the index futures price. Abhyankar (1995) considers the lead-lag relationship when transaction costs on the London equity market were decreased. Consistent with the Trading Cost Hypothesis, his evidence points to a reduction in the size and the asymmetric lead of the FT-SE100 futures returns over that of the underlying spot index.

According to Brooks, Garrett and Hinich (1999) "In the absence of transaction costs arbitrage between stock and stock index futures markets is based on deviations of the futures price from its fair value as given by the spot price adjusted for the cost of carrying the underlying portfolio to maturity of the futures contract. In the presence of transaction costs, however, there are bounds on such deviations within which arbitrage will not be triggered. Therefore, there will be thresholds within which the relative difference between the futures and spot price can fluctuate without triggering arbitrage. The result of this is nonlinearity in the relationship between stock and stock index futures markets and this nonlinearity may spill over into the lead-lag relationship between the markets"

The lead lag relationship between the two markets may be induced by infrequent trading of the stocks comprising the index. Component stocks may not trade every instant, as a result observed prices may not reflect the true value of the index. The spot index would not update actual developments in the component stocks, thereby lagging actual

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[4] Fleming J., Ostdiek B. and Whaley R.1996.Trading Costs and the Relative Rates of Price Discovery in Stock Futures and Option Markets. *Journal of Futures Markets*, 16 (4):353-387.

developments in the stock market. An index futures contract, however, represents a single claim, as opposed to a portfolio of component securities and therefore, should not suffer from asynchronous trading problem observed for the spot index [Stoll and Whaley (1990)]. Therefore, if futures prices reflect current information instantaneously, the cash index with some stale prices will lag the futures price. A number of studies have questioned whether non-synchronous trading was suitable as a sole explanation for the lead-lag relationship. Harris (1989), Stoll and Whaley (1990), Chan (1992), Wahab and Lashgari (1993), impose some form of non-synchronous trading adjustment. They find that non-synchronous trading accounted for only part of the asymmetric lead-lag relation.

Market frictions such as capital requirements and short selling restrictions may make it optimal for some to trade in the derivatives market rather than the cash market. Informed traders may find that they can act on their private information more rapidly and at a lower cost in the futures market than in the spot market. They are expected to trade in derivatives markets given the higher leverage effect they offer as compared to the underlying market. By doing so, they exploit at the most their advantage since derivatives require smaller capital outlays. Iihara, Kato and Tokunaga (1996) investigate the impact of the imposition of a higher initial margin and tightening special price quotation in the Nikkei Stock Average (NSA) index futures. They document a shorter lead-time of the NSA futures over the index in intraday return dynamics after the stricter measures were introduced. Their results imply that the lead from futures, if any, will reduce if the upfront cost is elevated.

By using index derivatives, investors can easily and rapidly carry out strategies on the basis of their expectations about the general market trends, without having to consider transaction costs (including mainly the bid-ask spread) and specific changes in each stock that constitutes the index**.** Long and short positions can be established more easily and less expensively in futures market, more so than in the spot market, trading based on revised expectations can take place more frequently in the futures market. Therefore futures prices may move first, followed by spot price movements in response to changes in expectations about the stock market.

Differences in liquidity between the spot and futures markets could also induce a lead-lag relationship. If the average time between trades for constituent firms in the index is longer than the average time between trades for the futures contracts, information will be impounded in futures prices more rapidly than the spot prices, resulting in a lead-lag relationship between spot and futures prices. The lead-lag relationship is a function of the relative liquidity of the two markets rather than their absolute liquidity.

A stronger lead from spot market to futures market may not be inconceivable since the value of the spot index and its more recent changes represent part of the information set used by futures traders. Changes in the spot market may induce changes in the futures market sentiment that would be reflected in subsequent futures price changes, giving rise to a tendency for index futures to lag index spot.

The present study examines the robustness of the previous findings about the contribution of derivatives, to the price discovery process, using index securities. It investigates the lead lag relationship between Nifty futures index and Nifty spot index by using high frequency data. Engle and Granger's Co-integration Analysis and Error Correction Model is applied to study the interrelationship between the two markets.[5]

Section II

Methodology

The finding that many time series may contain a unit root has spurred the development of the theory of non-stationary time series analysis. Engle and Granger (1987) pointed out that a linear combination of two or more non-stationary series may be stationary. If such a stationary, linear combination exists, then the non-stationary time series are said to be cointegrated. The stationary linear combination is called the cointegrating equation and may be interpreted as a long-run equilibrium relationship between the variables. Although the two series may be non stationary they may move closely together in the

[5] Some of the other studies that have applied this methodology are Wahab and Lashgari (1993) Ghosh (1993) and Tse (1995)

long run so that the difference between them is stationary. This section outlines the methodology of the Co-integration Analysis to study the relationship between Nifty spot index and Nifty futures index.

Two series S_t and F_t are said to be integrated of the order one, denoted by I(1), if they become stationary after first difference. If there are two such series which are I(1) integrated and their linear combination is stationary, then these two series are said to be cointegrated. This relationship is the long run equilibrium relationship between S_t and F_t. A principal feature of cointegrated variables is that their time paths are influenced by the extent of any deviation from long-run equilibrium. If the system is to return to its long-run equilibrium, the movement of at least one variable must respond to the magnitude of the disequilibrium. If cointegration exists between S_t and F_t, then Engle and Granger representation theorem suggests that there is a corresponding Error Correction Model (ECM). In an ECM, the short term dynamics of the variables in the system are influenced by the deviations from the equilibrium.

