Estimating the Optimal Hedge Ratio in the Indian Equity Futures Market

Kapil Gupta* and Balwinder Singh**

The present study attempts to suggest an optimal hedge ratio for Indian traders through the examination of three indices, i.e., Nifty, Bank Nifty and CNXIT, and 84 most liquid individual stock futures traded on the National Stock Exchange of India, over the sample period January 2003 to December 2006. The present study compares the efficiency of hedge ratios estimated through OLS, VAR, VECM, GARCH(p,q), TARCH(p,q) and EGARCH(p,q) in the minimum variance hedge ratio framework, as suggested by Ederington (1979). The Findings of the present study conform to the theoretical properties of futures markets and suggest that unconditional hedge ratio, after controlling for basis risk, outperforms the conditional hedge ratio. The results favor the hedge ratios estimated through VAR or VECM because both the markets are cointegrated in Engle and Granger (1987) framework, and the findings are consistent with that of Alexander (1999).

Introduction

Existence of organized futures markets furnishes an opportunity to legitimate traders to hedge the non-diversifiable risk element contained in their portfolios and help informed market participants to speculate on basis risk, so that they can secure risk-free profit, which is offered as a reward to restore market equilibrium. The reward to restore market equilibrium arises due to noise trading by uninformed market agents, which raises the degree of information asymmetry in the underlying asset market and initiates trading at disequilibrium price (which is reflected through jumps in the basis risk) (Cox, 1976; Danthine, 1978; Carlton, 1984; Hodgson and Nicholls, 1991; Castelino, 1992; Mckenzie *et al.*, 2001; Chatrath *et al.*, 2003; and Illueca and Lafuente, 2003). On the other hand, informed trading by market agents is expected to bring fairness in price change of the underlying asset and helps it to stabilize, consequently the required rate of return will decline (Bessembinder and Seguin, 1992; and Gulen and Mayhew, 2000). Therefore, an organized futures market is a joint product, where portfolio risk insurance is furnished to hedgers, gambling to speculators, and arbitrageurs undertake the responsibility to restore the market equilibrium (Telser, 1981).

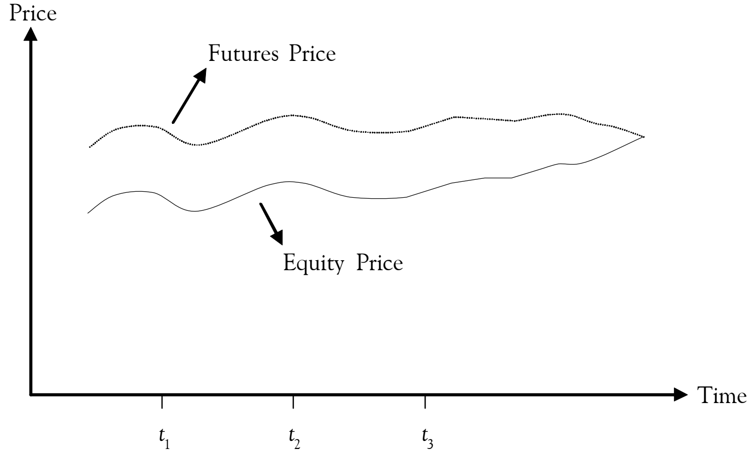
Academic literature has widely appreciated the information transmission role of futures markets, which implies that price movement in futures market can be efficiently used to price cash market transactions (Cox, 1976; Peck, 1976; Telser, 1981; Garbade and Sibler, 1983; and Carlton, 1984). Since both the markets are linked through an efficient

* Faculty Member, IBS, Gurgaon, Haryana, India, E-mail: Kapilfutures@gmail.com

** Reader, Department of Commerce and Business Management, Guru Nanak Dev University, Amritsar 143005, Punjab, India. E-mail: bksaini@gmail.com

arbitrage process (Garbade and Sibler, 1983; and Mackinlay and Ramaswamy, 1988), convergence of both markets on the maturity date is natural (Figure 1). However, they may deviate from each other during the short run.[1]

Figure 1: Illustration of Cost-of-Carry Relationship Between Two Markets over the Contract Cycle



Efficient information exchange role of futures market and strong and stationary comovement between the two markets[2] provide an important input for hedgers to transfer risk contained in their portfolio to the speculator's portfolio.[3] Hedging through futures market due to varied portfolio objectives of traders has different connotations; therefore, different hedging theories persist (viz., conventional hedging theory, Working's hedging theory, portfolio hedging theory, etc.) (Ederington, 1979; Howard and D'Antonio, 1984; Castelino, 1992; Pennings and Leuthold, 2000; and Lien and Tse, 2002).

Two Markets over the Contract Cycle

The conventional hedging theory (also known as naïve hedging) states that since both futures and cash markets are subject to common information set, which will bring equal price change in the two markets, hedgers should take a more inverse but equal in size

1 Carlton (1984), while explaining the contributions of organized futures markets, mentioned that futures markets perform the role of price discoverer; they help in transferring the risk involved in the portfolio, improving liquidity in the underlying asset market, and improving the price discovery efficiency of the underlying asset market. He further mentioned that prediction of cash market through futures market may sometimes attract uninformed traders in the market who make noise and deteriorate the pricing efficiency. Whereas, at the same time, simultaneous participation of arbitrageurs and speculators in the two markets will help restore market equilibrium.

2 *See* Fortenbery and Zapata (1997), Alexander (1999), Neuberger (1999), Sahadevan (2002), Lin *et al.* (2003), Kumar (2004), and Pattarin and Ferretti (2004).

3 *See,* for example, Ederington (1979), Telser (1981), Figlewski (1984), Merrick (Jr.) (1988), Castelino (1992), Kroner and Sultan (1993), Lien and Tse (1998), Neuberger (1999), Jensen *et al.* (2000), Pennings and Leuthold (2000), Frechette (2001), Giaccotto *et al.* (2001), Chen *et al.* (2002), Lo *et al.* (2002), Chen *et al.* (2004), Lien and Wang (2004), Terry (2005), and In and Kim (2006).

position in the futures market than in the cash market; hence portfolio risk will significantly decline. Since conventional hedging theory presumes that an information shock brings equal price change in both markets (because efficiency of conventional hedging theory is conditioned upon no market preference doctrine), therefore, the conventional hedging theory can successfully provide price risk hedge to the portfolio manager, but it fails to take care of basis risk, because both markets are in equilibrium in the long run. However, in the short run (due to the presence of various market frictions),[4] both markets observe statistically significant and strategically exploitable lead-lag relationship (Kawaller *et al.*, 1987; Ng, 1987; Stoll and Whaley, 1990; Chan, 1992; Wahab and Lashgari, 1993; Chan and Lien, 2001; Chen *et al.*, 2002; Lin *et al.*, 2002; Lien *et al.*, 2003; and Thomas, 2006), which offers risk-free profit-making opportunities (Cornell and French, 1983; Mackinlay and Ramaswamy, 1988; Yadav and Pope, 1990; Chung, 1991; Neal, 1996; Hsu and Wang, 2004; Lee, 2005; and Vipul, 2005).

Lien (2003) and Lien and Li (2003), after evaluating different hedging theories, mentioned that when the proportion of capital allocation in the underlying asset is low, the hedger may avoid basis risk as well as mark-to-market risk and may choose complete hedging, as suggested by conventional hedging theory; but as soon as the proportion of capital allocation increases, he will prefer to under-hedge, so that transaction cost escalations may be avoided (Lo *et al.*, 2002). Therefore, in order to hedge both price as well as basis risk, Working (1953) came out with a new hedging theory, which defines a hedger as a risk selector and not as a risk avoider. It assumes that the market agent's prime objective is profit maximization and not risk minimization. Working's hedging theory suggests that the hedger predominantly behaves like a speculator, who strives to exploit all profit-making opportunities available in the market. In other words, hedgers speculate on the change in basis rather than on the absolute value of basis. Therefore, a short hedger[5] will hedge portfolio risk if the basis is expected to fall, otherwise he will prefer an unhedged portfolio (Castelino, 1992; and Li and Vukina, 1998).