The present research, seeks to determine whether there exists an equilibrium relationship between Nifty spot index and Nifty futures index. Engle and Granger suggest a four step procedure to determine if the two variables are cointegrated. The first step in the analysis is to pre-test each variable to determine its order of integration, as cointegration necessitates that the two variables be integrated of the same order. Augmented Dickey-Fuller (ADF) test has been used to determine the order of integration. If the results in step one show that both the series are I(1) integrated then the next step is to establish the long run equilibrium relationship in the form

$$S_t = \beta_o + \beta_1 F_t + e_t \qquad (2)$$

Where S_t is the log of spot index price; F_t is the log of futures index prices at time t and e_t is the residual term. In order to determine if the variables are cointegrated we need to estimate the residual series from the above equation. The estimated residuals are denoted as (ê). Thus the ê series are the estimated values of the deviations from the long run relationship. If these deviations are found to be stationary, then the S_t and F_t series are cointegrated of the order (1,1). To test if the estimated residual series is stationary Engle-Granger test for co-integration was performed.

The third step is to determine the ECM from the saved residuals in the previous step.

$$\Delta S_t = \alpha_1 + \alpha_s \hat{e}_{t-1} + \text{lagged}(\Delta St, \Delta Ft) + \varepsilon_{st} \qquad (3)$$

$$\Delta F_t = \alpha_2 + \alpha_f \hat{e}_{t-1} + \text{lagged}(\Delta St, \Delta Ft) + \varepsilon_{ft} \qquad (4)$$

In equation 3 and 4, ΔS_t and ΔF_t denote, respectively, the first differences in the log of spot and futures prices for one time period. $\hat{e}_{t-1}$ is the lagged error correction term from the cointegrating equation and ε_{st} and ε_{ft} are the white noise disturbance terms. Equations 3 and 4 describe the short-run as well as long-run dynamics of the equilibrium relationship between spot index and futures index. They provide information about the feedback interaction between the two variables.

Equation (3) has the interpretation that, change in St is due to both, short-run effects, from lagged futures and lagged spot variables and to the last period equilibrium error ($\hat{e}_{t-1}$), which represents adjustment to the long-run equilibrium. The coefficient attached to the error correction term measures the single period response of changes in spot prices to departures from equilibrium. If this coefficient is small then spot prices have little tendency to adjust to correct a disequilibrium situation. Then most of the correction will happen in the other variable, in this case futures prices.

The last step involves testing the adequacy of the models by performing diagnostic checks to determine whether the residuals of the error correction equations approximate white noise. The reverse representation of Engle and Granger's Co-integration analysis along with the empirical findings has been given in the appendix. A pair wise Granger Causality test was done to establish the cause and effect relationship between spot index and futures index.

Data

The NSE provides a fully automated screen based trading system for futures and spot market transactions, on a nationwide basis and an online monitoring and surveillance mechanism. It supports an order driven market which provides complete transparency of trading operations and operates on strict price-time priority. The derivatives trading on the NSE commenced with the S&P CNX Nifty Index futures on June 12, 2000. NSE is the largest derivatives exchange in India, in terms of volume and turnover. Currently, the derivatives contracts have a maximum of 3-month expiration cycles. Three contracts are available for trading with 1-month, 2-months and 3-months expiry.

To examine the lead-lag relationship between the underlying spot market and the futures market, the basic data used in this study consists of intraday price histories, for the nearby contract of S&P CNX Nifty and S&P CNX Nifty futures. Nifty is a well diversified 50 stock index accounting for 22 sectors of the economy. It is used for a variety of purposes such as benchmarking fund portfolios, index based derivatives and index funds. Nifty stocks represent about 59.49% of the total market capitalization as on Sep 29, 2006. The index futures contracts has S&P CNX Nifty as the underlying index. The number of shares in the index is not too large, and it comprises of the most actively traded securities. Therefore, the risk of the spot index lagging behind the futures index due to non synchronous trading is negligible.

I have used tick by tick transaction data, for one year from April 2005 to March 2006. The data is filtered by using simultaneous data for spot and futures prices, at 5 minute interval. Within an interval the first observed price has been recorded for Nifty spot index and Nifty futures index. For index futures, prices quoted for the near month contract have been used. As the near month contract approaches expiration date, price data was rolled over to the next month. To maintain uniformity, next month price quotes were used three days before the contract expires. In NSE trading starts at 9.55 am and ends at 3.30 pm. I have taken the first quote at 10.am and then data is collected at every 5 minute interval. The last quote on each day is at 3.25 pm. For each trading day there are 67 observations and my total sample size is 15576. The analysis is based on 5 minute return data, so as to avoid any distortion in the results, overnight returns have been excluded. Trading data for few days was deleted like a special trading session on Saturday, Diwali trading etc. The logarithms of price series are analysed in this study. Data relating to the spot as well as the futures market in India has been collected from the historical data CD-ROM's made available, by the National Stock Exchange. These CD's have high frequency tick by tick data and they keep records of every trade that takes place. STATA[6] software has been used to extract the relevant data from the CD ROM's.

Section III

Empirical Findings

The data set consist of 15576 pairs of observations for Nifty spot index and Nifty futures index. These observations were at 5 minute interval, for a period of one year, from 1 April, 2005 to 31 March, 2006. In figure (1) the logarithmic values of spot index and futures index are plotted. Figure 2 shows the first differenced values of log of spot index and log of futures index. Inspection of the figures suggests that each of the series is non stationary in their level form, however both the series appear to have a common stochastic trend and seem to be cointegrated. The plot of the first differenced logarithmic values appears to be stationary suggestive of the series being integrated in I(1) form.

Augmented Dickey-Fuller test was performed to substantiate findings from graphical analysis. Table (1a and 1b) gives the results of ADF test. The test used log values of spot index and futures index. In both the cases, the null hypothesis that the series has unit root is accepted, as the ADF test statistics is more than the critical values. This shows that Nifty spot as well as futures are not stationary in their level form. The ADF test when done on the first differenced values of log Nifty spot and futures index gives a test statistics which is lower than the critical values. The null hypothesis of unit root is rejected (at 1% critical values) implying that Nifty spot index and Nifty futures index are I(1) integrated. One of the necessary conditions for any two series to be cointegrated

[6] STATA is a data analysis and statistical software.

Intra Day Nifty Spot Index and Nifty Futures Index

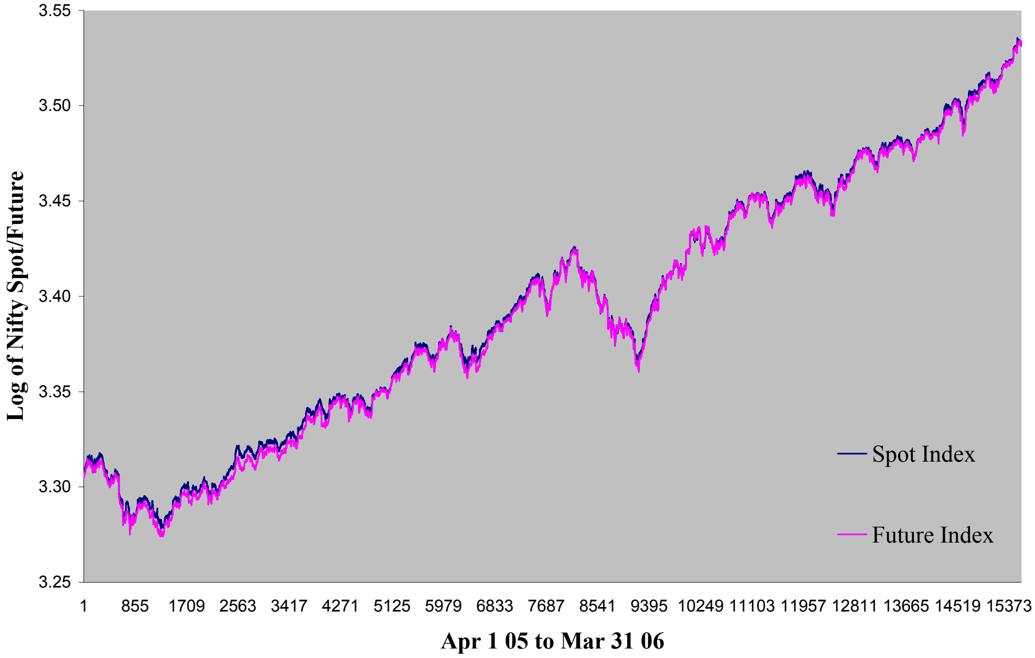

Figure 1

Differenced Logarithmic Nifty Spot and Futures Index

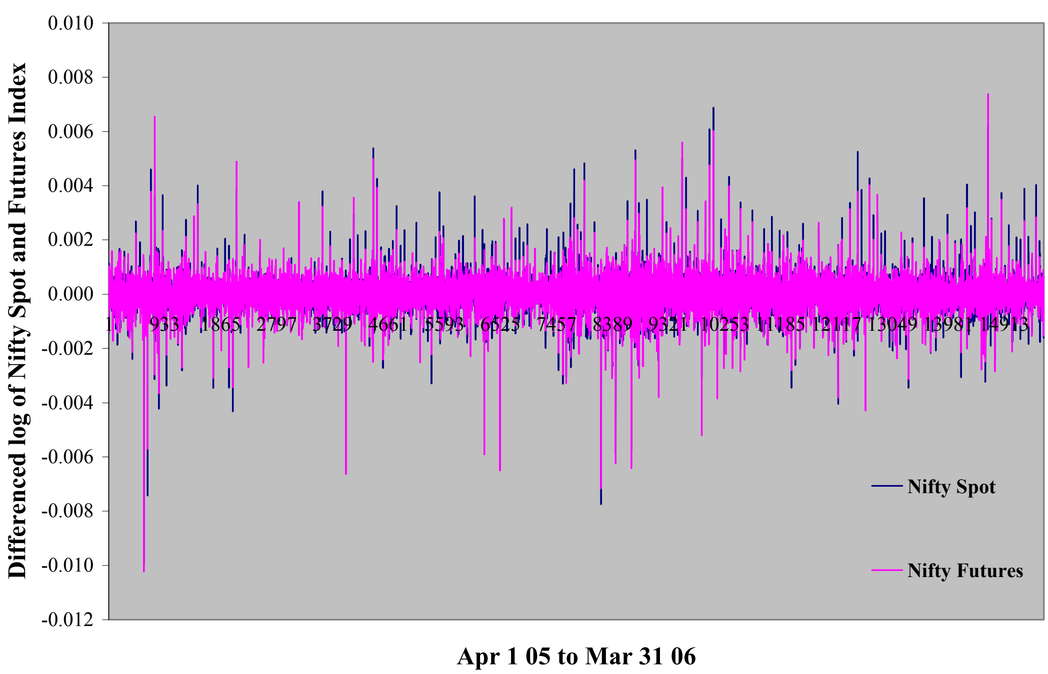

Figure 2

Table 1(a)

Augmented Dickey-Fuller Test On Nifty Spot Index and Nifty Futures Index

Level Form

ADF Test Statistic	0.672121	1% Critical Value*		-3.4340

*MacKinnon critical values for rejection of hypothesis of a unit root.