Working's hedging theory, although improves upon the conventional hedging theory, is again a biased theory because it presumes that hedgers are always determined to maximize their wealth at any risk level. However, Johnson (1960) and Stein (1961) observed that the hedger prefers optimum risk-return portfolio instead of only minimum risk portfolio or a portfolio which can offer the maximum return (Markowitz, 1952). Therefore, a new hedging approach emerged, known as portfolio hedging approach, which allows a wide range of hedge ratios to be efficient along with the efficient utility

4 Market frictions such as, infrequent trading of the component stocks of underlying index, difference in transaction cost in terms of bid-ask spread for the component stocks, difference in trading cost in terms of brokerage and other expenses to execute one transaction, time delays in the computation and reporting of the stock index values, and low initial investment to take position in futures market (for details, *see* Stoll and Whaley, 1990).

5 Short hedger means when trader is long in the cash market and hedges the cash market position by going short in the futures market.

maximization frontier, and the hedger may choose the optimal hedge ratio, depending upon his risk preference (Howard and D'Antonio, 1984; and Jensen *et al.*, 2000). Moreover, it is a well admitted fact that the presence of both informed as well as uninformed traders in both markets cause mean reversion in basis;[6] consequently basis risk varies over the contract cycle. Therefore, portfolio hedging approach became more popular because it allowed for estimating time-varying optimal hedge ratios, which otherwise was not possible in conventional and Working's hedging theories (Myers, 1991; Aggarwal and Demaskey, 1997; Theobald and Yallup, 1997; Ferguson and Leistikow, 1998; Koutmos and Pericli, 1998; Lien and Tse, 1998; Chen *et al.*, 2004; Yang and Allen, 2004; and Bhaduri and Durai, 2007).

One of the most popular portfolio hedging theories (which also suggests constant hedge ratio) was proposed by Ederington (1979), which presumes that the trader is a risk averter and the futures market is an unbiased predictor of the underlying cash market. Therefore, Ederington (1979), like a conventional hedging theorist, prefers a hedge ratio which reduces the hedged portfolio variance to minimum level; but unlike the naïve hedge ratio, Ederington's hedge ratio is the slope coefficient, which is computed as the ratio of covariance of futures and cash market returns series to the variance of futures market returns. Ederington's hedging theory implies that variance of the hedged portfolio and the correlation of futures and underlying asset are negatively associated, therefore comovement of two markets and early exploitation of arbitrage opportunities are preconditions for efficient hedging.

Ederington's efficient hedge ratio[7] has been empirically found to be negatively associated with hedging horizon, because decreasing time-to-expiry tends to restrict the flexibility of hedged portfolio, which implies that the longer the hedging horizon, the lower will be the hedge ratio; however as soon as the hedging horizon narrows, hedge ratio approaches unity (Franckle, 1980; Figlewski, 1984; Kamara and Siegel, 1987; Merrick, 1988; Castelino, 1992; Li and Vukina, 1998; and Chen *et al.*, 2002). Since basis risk has also been found to be negatively associated with time-to-expiry of the futures contract, the hedger, on expiration date, will be left with only price risk, which implies that in the short run (especially near to expiration date), conventional hedging theory may work efficiently[8] (Lien and Tse, 1999; Arias *et al.*, 2000; Collins, 2000; Lien, 2000; and Chen *et al.*, 2004).

[6] Mean reversion is a property of stochastic process where the variable value tends to revert to some normal value. Therefore, stationary basis is presumed to observe mean reverting behavior because when the spread between two prices is different from cost-of-carry, arbitrageur's activity will correct the deviation and the basis will start representing its cost-of-carry (Theobald and Yallup, 2001; Zeng, 2001; Monoyios and Sarno, 2002; and Pattarin and Ferretti, 2004).

[7] Assumed to comply with the properties of Ordinary Least Square (OLS) model. For a detailed discussion, *see* Ederington (1979).

[8] Castelino (1992) stated that if basis and futures price are negatively correlated, the minimum variance hedge ratio may be less than unity, and if they are positively correlated, the minimum variance hedge ratio will be greater than unity. However, when basis risk is zero, the minimum variance hedge ratio will be unity and the residual risk will be zero.

Ederington's efficient hedge ratio (which is not a time-varying hedge ratio) has gained immense support in academic literature.[9] Lien (2005) suggested that hedge ratio based upon Ordinary Least Square (OLS), despite the violation of statistical properties, will outperform the time-varying hedge ratio, except when major structural changes take place in the underlying asset market. Ferguson and Leistikow (1998), by applying Dickey-Fuller test, mentioned that rejection of constant hedge ratio hypothesis may be a result of inadequate data points, therefore, hedge ratio computed over long run will be stationary; and their findings are consistent with those of Grammatikos and Saunders (1983) and McNew and Fackler (1994) (see also Lo *et al.*, 2002).

Pennings and Meulenberg (1997) also found that Ederington's efficient hedge ratio is expected to reduce the portfolio variance to minimum level, but they doubted its efficiency when futures contracts observe thin trading. Moreover, nonsynchronous trading anomaly in the case of index futures (as found by Stoll and Whaley, 1990) may be another prominent factor responsible for spurious calculation of minimum variance hedge ratio (Theobald and Yallup, 1997 and 2001). In such cases, Anderson and Danthine (1981) suggested that cross hedging will efficiently help hedgers to achieve their portfolio objective rather than direct hedging, as proposed by previous theories (see also Broll and Wong, 1999).

Many empirical findings have further suggested that Ederington's hedging theory performs efficiently in the *ex post* setting rather than in *ex ante* setting, which implies that Ederington's efficient hedge ratio should be calculated by considering data for futures as well as cash markets of the same period. However, Ederington's hedge ratio, computed on the basis of historical data, may fail to minimize the portfolio variance (Figlewski, 1984; Kamara and Siegel, 1987; Myers, 1991; Holmes, 1995; Alexander, 1999; Neuberger, 1999; Arias *et al.*, 2000; Lien, 2000; Giaccotto *et al.*, 2001; and Lo *et al.*, 2002). Kamara and Siegel (1987), Myers (1991) and Holmes (1995) suggested that since traders lack perfect foresight with respect to cash and futures price relationship and the hedge ratio varies with the time-to-expiry,[10] hedge ratio estimated in *ex ante* setting may be more efficient than the hedge ratio estimated in *ex post* setting.

Furthermore, Franckle (1980) commented that since an efficient portfolio is expected to generate risk-free return plus risk premium (as per Capital Asset Pricing Model), Ederington's hedge ratio must be interpreted very cautiously because risk-free nominal rate can be earned only for a predetermined investment horizon. Therefore, if at the time of opening position(s) in both markets, hedging horizon is unknown, then change in the

[9] *See,* Aggarwal and Demaskey (1997), Theobald and Yallup (1997), Ferguson and Leistikow (1998), Chen *et al.* (2004), Yang and Allen (2004), and Bhaduri and Durai (2007).

[10] *See,* Kroner and Sultan (1993), Park and Switzer (1995), Lien and Tse (1998), Harris and Shen (2003), Poomimars *et al.* (2003), Floros and Vougas (2004), Pattarin and Ferretti (2004), Yang and Allen (2004), Kofman and McGlenchy (2005), Floros and Vougas (2006), Hatemi and Roca (2006), Bhaduri and Durai (2007), and Lee and Yoder (2007).

hedge ratio over the contract cycle may result in either large gains or losses. This empirical observation should not be surprising because time-varying basis risk will not allow the hedge ratio to be constant over the hedging horizon (Figlewski, 1984; and Myers, 1991).