Dependent Variable: D(LNNIFTY)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNNIFTY(-1)	4.62E-05	6.87E-05	0.672121	0.5015
D(LNNIFTY(-1))	-0.081902	0.008013	-10.22083	0.0000
D(LNNIFTY(-2))	-0.029798	0.008037	-3.707593	0.0002
D(LNNIFTY(-3))	0.028219	0.008036	3.511580	0.0004
D(LNNIFTY(-4))	0.029656	0.008012	3.701644	0.0002
C	-0.000142	0.000233	-0.606788	0.5440

ADF Test Statistic	0.520434	1% Critical Value*		-3.4340

*MacKinnon critical values for rejection of hypothesis of a unit root.

Dependent Variable: D(LNNIFTY FUTURE)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNFUTURE(-1)	3.59E-05	6.90E-05	0.520434	0.6028
D(LNFUTURE(-1))	-0.067720	0.008016	-8.447798	0.0000
D(LNFUTURE(-2))	-0.004511	0.008019	-0.562486	0.5738
D(LNFUTURE(-3))	0.038649	0.008018	4.820162	0.0000
D(LNFUTURE(-4))	0.037105	0.008004	4.636016	0.0000
C	-0.000108	0.000234	-0.459977	0.6455

Table 1(b)

Augmented Dickey-Fuller Test On Nifty Spot Index and Nifty Futures Index

First Differenced Form

ADF Test Statistic	-54.94275	1% Critical Value*		-3.4340

*MacKinnon critical values for rejection of hypothesis of a unit root.

Dependent Variable: D(DNIFTY)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DNIFTY(-1)	-1.049608	0.019104	-54.94275	0.0000
D(DNIFTY (-1))	-0.032313	0.017141	-1.885131	0.0594
D(DNIFTY (-2))	-0.062209	0.014783	-4.208254	0.0000
D(DNIFTY (-3))	-0.033508	0.011807	-2.838055	0.0045
D(DNIFTY (-4))	-0.003621	0.008016	-0.451732	0.6515
C	1.51E-05	4.66E-06	3.232265	0.0012

ADF Test Statistic	-53.58602	1% Critical Value*		-3.4340

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(DNIFTY FUTURE)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D FUTURE (-1)	-0.992285	0.018518	-53.58602	0.0000
D(D FUTURE (-1))	-0.075471	0.016704	-4.518137	0.0000
D(D FUTURE (-2))	-0.079934	0.014517	-5.506176	0.0000
D(D FUTURE (-3))	-0.040923	0.011717	-3.492739	0.0005
D(D FUTURE (-4))	-0.003692	0.008010	-0.460847	0.6449
C	1.41E-05	4.73E-06	2.967895	0.0030

is that they should be integrated of the same order. Both the series are I(1) integrated so, the long-run relationship between spot index and futures index can be tested.

A simple regression with log Nifty as the dependent variable and log futures as the independent variable was done by applying equation (2). The results of the regression are given in table 2. The coefficient of log futures is 0.989457 and is highly significant. The probability of the variable being insignificant is zero, therefore, the null hypothesis that there is no relationship between Nifty spot and Nifty futures index, is rejected. The R-squared term is close to 1 showing that there is a very strong relationship between the two variables.

Residuals were estimated from the regression equation and Engle-Granger test was performed on the estimated residuals. Table 3 gives the results of the Engle-Granger test. Since the test statistic is lower than the critical values at 1% level of significance it shows that the residual variable is stationary. The Durbin Watson statistic is close to 2 showing that there is no serial correlation in the residual variable. The results indicate that spot index and futures index are cointegrated and both the variables have a stable long-run equilibrium relationship.

Table 2

Cointegration Equation For Nifty Spot and Nifty Futures Index

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.037959	0.000539	70.36354	0.0000
LNFUT	0.989457	0.000159	6223.594	0.0000

R-squared	0.999598	Mean dependent variable	3.394740
Adjusted R-squared	0.999598	S.D. dependent variable	0.067825
S.E. of regression	0.001360	Akaike info criterion	10.36284
Sum squared residual	0.028797	Schwarz criterion	10.36186
Log likelihood	80707.82	F-statistic	3873319
Durbin-Watson stat	0.066039	Probability(F-statistic)	0.000000

Table 3

Engle-Granger Test on Cointegration Equation Residuals

ADF Test Statistic	-7.903632	1% Critical Value*		-3.921

*Critical values for Engle-Granger Co-integration test

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(RESID1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID1(-1)	-0.014924	0.001888	-7.903632	0.0000
D(RESID1(-1))	-0.463922	0.008103	-57.25092	0.0000
D(RESID1(-2))	-0.216083	0.008857	-24.39825	0.0000
D(RESID1(-3))	-0.113266	0.008833	-12.82291	0.0000
D(RESID1(-4))	-0.048719	0.008007	-6.084240	0.0000
C	6.64E-08	2.52E-06	0.026282	0.9790

R-squared	0.187728	Mean dependent variable	1.46E-08
Adjusted R-squared	0.187467	S.D. dependent variable	0.000349
S.E. of regression	0.000315	Akaike info criterion	-13.28744
Sum squared residual	0.001545	Schwarz criterion	-13.28450
Log likelihood	103455.4	F-statistic	719.4618
Durbin-Watson stat	2.002767	Probability (F-statistic)	0.000000

If the spot index and the futures index are cointegrated in the long run, then according to Engle and Granger there exists a corresponding Error Correction Representation. The ECM describes the short-run as well as long-run dynamics of the two variables. To estimate ECM equation (3) and (4) are used, in which lagged estimated residuals ($\hat{e}_{t-1}$) from the cointegration equation and lagged changes in the spot index and futures index have been included. Error correction equation is estimated using Ordinary Least Squares, adding lagged variables, one at a time, upto Eight lags. It was found that the 7th and 8th lags were insignificant for both futures as well as spot index, therefore the lags were restricted to Six periods for both the variables. The Akaike information criterion was also lowest at 6 lags. The results of the ECM are given in table 4 and 5.

The estimates of α_s (-0.007934) is very small it is close to 0, but it is significant at 5% level. This implies that there is very little correction required in the spot index to adjust to the long term equilibrium value because most of the information gets absorbed in the first five minutes. Since the coefficient of α_s is negative whatever little correction takes place in the short-run in the spot index, is a downward adjustment. The lagged spot as well as lagged futures terms are highly significant upto 6 lags. This shows that the spot market

Table 4

Error Correction Model For Change in Nifty Spot Index

ECM with change in spot index as the dependent variable.

$\Delta S_t = \alpha_1 + \alpha_s \hat{e}_{t-1} + \text{lagged}(\Delta St, \Delta Ft) + \varepsilon_{st}$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.41E-05	4.51E-06	3.116643	0.0018
RESID1(-1)	-0.007934	0.003380	-2.347339	0.0189
DSPOT(-1)	-0.502943	0.015423	-32.60983	0.0000
DSPOT(-2)	-0.228351	0.016841	-13.55900	0.0000
DSPOT(-3)	-0.118804	0.017105	-6.945733	0.0000
DSPOT(-4)	-0.063898	0.017077	-3.741830	0.0002
DSPOT(-5)	-0.058415	0.016751	-3.487311	0.0005
DSPOT(-6)	-0.039873	0.014888	-2.678256	0.0074
DFUT(-1)	0.469819	0.014716	31.92577	0.0000
DFUT(-2)	0.215180	0.016403	13.11847	0.0000
DFUT(-3)	0.145039	0.016643	8.714724	0.0000
DFUT(-4)	0.089148	0.016634	5.359382	0.0000
DFUT(-5)	0.053255	0.016386	3.250011	0.0012
DFUT(-6)	0.051396	0.014996	3.427227	0.0006

R-squared	0.074645	Mean dependent variable	1.43E-05
Adjusted R-squared	0.073871	S.D. dependent variable	0.000583
S.E. of regression	0.000561	Akaike info criterion	-12.13119
Sum squared residual	0.004903	Schwarz criterion	-12.12431
Log likelihood	94449.24	F-statistic	96.51999
Durbin-Watson stat	1.999564	Probability (F-statistic)	0.000000

Table 5

Error Correction Model For Change in Nifty Futures Index

ECM with change in futures index as the dependent variable.

$\Delta F_t = \alpha_2 + \alpha_f \hat{e}_{t-1} + \text{lagged}(\Delta St, \Delta Ft) + \varepsilon_{ft}$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.43E-05	4.74E-06	3.027706	0.0025
RESID1(-1)	0.005917	0.003550	1.666821	0.0956
DSPOT(-1)	-0.068864	0.016199	-4.251135	0.0000
DSPOT(-2)	-0.016186	0.017689	-0.915027	0.3602
DSPOT(-3)	0.009548	0.017965	0.531462	0.5951
DSPOT(-4)	0.016041	0.017936	0.894325	0.3712
DSPOT(-5)	-0.001216	0.017594	-0.069114	0.9449
DSPOT(-6)	-8.37E-05	0.015637	-0.005351	0.9957
DFUT(-1)	-0.010844	0.015456	-0.701577	0.4830
DFUT(-2)	0.016352	0.017228	0.949123	0.3426
DFUT(-3)	0.031206	0.017480	1.785210	0.0742
DFUT(-4)	0.023056	0.017471	1.319707	0.1870
DFUT(-5)	0.004011	0.017211	0.233077	0.8157
DFUT(-6)	0.009378	0.015751	0.595419	0.5516

R-squared	0.008571	Mean dependent variable	1.45E-05
Adjusted R-squared	0.007742	S.D. dependent variable	0.000592
S.E. of regression	0.000590	Akaike info criterion	-12.03301
Sum squared residual	0.005409	Schwarz criterion	-12.02613
Log likelihood	93684.97	F-statistic	10.34414
Durbin-Watson stat	1.999535	Probability (F-statistic)	0.000000

reacts to lagged prices in the spot aswell as futures market. Last, half an hour information in the spot and futures index is relevant for short term corrections in the spot market. The first 3 coefficients of lagged spot index and futures index are high, the other coefficients are relatively small. This shows that most of the correction in the spot market happens in the first 15 minutes and the entire correction takes place in maximum 30 minutes.