In addition, the trader has been assumed to be risk averter, which seems unreal because his prime objective is to maximize portfolio value; therefore the hedger acts as loss averter rather than being risk avoider (Lien and Tse, 1998). Therefore, if the objective of the trader is portfolio utility maximization, the utility function will always be concave when there are gains and convex when there are losses (Myers and Hanson, 1996; and Lien, 2001). Howard and D'Antonio (1984) developed a model which emphasizes upon the portfolio utility maximization objective and suggests that taking position(s) in futures market does not depend only on the correlation between futures and cash markets, but the risk-return relative also affects the portfolio utility, because the trader is more interested in the change of wealth locked in portfolio rather than the absolute value of wealth (Myers, 1991; Theobald and Yallup, 2001; and Lien, 2001).

Furthermore, besides the theoretical progress on account of suggesting optimum hedging strategy through futures contracts (as discussed above), the empirical literature of futures hedging has progressively benefited from recent developments in the literature of financial econometrics (Lien and Tse, 2002). Various hedging theories (including conventional, Working's and Ederington's) assume constant hedging ratio, however, a large body of literature (see Table 1) finds that time-varying hedge ratio is more efficient than constant hedge ratio (Myers, 1991; Aggarwal and Demaskey, 1997; Theobald and Yallup, 1997; Ferguson and Leistikow, 1998; Koutmos and Pericli, 1998; Lien and Tse, 1998; Chen *et al.*, 2004; Yang and Allen, 2004; and Bhaduri and Durai, 2007).

In addition, voluminous empirical literature is available, which suggests that since both markets observe long-run relationship and are integrated of same order, hedge ratio computed through Error Correction Methodology (ECM) developed by Engle and Granger (1987) may be more efficient than other hedge ratios (Castelino, 1992; Park and Switzer, 1995; Koutmos and Pericli, 1998; Alexander, 1999; Poomimars *et al.*, 2003; Alizadeh and Nomikos, 2004; Floros and Vougas, 2004; Pattarin and Ferretti, 2004; Yang and Allen, 2004; Lien and Shrestha, 2005; Floros and Vougas, 2006; Bhaduri and Durai, 2007; and Bhargava and Malhotra, 2007).

The statistical criticism of conventional, Working's and Ederington's hedging strategies can be drawn from the fact that hedge ratios in these hedging models are slope coefficients, which reflect the ratio of unconditional covariance of futures and cash price series to the unconditional variance of futures prices. However, the optimal hedging rule requires conditional moments, which depend upon the information available at the time when hedging decision is made (Myers, 1991; Lien and Luo, 1994; and Myers and Hanson, 1996). Moreover, it is an established fact that financial time series observe time-varying patterns, and volatility clustering is their innate feature;[11] therefore, time-varying hedge ratio may be statistically as well as economically more appropriate and reliable than others (Myers, 1991; Kroner and Sultan, 1993; Park and Switzer, 1995; Koutmos and Pericli, 1998; Harris and Shen, 2003; Floros and Vougas, 2004; Pattarin and Ferretti, 2004; Kofman and McGlenchy, 2005; Hatemi and Roca, 2006; Bhaduri and Durai, 2007; and Lee and Yoder, 2007).

Alexander (1999) further documented that in *ex ante* setting—where historical prices contain significant information about the prospective price movements in the two markets (Holmes, 1995) and bidirectional causal relationship between these is an established fact[12]—ECM proposed by Engle and Granger (1987) may provide better estimate of efficient hedge ratio than other methodologies. These findings were further tested by Kroner and Sultan (1993), Lien and Luo (1994), Park and Switzer (1995), Koutmos and Pericli (1998), Lien and Tse (1999), Poomimars *et al.* (2003), Alizadeh and Nomikos (2004), Floros and Vougas (2004), Pattarin and Ferretti (2004), Yang and Allen (2004), Lien and Shrestha (2005), Floros and Vougas (2006), Hatemi and Roca (2006), and Bhaduri and Durai (2007), and they all found that hedge ratio computed through ECM provides better results than constant hedge ratio, but it could not outperform the hedge ratio estimated through different models of GARCH methodology (except Lien and Tse, 1999; and Lien and Shrestha, 2005).

Moreover, Telser (1981), Neuberger (1999), Giaccotto *et al.* (2001), and Lo *et al.* (2002) appreciated the coexistence of multiple futures contracts with varied expiry dates having same or different underlying asset, because this will help the traders to hedge through liquid futures contracts.[13 and 14] In order to mitigate the impact of illiquidity on hedging activity, traders prefer to hedge through near to expiry futures contracts and achieve the long-term hedging objective by rolling positions to the next contract. Harris and Shen (2003) and Kofman and McGlenchy (2005) examined the same hypothesis and found that rolling window methodology outperformed the constant hedge ratio, but still failed to provide better forecast than hedge ratio estimated through different models of GARCH methodology. Therefore, time-varying hedge ratio estimated through appropriate version of GARCH family (such as, BGARCH, EGARCH, MGARCH, etc.) is found to be both statistically and economically a robust hedge ratio, which outperforms other hedge ratios.

[11] *See* Engle (1982), Bollerslev (1986), Lo and Mackinlay (1988), and Bollerslev *et al.* (1992).

[12] *See,* for example, Kawaller *et al.* (1987), Stoll and Whaley (1990), Chan (1992), and Wahab and Lashgari (1993).

[13] In academic literature, it has been widely documented that futures contracts near the expiry date are more liquid as compared to the futures contracts with far maturity date (Moschini and Myers, 2002; and Thomas, 2006).

[14] Lien (2003) mentioned that liquidity constraint in either or both markets is a critical factor, which forces the hedger to partially hedge the undiversifiable risk components so that the hedger can avoid additional transaction cost due to mark-to-market losses. Therefore, optimal futures position increases with the size of capital allocation in underlying asset, which implies that if the capital allocation is small, the hedger tends to completely hedge as per conventional hedging theory. However, the optimal futures position decreases with the increase in capital allocation (*also see* Arias *et al.*, 2000; Frechette, 2001; and Haigh and Holt, 2002).

On the basis of the above discussion, two empirical issues can be extracted, which are equally important for policy makers, market makers, traders, practitioners and academicians. Firstly, if two markets observe stable long-run relationship, whether it can be economically translated to help traders in optimizing their portfolio value. Secondly, till date, it is a debatable issue as to which hedge ratio can help traders to achieve their portfolio objectives. Both issues have been widely examined in developed markets like the US and the UK, whereas to the best of our knowledge, in emerging markets (which hold prominent position among different derivative markets of the world), these issues are still unexplored (Table 1). In India, to the best of our knowledge, Bhaduri and Durai's (2007) has been the only attempt to address the second issue, but the study suffers from two limitations.

Table 1: Empirical Evidence on Hedging Efficiency of Futures Markets

Author (Year of Study)	Market Under Study	Contracts	Sample Period	Methodology Applied	Hedging Effectiveness
Ederington (1979)	US	GNMA and T-Bill Futures Markets	January 1976 to December 1977 and March 1976 to December 1977	**OLS**	Futures hedging is better for long period than short period.
Figlewski (1984)	US	S&P 500, NYSE, AMEX, NASDAQ, DOW	June 1982 to September 1983	**OLS**	Basis risk disturbs the hedging effectiveness, therefore, one week hedging is better than overnight hedging.
Kamara and Siegel (1987)	US	Soft Wheat and Hard Wheat	January 1970 to March 1981	**OLS**	Far period hedging is better than near to expiration period.
Myers (1991)	US	Wheat Futures	June 1977 to May 1983	OLS and **BGARCH**	Time-varying hedge ratio is better than constant hedge ratio.
Kroner and Sultan (1993)	US	BP, CD, GM, JY and SF	February 1985 to February 1990	Naïve, OLS, ECM and **ECM-GARCH**	Time-varying error correction methodology takes care of transaction cost, thus it outperforms other methodologies.
Lien and Luo (1994)	US	BP, CD, GM, JY and SF	March 1980 to December 1988	OLS, **BGARCH**, ECM	If trader is extremely risk averter, both constant and time-varying hedge ratios are equally efficient, whereas

Table 1 (Cont.)