In table 5 the lagged residual term is 0.005917 which is also very small but is significant at 10% level of significance. The futures index also has a very small correction in the short term, to adjust to the long term equilibrium. Very small value of the correction term reinforces the fact that most of the price discovery happens in the first five minutes. The positive value of the correction term suggests that there is an upward correction in the futures index. In table 5 only lag 1 coefficient of the spot index is significant. All other lagged terms for the spot index and the futures index are insignificant. This show that the futures index reacts to the immediately preceding spot index value. Only the first 5 minutes spot market information is relevant for the futures index. Any information prior to that period has no relevance for the futures market. Also the futures market is not influenced by any of the lagged variables in the same market. This implies whatever information is available in the futures market is immediately absorbed in the current futures price. Lagged futures index has no impact on the current value of the futures index. All publicly available information is immediately reflected in the prevailing futures prices. Beyond 5 minutes even the lagged spot index has no impact on the futures index. This shows that the futures market is highly efficient and all available information is quickly absorbed and reflected in the prevailing market prices.

To test the adequacy of the models diagnostic checks were performed to determine whether the residuals of the error correction equations approximate white noise. The results of ADF test are given in table 6 and 7. The ADF test statistic is lower than the critical value at 1% level of significance, implying that the residuals of the error correction model are stationary. This shows that the ECM is a good fit. Only the first residual is significant so it is a Markov chain of first degree which indicates that

Table 6

Augmented Dickey-Fuller Test On Residuals Of Error Correction Model For Nifty Spot Index

ADF Test Statistic	-55.91913	1% Critical Value*	-3.4340

*MacKinnon critical values for rejection of hypothesis of a unit root.
Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RESIDS)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESIDS(-1)	-1.002577	0.017929	-55.91913	0.0000
D(RESIDS(-1))	0.002886	0.016032	0.179992	0.8572
D(RESIDS(-2))	0.002631	0.013885	0.189450	0.8497
D(RESIDS(-3))	0.002678	0.011338	0.236235	0.8133
D(RESIDS(-4))	0.001489	0.008018	0.185663	0.8527
C	-4.54E-08	4.50E-06	-0.010098	0.9919

R-squared	0.499813	Mean dependent variable	-6.01E-08
Adjusted R-squared	0.499653	S.D. dependent variable	0.000793
S.E. of regression	0.000561	Akaike info criterion	-12.13249
Sum squared residual	0.004900	Schwarz criterion	-12.12954
Log likelihood	94421.02	F-statistic	3109.279
Durbin-Watson stat	1.999844	Probability (F-statistic)	0.000000

Table 7

Augmented Dickey-Fuller Test On Residuals Of Error Correction Model For Nifty Futures Index

ADF Test Statistic	-55.80565	1% Critical Value*	-3.4340

*MacKinnon critical values for rejection of hypothesis of a unit root.
Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RESIDF)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESIDF(-1)	-1.000389	0.017926	-55.80565	0.0000
D(RESIDF(-1))	0.000640	0.016033	0.039913	0.9682
D(RESIDF(-2))	0.000393	0.013886	0.028277	0.9774
D(RESIDF(-3))	0.000442	0.011338	0.039000	0.9689
D(RESIDF(-4))	0.000221	0.008018	0.027550	0.9780
C	-8.02E-08	4.73E-06	-0.016980	0.9865

R-squared	0.499874	Mean dependent var	-3.62E-09
Adjusted R-squared	0.499713	S.D. dependent var	0.000834
S.E. of regression	0.000590	Akaike info criterion	-12.03406
Sum squared resid	0.005407	Schwarz criterion	-12.03111
Log likelihood	93655.02	F-statistic	3110.033
Durbin-Watson stat	1.999968	Prob(F-statistic)	0.000000

innovation embeds itself into the data generating process. The entire exercise was repeated by obtaining a reverse representation of Engle and Grangers co-integration regression. Simple regression analysis with log futures index as a dependent variable and log of spot index as the independent variable was done. The estimated residuals from this equation were substituted in the two error correction specifications. Almost identical results were obtained in the reverse representation. The results of the reverse representation are given in the appendix.

Granger causality test was done to study the cause and effect relationship between spot index and futures index. Results of the same are given in table 8. Here the null hypothesis that futures does not cause spot index is rejected and the second hypothesis that Spot index does not cause futures index is also rejected. This means that futures index causes spot index and vice versa. Therefore there is a bidirectional relationship and both the variables are influencing each other.

Table 8

Pairwise Granger Causality Tests On Nifty Spot And Futures Index

Sample size:15576 Lags: 2

Null Hypothesis:	Observations	F-Statistic	Probability
LNFUT does not Granger Cause LNNIFTY	15565	456.229	0.00000
LNNIFTY does not Granger Cause LNFUT		10.6295	2.4E-05

Section IV

Conclusion

In an efficient market, information processing should be expeditious and the most information-efficient market should lead the other. Our empirical findings show that price discovery occurs in both the futures as also the spot markets fairly efficiently and most of the information gets processed within the first five minutes of it being publicly available. However, Nifty futures index is more efficient relative to its corresponding underlying index, as it processes information faster than the spot market. The spot market has a memory of 30 minutes whereas futures market processes all the information in 5 minutes.