Author (Year of Study)	Market Under Study	Contracts	Sample Period	Methodology Applied	Hedging Effectiveness
					to achieve utility maximization objective GARCH hedge ratio is most efficient.
Holmes (1995)	UK	FTSE 100 Futures and FTSE 100 Index	July 1984 to June 1992	*Ex post* MVHR, *Ex ante* MVHR and Beta	MVHR based upon historical data is better.
Park and Switzer (1995)	US and Canada	S&P 500, MMI and TSE 35	June 1988 to December 1991	Naïve, OLS, OLS with Cointegration and **BGARCH**	Time-varying hedge ratio is superior to constant hedge ratios.
Aggarwal and Demaskey (1997)	Hong Kong, South Korea, Singapore, Taiwan, Indonesia, Philippines and Thailand	BP, CD, GM, JY and SF	January 1983 to December 1992	Naïve and **OLS**	Cross hedging is beneficial.
Theobald and Yallup (1997)	UK	FTSE 100 Futures and FTSE 100 Index	January 1985 to December 1995	OLS	Futures contracts can provide hedging benefit only when both markets do not suffer from the problem of nonsynchronous trading.
Li and Vukina (1998)	US	Corn Yield Futures	January 1951 to December 1994	OLS	Dual hedging through price as well as yield futures contracts can be more effective than through price futures only.
Lien and Shaffer (1999)	Japan, US, South Korea, Hong Kong and Spain	Nikkei, S&P 500, TOPIX, KOSPI, Hang Seng and IBEX Futures	September 1986 to September 1989, April 1982 to April 1985, April 1990 to December 1993, May 1996 to December 1996, January 1987 to	Minimum-Extended Gini Hedge Ratio	The extended Gini coefficient as an alternative measure of dispersion has strong theoretical promise for use in futures hedging because it does not require the

Table 1 (Cont.)

Author (Year of Study)	Market Under Study	Contracts	Sample Period	Methodology Applied	Hedging Effectiveness
			December 1989, and April 1993 to March 1995		restrictive requirement of quadratic utility functions.
Lien and Tse (1999)	Singapore	Nikkei Futures	January 1989 to August 1997	ARFIMA-GARCH, OLS, VAR, **EC**, FIEC	Consideration of cointegration framework improves the hedging performance.
Neuberger (1999)	US	Crude Oil Futures	July 1986 to December 1994	*Ex ante* OLS	Rollover of futures contracts adds to hedging effectiveness.
Kavussanos and Nomikos (2003)	UK	BIFFEX	August 1988 to October 1997	OLS, VECM-GARCH	Structural changes help in improving hedging efficiency of futures market.
Chen *et al.* (2001)	US	S&P 500 Futures	April 1982 to December 1991	**M-GSV**, MEG, Sharpe, OLS and Standard Mean Variance	M-GSV minimizes the portfolio variance by maximum.
Haigh and Holt (2002)	UK	Corn, Soybean, Wheat and BIFFEX	May 1985 to January 1998	OLS, SUR and **BEKK**	Though time-varying hedge ratio is more expensive, reward in terms of reduced volatility considerably outweighs the extra transaction costs.
Moschini and Myers (2002)	US	Corn Futures	January 1976 to June 1997	BEKK, GARCH and OLS	Supports time-varying hedge ratio.
Chen *et al.* (2002)	Taiwan	TAIFEX-TAIEX-TAIEX and SGXMSCI[b], MSCI[b]	July 1998 to July 2000	OLS, **Bayesian Approach**	Hedging effectiveness observes positive relationship with hedging horizon.
Harris and Shen (2003)	UK	FTSE 100 Futures and FTSE 100 Index	May 1984 to May 2002	EWMA, Rolling Window **ROHR**	Time-varying hedge ratio is better, but ROHR, which accounts for non-normality of data, proves to be a better hedge ratio.

Table 1 (Cont.)

Author (Year of Study)	Market Under Study	Contracts	Sample Period	Methodology Applied	Hedging Effectiveness
Veld-Merkoulova and De Roon (2003)	US	Crude oil, orange juice and lumber	February 1984 to June 1998, January 1973 to May 1998, and January 1974 to March 1998	Naïve and **One Factor Model**	Presence of multiple maturity contracts helps to efficiently achieve the objective of a mean-variance portfolio.
Alizadeh and Nomikos (2004)	US, UK	S&P 500 Futures and S&P 500 Index, and FTSE 100 Futures and FTSE 100 Index	May 1984 to March 2001	OLS, ECM, GARCH and **Markov Regime Switching Models**	By allowing the hedge ratio to be dependent upon the state of market, one may obtain a more efficient hedge ratio.
Chen *et al.* (2004)	US, UK Canada, Japan, Australia	Seven Stock Market Index Futures, 11 Commodity futures, two metals and five currencies	June 1982 to December 1997	OLS	Short-run hedge ratio is significantly <1, but as the hedge horizon increases, it approaches to one and the hedging effectiveness also improves.
Pattarin and Ferretti (2004)	Italy	FIB 30 and MIB 30 Index	November 1994 to September 2002	Naïve, OLS, ECM, GARCH, **EWMA**	Time-varying hedge ratio based upon EWMA is better.
Yang and Allen (2004)	Australia	AOI and SPI	June 1992 to December 2000	**OLS**, VAR, VECM and **MGARCH**	Risk minimization theory prefers time-varying hedge ratio, however when return effects are also considered, the utility-based measure prefers OLS. During the out-of-sample hedging, dynamic hedge ratio proves better than OLS.
Kofman and McGlenchy (2005)	Hong Kong	HSIF and HIS	January 1994 to July 2003	Naïve, Expanding Window, Rolling Window, EWLS and **ROC**	Dynamic hedging is better than constant hedging.

Table 1 (Cont.)

Author (Year of Study)	Market Under Study	Contracts	Sample Period	Methodology Applied	Hedging Effectiveness
Lien and Shrestha (2005)	US, UK Canada, Japan, Australia	Seven Stock Index Futures, Two precious metals, Five currencies and Ten commodities	1982 to 1997	**ECM (AIC)** and **ECM (FIC)**	Both are equally fruitful, but ECM (AIC) is little bit better than the other.
Floros and Vougas (2006)	Greece	FTSE/ASE 20 Index Futures and FTSE/ ASE Mid 40 Index Futures	August 1999 to August 2001 and January 2000 to August 2001	OLS, ECM, VECM and **BGARCH**	Time-varying hedge ratio is superior to constant hedge ratios.
In and Kim (2006)	US	S&P 500 Futures and S&P 500 Index	April 1982 to December 2001	**Wavelet Analysis**	Hedging effectiveness not only depends upon hedging horizon, but risk aversion of hedger also affects the hedging effectiveness. Investors with low risk aversion have short run hedging effective-ness and vice versa.
Bhaduri and Durai (2007)	India	Nifty Futures and Nifty	September 2000 to August 2005	**OLS**, ECM, BVAR and **MGARCH**	GARCH model performs better in the long run, whereas OLS is a better measure in the short run.
Bhargava and Malhotra (2007)	US	Cotton and Soybeans Futures	January 1994 to December 1999 and January 1995 to December 2000	Traditional regression method, Modified regression method and ECM	Traditional regression method performs better than the others.
Lee and Yoder (2007)	UK	Corn and Nickel Futures and Spot Markets	January 1991 to December 2004	**RS-BEKK**, BEKK and OLS	Time-varying hedge ratio performs better.