Therefore, S&P CNX Nifty futures index leads the S&P CNX Nifty index by 10 to 25 minutes.

Market frictions such as differences in capital market requirements, short selling restrictions and transaction costs differential make trading in futures market more attractive than in the spot market. Futures market is the preferred trading platform, as reflected in the higher trading volumes and the presence of large operators in the futures market, leading to a faster price discovery.

The finding that the futures market leads the spot market has important implications for arbitrageurs, who take offsetting positions in the two markets to earn assured risk free returns. Futures index leading the spot index by 10 to 25 minutes suggests that for a short period of time the prices in the two markets could be out of line, resulting in profitable arbitrage opportunities. Traders can profit from the discrepancy in the prices of Nifty futures and Nifty spot, provided they can react quickly. An arbitrageur is required to complete both legs of an index arbitrage transaction within a short time span. The prior knowledge of index futures leading the spot index could likely influence his decision as to which market should he react in first, which leads to the initial trade in the futures market.

These findings lend support to Thenmozhi's (2002) study on the Indian stock markets, which showed that futures returns lead the spot market returns. However, Thenmozhi's study could not establish the lead time as it was based on daily closing prices. The study also corroborates the findings of similar studies by Stoll and Whaley (1990), Chan (1992), Ghosh (1993) and Abhyankar (1998) in U.S and U.K markets.

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Appendix

Reverse Representation of Engle and Granger's Co-integration Regression

Step 1: The first step is to pretest the variables for their order of integration. This has been done in the main section and the results are given in table 1(a) and 1(b).

Step 2: To test the long run equilibrium relation, a cointegration equation was run, with Nifty futures index as the dependent variable.

$$F_t = \beta'_o + \beta'_1 S_t + e'_t \tag{5}$$

Where F_t is the log of futures index prices at time t, S_t is the log of spot index price and e'_t is the residual term.

Table 9

Co-integration Equation For Nifty Spot and Nifty Futures Index

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.036985	0.000551	-67.10312	0.0000
LNNIFTY	1.010249	0.000162	6223.594	0.0000

R-squared	0.999598	Mean dependent variable	3.392546
Adjusted R-squared	0.999598	S.D. dependent variable	0.068533
S.E. of regression	0.001374	Akaike info criterion	-10.34205
Sum squared residual	0.029402	Schwarz criterion	-10.34106
Log likelihood	80545.86	F-statistic	38733119
Durbin-Watson stat	0.066040	Probability(F-statistic)	0.000000

Table 10

Engle-Granger Test on Cointegration Equation Residuals

ADF Test Statistic	-7.901474	1% Critical Value*	-3.921

*Critical values for Engle-Granger Co-integration test.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(RESIDUAL2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESIDUAL2(-1)	-0.014921	0.001888	-7.901474	0.0000
D(RESIDUAL2(-1))	-0.463863	0.008103	-57.24315	0.0000
D(RESIDUAL2(-2))	-0.215992	0.008856	-24.38813	0.0000
D(RESIDUAL2(-3))	-0.113186	0.008833	-12.81402	0.0000
D(RESIDUAL2(-4))	-0.048668	0.008007	-6.077879	0.0000
C	-5.62E-08	2.55E-06	-0.022014	0.9824

R-squared	0.187687	Mean dependent variable	-8.87E-09
Adjusted R-squared	0.187426	S.D. dependent variable	0.000353
S.E. of regression	0.000318	Akaike info criterion	-13.26659
Sum squared residual	0.001577	Schwarz criterion	-13.26364
Log likelihood	103293.0	F-statistic	719.2654
Durbin-Watson stat	2.002760	Probability (F-statistic)	0.000000

The above table gives the Engle-Granger test results on the residuals of Co-integration equation. This test is done to determine if the residuals of the Co-integration equation are stationary.

Step 3: Estimating the Error Correction Model by regressing changes in spot index on last periods futures index equilibrium error and lagged futures and spot index (equation 6). Regressing changes in futures index on last periods futures index equilibrium error and lagged futures and spot index (equation 7).

$$\Delta S_t = \alpha'_1 + \alpha'_s \hat{e}'_{t-1} + \text{lagged}(\Delta St, \Delta Ft) + \varepsilon'_{st} \quad (6)$$

$$\Delta F_t = \alpha'_2 + \alpha'_f \hat{e}'_{t-1} + \text{lagged}(\Delta St, \Delta Ft) + \varepsilon'_{ft} \quad (7)$$

In equation 6 and 7, ΔS_t and ΔF_t denote, respectively, the first differences in the log of spot and futures prices for one time period. $\hat{e}'_{t-1}$ is the lagged error correction term from the co-integrating equation and ε'_{st} and ε'_{ft} are the white noise disturbance terms.

Table 11

Error Correction Model For Change in Nifty Spot Index

ECM with change in spot index as the dependent variable.