Note: AIC = Akaike Information Criteria, AOI = All Ordinary Share Price Index, BP = British Pound, CD = Canadian Dollar, ECM = Error Correction Methodology, EWMA = Exponential Weighted Moving Average, GARCH = Generalized Autoregressive Conditional Heteroscedasticity, GM = German Mark, HIS = Hang Seng Index, HSIF = Hang Seng Index Futures, MVHR = Minimum Variance Hedge Ratio, SF = Swiss Franc, SPI = Share Price Index Futures, OLS = Ordinary Least Square, US = United States, UK = United Kingdom, and VAR = Vector Autoregression.

Source: Compiled from Various Empirical Studies

Firstly, the scope of Bhaduri and Durai (2007) is limited to hedging through Nifty futures only. Although Nifty futures hold good reputation in the market (in terms of trading volume), but Bhaduri and Durai did not address the issue whether an index whose all constituent stocks are not allowed to trade in the futures and options segment can provide same hedging efficiency. Secondly, Bhaduri and Durai restricted the scope of study to hedging efficiency of index portfolio, whereas it has been widely documented that index portfolio suffers from the problem of nonsynchronous trading of constituent stocks (Stoll and Whaley, 1990). Therefore, it would be rather more useful, if hedging efficiency of individual stock futures is examined. The present study is an attempt to suggest a procedure to estimate an efficient hedge ratio and to plug both limitations of Bhaduri and Durai.

Further, the study discusses the research design, including database and research methodology employed for estimating the optimum hedge ratio. Then, it discusses the hedged portfolio variance results obtained for different hedge ratios estimated from the various methodologies employed, and finally offers the conclusion.

Database and Research Methodology

Since this study aims to examine the hedging efficiency of the Indian equity futures (both in terms of index as well as individual stock portfolios), in order to secure sufficient data points,[15] the hedging efficiency of all those indices and individual stock futures has been examined, which, as on December 31, 2006 have observed at least one continued trading year history in the Futures and Options (F&O) segment of the National Stock Exchange of India. The sample period starts on January 1, 2003, i.e., the period when the F&O segment in India began observing immense success, reflected in the phenomenal growth of their trading volume. Therefore, because of insufficient liquidity, initial trading/ inception period for both index as well as individual stock futures contracts have been excluded from the sample period.

Moreover, the scope of the study has been restricted to examine whether equity futures contracts traded in India provide optimum hedging benefit. If yes, then which statistical methodology can help hedgers to compute optimal hedge ratio so that they can minimize portfolio variance to the minimum level at minimum trading as well as transaction cost to execute such strategy which would result in increased portfolio value? Therefore, in order to avoid the potential bias of information dissemination efficiency of individual stocks as well as stock futures contracts, the study includes only those individual stocks whose prices have not been adjusted due to any corporate action (such as stock splits or issue of bonus shares), because in the literature of Efficient Market Hypothesis,[16] it is an established fact that in addition to the price adjustment on record date, these corporate actions affect the portfolio value due to information leakage and other pricing anomalies

[15] For reference, *see* Nath (2003).

[16] *See* Fama (1970 and 1991) and Dimson and Mussavian (1998).

prior and post to the record date as well. As a result of the above-mentioned sample selection criterion, the sample size of the study has been restricted to three indices (i.e., Nifty, Bank Nifty and CNXIT) and 84 individual stocks.

Hedging theory requires that the trader has to take simultaneous but opposite in sign trading positions in the two markets, with the magnitude of prediction of one market (cash market) through other (futures market), which is known as the hedge ratio. Since, estimation of hedge ratio is a statistical process, which involves regressing cash market returns on futures returns, prior to undertaking any statistical procedures, it would be important to examine the time series properties of data under investigation. The very first step in any econometric investigation of a time series is to examine whether the time series under examination contains unit roots, if yes, then it should be transformed for further examination; otherwise, the statistical results would be spurious. Therefore two econometric test procedures, i.e., Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, have been undertaken to investigate whether the prices of three indices and 84 individual stocks in cash and futures markets are stationary or not.

Results in Table 2 are consistent with the findings of the literature of financial econometrics that financial time series contain unit roots; therefore, both series are transformed by taking first log difference, which has been found to be stationary. The rationale of taking first log difference, instead of first difference, can be understood from the fact that because of divergent trading interests of different traders and different perception(s) to same information, stock prices are always significantly skewed. For instance, every dip in a rising market is considered as a buying opportunity, which causes jumps in the trading volume of such stocks, and stock prices start wandering away from their intrinsic value. Taking log of the series helps researchers to avoid skewness to an extent; therefore, for further examination, first log difference of both series has been used (for detailed discussion, see Karpoff, 1987; and Moolman, 2004).

As already mentioned, both cash and futures markets are linked through arbitrage process, and the price of futures contract, determined through cost-of-carry model in the long run, is not expected to be different from spot price plus risk premium to hold positions in the cash market. Therefore, appreciating the stationary and stable long-run relationship between two markets, different models have been constructed to hedge the portfolio risk. Six econometrical procedures have been undertaken, which address various economic as well as statistical issues involved in estimating an optimal hedge ratio, and an efficient hedge ratio would be one which can help hedgers to minimize portfolio variance to minimum level.

Ederington (1979) suggested an optimum hedge ratio, which presumes a stable and strong long-run relationship between two markets and the hedging effectiveness will depend upon the coefficient of R^2; thus, the higher the R^2, the more efficient will be the hedge ratio and vice versa. Equation (1) explains the procedure suggested by Ederington (1979),

Table 2: Unit Root Test Results					
Symbols	Variables	Augmented Dickey-Fuller Test		Phillips-Perron Test	
		Without Drift	With Drift and Trend	Without Drift	With Drift and Trend
BANKNIFTY	FUTURES	–16.73*	–16.76*	–16.74*	–16.65*
	CASH	–14.19*	–14.26*	–16.24*	–16.20*
	BASIS	–6.32*	–6.34*	–10.21*	–10.22*
CNXIT	FUTURES	–30.17*	–30.34*	–30.48*	–31.03*
	CASH	–29.04*	–29.21*	–29.30*	–29.75*
	BASIS	–6.49*	–6.58*	–16.15*	–16.36*
NIFTY	FUTURES	–31.16*	–24.31*	–31.16*	–31.33*
	CASH	–23.77*	–24.01*	–28.52*	–28.72*
	BASIS	–7.76*	–8.61*	–12.25*	–13.80*
ABB	FUTURES	–18.74*	–18.94*	–18.97*	–19.05*
	CASH	–17.77*	–17.97*	–17.93*	–18.06*
	BASIS	–8.24*	–8.35*	–8.09*	–8.19*
ACC	FUTURES	–31.38*	–31.61*	–31.39*	–31.62*
	CASH	–30.82*	–31.06*	–30.82*	–31.07*
	BASIS	–10.24*	–10.78*	–10.29*	–10.82*
ALBK	FUTURES	–18.95*	–18.92*	–18.95*	–18.92*
	CASH	–18.53*	–18.49*	–18.54*	–18.50*
	BASIS	–3.34*	–3.38**	–4.02*	–4.10*
ALOKTEXT	FUTURES	–15.98*	–15.94*	–18.98*	–18.93*
	CASH	–16.16*	–16.12*	–18.30*	–18.25*
	BASIS	–5.70*	–5.80*	–7.55*	–7.72*
ANDHRABANK	FUTURES	–21.84*	–21.84*	–25.35*	–25.34*
	CASH	–21.53*	–21.53*	–24.86*	–24.85*
	BASIS	–7.31*	–9.09*	–12.46*	–13.35*
ARVINDMILLS	FUTURES	–20.34*	–20.45*	–24.89*	–24.94*
	CASH	–20.27*	–20.40*	–24.65*	–24.71*
	BASIS	–31.06*	–31.02*	–77.93*	–77.95*
ASHOKLEY	FUTURES	–15.58*	–15.66*	–18.57*	–18.62*
	CASH	–18.24*	–18.29*	–18.15*	–18.19*
	BASIS	–6.37*	–7.03*	–7.59*	–8.23*

Table 2 (Cont.)

Symbols	Variables	Augmented Dickey-Fuller Test		Phillips-Perron Test	
		Without Drift	With Drift and Trend	Without Drift	With Drift and Trend
AUROPHARMA	FUTURES	–19.65*	–19.73*	–19.66*	–19.73*
	CASH	–19.70*	–19.79*	–19.70*	–19.79*
	BASIS	–5.07*	–6.87*	–12.73*	–15.13*
BAJAJAUTO	FUTURES	–31.07*	–31.26*	–31.07*	–31.26*
	CASH	–31.29*	–31.48*	–31.29*	–31.48*
	BASIS	–6.84*	–6.92*	–13.16*	–13.26*
BANKBARODA	FUTURES	–22.19*	–22.18*	–26.05*	–26.06*
	CASH	–21.67*	–21.66*	–24.90*	–24.91*
	BASIS	–7.33*	–7.60*	–12.83*	–13.29*
BANKINDIA	FUTURES	–25.86*	–25.89*	–25.72*	–25.74*
	CASH	–25.83*	–25.86*	–25.69*	–25.71*
	BASIS	–7.82*	–9.71*	–13.78*	–14.77*
BEL	FUTURES	–28.87*	–29.01*	–28.78*	–28.93*
	CASH	–28.54*	–28.69*	–28.44*	–28.59*
	BASIS	–6.96*	–8.62*	–14.67*	–17.68*
BHEL	FUTURES	–24.97*	–25.41*	–29.68*	–30.03*
	CASH	–24.72*	–25.16*	–29.28*	–29.65*
	BASIS	–8.31*	–8.42*	–20.03*	–20.03*
BILT	FUTURES	–20.82*	–20.78*	–20.82*	–20.78*
	CASH	–16.37*	–16.35*	–20.66*	–20.63*
	BASIS	–6.47*	–7.85*	–9.78*	–11.40*
BONGAIREFN	FUTURES	–18.26*	–18.29*	–18.26*	–18.28*
	CASH	–17.71*	–17.74*	–17.71*	–17.75*
	BASIS	–5.05*	–5.08*	–5.27*	–5.31*
BPCL	FUTURES	–29.69*	–29.70*	–29.74*	–29.75*
	CASH	–30.61*	–30.63*	–30.62*	–30.66*
	BASIS	–7.12*	–7.37*	–16.25*	–16.45*
CANBANK	FUTURES	–22.24*	–22.24*	–26.75*	–26.80*
	CASH	–22.15*	–22.15*	–27.34*	–27.40*
	BASIS	–7.11*	–7.21*	–13.32*	–13.55*

Table 2 (Cont.)

Symbols	Variables	Augmented Dickey-Fuller Test		Phillips-Perron Test	
		Without Drift	With Drift and Trend	Without Drift	With Drift and Trend
CENTURYTEXT	FUTURES	–21.73*	–21.82*	–21.69*	–21.79*
	CASH	–21.47*	–21.57*	–21.44*	–21.54*
	BASIS	–3.06*	–6.08*	–6.84*	–12.04*
CESC	FUTURES	–19.21*	–19.21*	–19.21*	–19.20*
	CASH	–19.34*	–19.35*	–19.34*	–19.35*
	BASIS	–4.74*	–5.96*	–10.32*	–12.62*
CHAMBLFERT	FUTURES	–19.59*	–19.56*	–19.59*	–19.56*
	CASH	–18.96*	–18.94*	–18.97*	–18.94*
	BASIS	–4.13*	–4.13*	–4.98*	–4.99*
COLGATE	FUTURES	–20.46*	–20.52*	–20.46*	–20.53*
	CASH	–20.59*	–20.67*	–20.59*	–20.68*
	BASIS	–6.59*	–11.23*	–11.20*	–11.78*
CORPBANK	FUTURES	–17.64*	–17.59*	–17.61*	–17.56*
	CASH	–17.14*	–17.10*	–17.08*	–17.04*
	BASIS	–6.27*	–6.85*	–8.98*	–9.80*
CUMMINSIND	FUTURES	–19.76*	–19.80*	–19.76*	–19.81*
	CASH	–19.58*	–19.62*	–19.58*	–19.62*
	BASIS	–5.45*	–7.05*	–8.96*	–11.50*
DIVISLAB	FUTURES	–18.68*	–18.83*	–18.71*	–18.83*
	CASH	–18.21*	–18.36*	–18.25*	–18.37*
	BASIS	–5.56*	–8.29*	–11.27*	–15.07*
ESCORTS	FUTURES	–19.70*	–19.66*	–19.71*	–19.67*
	CASH	–19.36*	–19.32*	–19.35*	–19.31*
	BASIS	–18.69*	–19.10*	–18.69*	–19.09*
ESSAROIL	FUTURES	–20.53*	–20.49*	–20.62*	–20.59*
	CASH	–20.36*	–20.32*	–20.48*	–20.44*
	BASIS	–2.82*	–9.00*	–7.63*	–13.69*
FEDERALBANK	FUTURES	–16.78*	–16.76*	–20.21*	–20.18*
	CASH	–17.37*	–17.35*	–20.51*	–20.54*
	BASIS	–6.17*	–6.94*	–9.13*	–10.26*

Table 2 (Cont.)

Symbols	Variables	Augmented Dickey-Fuller Test		Phillips-Perron Test	
		Without Drift	With Drift and Trend	Without Drift	With Drift and Trend
GAIL	FUTURES	–22.78*	–22.79*	–28.56*	–28.57*
	CASH	–22.62*	–22.63*	–27.92*	–27.93*
	BASIS	–6.74*	–7.51*	–9.21*	–10.33*
GLAXO	FUTURES	–20.47*	–20.54*	–20.48*	–20.57*
	CASH	–16.45*	–16.56*	–20.06*	–20.16*
	BASIS	–5.98*	–5.99*	–9.80*	–9.83*
GNFC	FUTURES	–19.62*	–19.61*	–19.67*	–19.66*
	CASH	–19.63*	–19.62*	–19.67*	–19.70*
	BASIS	–4.39*	–4.97*	–5.47*	–6.43*
GRASIM	FUTURES	–30.81*	–31.09*	–30.85*	–31.09*
	CASH	–30.67*	–30.96*	–30.73*	–30.96*
	BASIS	–9.36*	–9.74*	–13.78*	–14.39*
HCLTCH	FUTURES	–32.26*	–32.31*	–32.66*	–32.99*
	CASH	–31.61*	–31.66*	–32.02*	–32.28*
	BASIS	–5.45*	–6.10*	–23.73*	–23.89*
HDFC	FUTURES	–24.58*	–24.75*	–31.90*	–32.26*
	CASH	–24.69*	–24.86*	–32.06*	–32.43*
	BASIS	–9.23*	–9.38*	–17.95*	–18.14*
HDFCBANK	FUTURES	–30.64*	–22.96*	–30.71*	–31.00*
	CASH	–23.07*	–23.26*	–31.06*	–31.44*
	BASIS	–7.88*	–8.19*	–18.06*	–18.51*
HEROHONDA	FUTURES	–30.33*	–30.39*	–30.40*	–30.55*
	CASH	–30.63*	–30.69*	–30.81*	–31.00*
	BASIS	–7.86*	–8.08*	–9.55*	–9.85*
HINDLEVER	FUTURES	–30.68*	–30.67*	–30.68*	–30.67*
	CASH	–29.54*	–29.53*	–29.52*	–29.50*
	BASIS	–7.85*	–7.88*	–10.08*	–10.11*
HINDPETRO	FUTURES	–29.48*	–29.46*	–29.46*	–29.44*
	CASH	–28.60*	–28.58*	–28.57*	–28.54*
	BASIS	–9.32*	–9.42*	–12.42*	–12.58*

Table 2 (Cont.)