$\Delta S_t = \alpha'_1 + \alpha'_s \hat{e}'_{t-1} + \text{lagged}(\Delta St, \Delta Ft) + \varepsilon'_{st}$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.41E-05	4.51E-06	3.116766	0.0018
RESID2(-1)	-0.007897	0.003345	2.360822	0.0182
DSPOT(-1)	-0.502913	0.015423	-32.60834	0.0000
DSPOT(-2)	-0.228328	0.016841	-13.55775	0.0000
DSPOT(-3)	-0.118784	0.017104	-6.944620	0.0000
DSPOT(-4)	-0.063881	0.017077	-3.740852	0.0002
DSPOT(-5)	-0.058401	0.016751	-3.486510	0.0005
DSPOT(-6)	-0.039866	0.014888	-2.677827	0.0074
DFUT(-1)	0.469783	0.014716	31.92298	0.0000
DFUT(-2)	0.215151	0.016403	13.11663	0.0000
DFUT(-3)	0.145013	0.016643	8.713111	0.0000
DFUT(-4)	0.089124	0.016634	5.357930	0.0000
DFUT(-5)	0.053234	0.016386	3.248717	0.0012
DFUT(-6)	0.051381	0.014996	3.426258	0.0006

R-squared	0.074648	Mean dependent variable	1.43E-05
Adjusted R-squared	0.073875	S.D. dependent variable	0.000583
S.E. of regression	0.000561	Akaike info criterion	-12.13119
Sum squared residual	0.004903	Schwarz criterion	-12.12431
Log likelihood	94449.27	F-statistic	96.52526
Durbin-Watson stat	1.999564	Probability (F-statistic)	0.000000

Table 12

Error Correction Model For Change in Nifty Futures Index

ECM with change in futures index as the dependent variable.

$\Delta F_t = \alpha'_2 + \alpha'_f \hat{e}'_{t-1} + \text{lagged}(\Delta St, \Delta Ft) + \varepsilon'_{ft}$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.43E-05	4.74E-06	3.027666	0.0025
RESID2(-1)	0.005810	0.003513	-1.653788	0.0982
DSPOT(-1)	-0.068829	0.016199	-4.248976	0.0000
DSPOT(-2)	-0.016156	0.017689	-0.913338	0.3611
DSPOT(-3)	0.009574	0.017965	0.532935	0.5941
DSPOT(-4)	0.016064	0.017936	0.895619	0.3705
DSPOT(-5)	-0.001197	0.017593	-0.068011	0.9458
DSPOT(-6)	-7.08E-05	0.015637	-0.004525	0.9964
DFUT(-1)	-0.010876	0.015457	-0.703657	0.4817
DFUT(-2)	0.016325	0.017228	0.947597	0.3433
DFUT(-3)	0.031183	0.017480	1.783893	0.0745
DFUT(-4)	0.023037	0.017471	1.318561	0.1873
DFUT(-5)	0.003995	0.017211	0.232116	0.8165
DFUT(-6)	0.009367	0.015751	0.594710	0.5520

R-squared	0.008568	Mean dependent variable	-6.01E-08
Adjusted R-squared	0.007740	S.D. dependent variable	0.000793
S.E. of regression	0.000590	Akaike info criterion	-12.13249
Sum squared residual	0.005409	Schwarz criterion	-12.12954
Log likelihood	93684.95	F-statistic	3109.278
Durbin-Watson stat	1.999535	Probability (F-statistic)	0.000000

Step 4: Finally testing the adequacy of the Error Correction Model by performing diagnostic checks to determine whether the residuals of the ECM equations approximate white noise.

Table 13

Augmented Dickey-Fuller Test On Residuals Of Error Correction Model For Nifty Spot Index

ADF Test Statistic	-55.91893	1% Critical Value*	-3.4340

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(RESIDS)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESIDS(-1)	-1.002573	0.017929	-55.91893	0.0000
D(RESIDS(-1))	0.002881	0.016032	0.179714	0.8574
D(RESIDS(-2))	0.002626	0.013885	0.189152	0.8500
D(RESIDS(-3))	0.002675	0.011338	0.235941	0.8135
D(RESIDS(-4))	0.001487	0.008018	0.185416	0.8529
C	-4.55E-08	4.50E-06	-0.010114	0.9919

R-squared	0.499813	Mean dependent variable	-6.01E-08
Adjusted R-squared	0.499653	S.D. dependent variable	0.000793
S.E. of regression	0.000561	Akaike info criterion	-12.13249
Sum squared residual	0.004900	Schwarz criterion	-12.12954
Log likelihood	94421.05	F-statistic	3109.278
Durbin-Watson stat	1.999844	Probability (F-statistic)	0.000000

Table 14

Augmented Dickey-Fuller Test On Residuals Of Error Correction Model For Nifty Futures Index

ADF Test Statistic	-55.80566	1% Critical Value*	-3.4340

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(RESIDF)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESIDF(-1)	-1.000389	0.017926	-55.80566	0.0000
D(RESIDF(-1))	0.000640	0.016033	0.039937	0.9681
D(RESIDF(-2))	0.000393	0.013886	0.028301	0.9774
D(RESIDF(-3))	0.000442	0.011338	0.039019	0.9689
D(RESIDF(-4))	0.000221	0.008018	0.027565	0.9780
C	-8.02E-08	4.73E-06	-0.016963	0.9865

R-squared	0.499874	Mean dependent variable	-3.58E-09
Adjusted R-squared	0.499713	S.D. dependent variable	0.000834
S.E. of regression	0.000590	Akaike info criterion	-12.03405
Sum squared residual	0.005407	Schwarz criterion	-12.03110
Log likelihood	93655.00	F-statistic	3110.033
Durbin-Watson stat	1.999968	Probability (F-statistic)	0.000000