Symbols	Variables	Augmented Dickey-Fuller Test		Phillips-Perron Test	
		Without Drift	With Drift and Trend	Without Drift	With Drift and Trend
ICICIBANK	FUTURES	–22.92*	–23.11*	–28.09*	–28.40*
	CASH	–22.72*	–22.90*	–27.75*	–28.06*
	BASIS	–5.65*	–7.05*	–14.67*	–15.69*
IDBI	FUTURES	–18.90*	–18.86*	–18.88*	–18.84*
	CASH	–18.70*	–18.66*	–18.68*	–18.64*
	BASIS	–3.75*	–6.32*	–7.41*	–9.55*
IDFC	FUTURES	–14.65*	–14.64*	–18.48*	–18.45*
	CASH	–14.61*	–14.60*	–18.75*	–18.71*
	BASIS	–4.85*	–4.98*	–6.10*	–6.30*
IFCI	FUTURES	–18.27*	–18.23*	–18.24*	–18.19*
	CASH	–17.93*	–17.89*	–17.85*	–17.80*
	BASIS	–2.57*	–9.34*	–6.45*	–13.97*
INDUSINDBANK	FUTURES	–18.90*	–18.86*	–18.91*	–18.86*
	CASH	–18.92*	–18.88*	–18.93*	–18.88*
	BASIS	–4.58*	–7.05*	–8.16*	–10.85*
IOB	FUTURES	–17.73*	–17.71*	–17.78*	–17.78*
	CASH	–15.53*	–15.52*	–17.93*	–17.93*
	BASIS	–6.29*	–6.65*	–7.74*	–7.83*
IOC	FUTURES	–24.42*	–20.07*	–24.38*	–24.35*
	CASH	–23.53*	–23.50*	–23.52*	–23.49*
	BASIS	–7.13*	–7.16*	–15.13*	–15.18*
IPCL	FUTURES	–25.19*	–25.25*	–33.22*	–33.32*
	CASH	–25.29*	–25.35*	–32.82*	–32.93*
	BASIS	–7.10*	–8.62*	–8.08*	–8.80*
JETAIRWAYS	FUTURES	–20.06*	–20.10*	–20.05*	–20.10*
	CASH	–19.19*	–19.23*	–19.13*	–19.21*
	BASIS	–5.87*	–6.16*	–13.36*	–13.69*
JINDALSTEL	FUTURES	–9.09*	–9.21*	–18.32*	–18.35*
	CASH	–9.03*	–9.16*	–18.12*	–18.16*
	BASIS	–4.59*	–7.51*	–10.25*	–13.50*

Table 2 (Cont.)

Symbols	Variables	Augmented Dickey-Fuller Test		Phillips-Perron Test	
		Without Drift	With Drift and Trend	Without Drift	With Drift and Trend
JPHYDRO	FUTURES	–19.25*	–19.20*	–19.22*	–19.17*
	CASH	–18.78*	–18.74*	–18.74*	–18.69*
	BASIS	–4.60*	–8.05*	–7.11*	–12.28*
JSTAINLESS	FUTURES	–21.01*	–20.97*	–21.01*	–20.97*
	CASH	–21.54*	–21.49*	–21.55*	–21.50*
	BASIS	–6.01*	–8.68*	–8.38*	–11.82*
KTKBANK	FUTURES	–20.04*	–20.04*	–20.04*	–20.04*
	CASH	–19.74*	–19.74*	–19.74*	–19.74*
	BASIS	–3.94*	–4.09*	–4.87*	–5.15*
LICHSGFIN	FUTURES	–18.65*	–18.65*	–18.61*	–18.61*
	CASH	–18.46*	–18.46*	–18.46*	–18.46*
	BASIS	–4.68*	–4.93*	–5.89*	–6.41*
MARUTI	FUTURES	–29.41*	–29.59*	–29.41*	–29.60*
	CASH	–29.31*	–29.49*	–29.31*	–29.51*
	BASIS	–8.11*	–8.58*	–16.10*	–17.05*
MATRIXLABS	FUTURES	–16.79*	–16.83*	–21.10*	–21.10*
	CASH	–16.88*	–16.94*	–21.10*	–21.15*
	BASIS	–6.12*	–6.56*	–4.77*	–5.04*
MRPL	FUTURES	–19.82*	–19.78*	–19.81*	–19.76*
	CASH	–19.74*	–19.69*	–19.74*	–19.69*
	BASIS	–3.95*	–6.22*	–5.98*	–8.63*
MTNL	FUTURES	–23.84*	–23.84*	–29.73*	–29.72*
	CASH	–23.81*	–23.80*	–30.09*	–30.08*
	BASIS	–8.84*	–9.57*	–11.33*	–12.33*
NAGARFERT	FUTURES	–17.96*	–17.92*	–17.87*	–17.82*
	CASH	–17.73*	–17.69*	–17.62*	–17.57*
	BASIS	–3.57*	–7.23*	–7.09*	–14.01*
NATIONALUM	FUTURES	–29.07*	–29.07*	–29.02*	–29.02*
	CASH	–28.17*	–28.18*	–28.09*	–28.09*
	BASIS	–5.73*	–6.77*	–11.98*	–13.95*

Table 2 (Cont.)

Symbols	Variables	Augmented Dickey-Fuller Test		Phillips-Perron Test	
		Without Drift	With Drift and Trend	Without Drift	With Drift and Trend
NDTV	FUTURES	–18.38*	–18.34*	–18.39*	–18.35*
	CASH	–18.28*	–18.24*	–18.25*	–18.21*
	BASIS	–2.88*	–9.66*	–9.54*	–15.24*
NEYVELILIG	FUTURES	–18.68*	–18.66*	–18.64*	–18.62*
	CASH	–17.80*	–17.78*	–17.71*	–17.69*
	BASIS	–5.58*	–7.44*	–10.43*	–13.43*
NICOLAPIR	FUTURES	–19.58*	–19.53*	–19.56*	–19.52*
	CASH	–19.01*	–18.97*	–18.98*	–18.93*
	BASIS	–5.21*	–5.57*	–11.29*	–11.93*
NTPC	FUTURES	–22.51*	–22.55*	–22.53*	–22.60*
	CASH	–18.19*	–18.27*	–22.25*	–22.31*
	BASIS	–4.99*	–5.90*	–9.62*	–11.05*
ORIENTBANK	FUTURES	–21.91*	–21.91*	–24.89*	–24.88*
	CASH	–22.46*	–22.46*	–24.61*	–24.60*
	BASIS	–8.81*	–9.06*	–10.77*	–11.12*
PATNI	FUTURES	–15.70*	–15.69*	–18.89*	–18.86*
	CASH	–19.63*	–19.60*	–19.60*	–19.58*
	BASIS	–8.37*	–9.84*	–13.86*	–14.48*
PNB	FUTURES	–26.68*	–26.71*	–26.61*	–26.64*
	CASH	–25.98*	–26.01*	–25.91*	–25.92*
	BASIS	–4.83*	–4.98*	–9.02*	–9.19*
POLARIS	FUTURES	–29.54*	–29.52*	–29.50*	–29.49*
	CASH	–29.04*	–29.03*	–28.99*	–28.97*
	BASIS	–5.21*	–7.92*	–8.95*	–14.77*
REL	FUTURES	–22.08*	–22.07*	–28.34*	–28.33*
	CASH	–21.52*	–21.51*	–27.60*	–27.57*
	BASIS	–4.45*	–4.48*	–10.55*	–10.60*
RELCAPITAL	FUTURES	–19.62*	–19.74*	–19.70*	–19.77*
	CASH	–19.29*	–19.41*	–19.37*	–19.43*
	BASIS	–3.18*	–7.54*	–6.62*	–11.88*

Table 2 (Cont.)

Symbols	Variables	Augmented Dickey-Fuller Test		Phillips-Perron Test	
		Without Drift	With Drift and Trend	Without Drift	With Drift and Trend
RELIANCE	FUTURES	–31.77*	–31.90*	–31.78*	–31.90*
	CASH	–32.65*	–32.78*	–32.64*	–32.80*
	BASIS	–6.55*	–8.79*	–14.54*	–17.05*
SBIN	FUTURES	–30.31*	–30.40*	–30.28*	–30.39*
	CASH	–23.64*	–23.78*	–29.70*	–29.81*
	BASIS	–6.58*	–7.88*	–9.22*	–11.73*
SCI	FUTURES	–28.86*	–28.87*	–28.79*	–28.80*
	CASH	–29.40*	–29.41*	–29.36*	–29.37*
	BASIS	–8.63*	–9.20*	–12.44*	–13.13*
SRF	FUTURES	–18.56*	–18.67*	–18.64*	–18.71*
	CASH	–18.37*	–18.49*	–18.45*	–18.52*
	BASIS	–4.81*	–6.51*	–6.58*	–9.41*
STAR	FUTURES	–20.08*	–20.04*	–20.10*	–20.07*
	CASH	–18.68*	–18.65*	–18.63*	–18.60*
	BASIS	–4.57*	–5.10*	–12.44*	–13.06*
SUNPHARMA	FUTURES	–20.97*	–21.11*	–20.97*	–21.16*
	CASH	–20.57*	–20.70*	–20.58*	–20.78*
	BASIS	–3.11*	–10.56*	–7.54*	–10.57*
SYNDIBANK	FUTURES	–20.70*	–20.72*	–24.29*	–24.29*
	CASH	–20.71*	–20.73*	–24.55*	–24.56*
	BASIS	–6.07*	–6.20*	–9.50*	–9.77*
TATACHEM	FUTURES	–21.80*	–21.85*	–21.80*	–21.88*
	CASH	–21.16*	–21.24*	–21.15*	–21.24*
	BASIS	–2.58*	–2.58	–5.45*	–5.49*
TATAMOTORS	FUTURES	–31.41*	–31.55*	–31.44*	–31.65*
	CASH	–24.07*	–24.27*	–30.73*	–30.90*
	BASIS	–6.18*	–6.33*	–14.80*	–15.44*
TATAPOWER	FUTURES	–24.69*	–24.87*	–30.26*	–30.39*
	CASH	–24.57*	–24.76*	–29.52*	–29.65*
	BASIS	–7.25*	–7.75*	–11.54*	–12.38*

Table 2 (Cont.)

Symbols	Variables	Augmented Dickey-Fuller Test		Phillips-Perron Test	
		Without Drift	With Drift and Trend	Without Drift	With Drift and Trend
TATATEA	FUTURES	–28.31*	–28.43*	–28.19*	–28.27*
	CASH	–28.08*	–28.22*	–27.96*	–28.04*
	BASIS	–7.01*	–7.58*	–10.77*	–11.95*
TITAN	FUTURES	–18.14*	–18.27*	–18.15*	–18.24*
	CASH	–18.00*	–18.13*	–18.01*	–18.09*
	BASIS	–4.24*	–7.62*	–6.50*	–10.19*
TVSMOTORS	FUTURES	–18.92*	–18.96*	–18.90*	–18.92*
	CASH	–18.44*	–18.48*	–18.39*	–18.42*
	BASIS	–4.99*	–5.67*	–9.06*	–10.49*
UNIONBANK	FUTURES	–25.56*	–20.94*	–25.38*	–25.39*
	CASH	–21.29*	–21.32*	–25.69*	–25.71*
	BASIS	–7.87*	–8.22*	–12.00*	–12.50*
UTIBANK	FUTURES	–19.68*	–19.74*	–19.69*	–19.72*
	CASH	–20.04*	–20.08*	–20.04*	–20.11*
	BASIS	–8.45*	–8.79*	–13.21*	–13.68*
VIJAYABANK	FUTURES	–19.21*	–19.17*	–19.21*	–19.17*
	CASH	–19.35*	–19.31*	–19.38*	–19.34*
	BASIS	–5.13*	–8.30*	–9.62*	–12.64*
WOCKPHARMA	FUTURES	–18.52*	–18.56*	–18.48*	–18.50*
	CASH	–17.76*	–17.80*	–17.66*	–17.68*
	BASIS	–4.81*	–6.06*	–9.30*	–12.21*

which will work efficiently when futures market returns are unbiased predictor of prospective cash market returns. In Equation (1), $R_{s,t}$ is cash market returns, $R_{f,t}$ is futures market returns, α_0 is the intercept term and ε_t is the error term. As already mentioned, the futures contract price, as per the cost-of-carry model, is assumed to be the unbiased predictor of prospective cash market price; therefore, the intercept and error term should not be significantly different from zero, and consequently the R^2 will improve, and hence the hedging effectiveness.

$$R_{s,t} = \alpha_0 + \beta_1 R_{f,t} + \varepsilon_t \quad \text{...(1)}$$

Equation (1), though, may be economically justifiable; but until the statistical properties of the estimation procedure are satisfied, the estimated value of β_1 would not be reliable. In addition to containing unit root, another feature of financial time series is that they are autocorrelated, which implies that successive returns of one speculative asset are significantly predictable. Significantly, autocorrelated cash and futures market returns suggest that successive stock and/or futures returns are not random, rather due to mean reversion, volatility clustering, information asymmetry or inefficient microstructure system[17] are functions of previous information set(s). Therefore, if stock returns are autocorrelated, then avoidance of it may bias the estimated hedge ratio. Hence, Equation (1) modified to Equation (2) (to include the autoregressive terms[18] of cash market returns) may provide better results, and hence an improved R^2, which otherwise could have been biased on account of significant serial correlation. In Equation (2), $R_{s,t}$ is cash market returns, $R_{f,t}$ is (are) futures market returns, $R_{s,t-i}$ is autoregressive term(s) whose order varies between i to p determined as per Schwarz Information Criterion, α_0 is the intercept term, and ε_t is the error term.

$$R_{s,t} = \alpha_0 + \sum_{i=1}^{p} \alpha_i R_{s,t-i} + \beta_1 R_{f,t} + \varepsilon_t \qquad \text{...(2)}$$

Although inclusion of autoregressive terms of cash market returns, as shown in Equation (2), may improve the statistical output, yet on theoretical grounds, Equation (2) requires two more variables, which are lagged futures returns and joint dynamics of both markets (i.e., basis). Unbiased prediction of prospective cash market price is a strong theoretical property of futures contract; therefore, until the lagged futures contract returns are included in the model, an efficient hedge ratio cannot be estimated. In addition, Fama and French (1987)[19] appreciated the function of basis as an error correction term, which corrects the deviation of current cash market price from its equilibrium price (i.e., forward price assuming futures markets are efficient price discovery vehicles). Therefore, Equation (4) improves upon Equation (2) by including the lagged futures returns and basis. First lag of futures returns has been included in Equation (4), because the current study employs daily data,

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17 For detailed discussion, *see* Fama (1970 and 1991) and Dimson and Mussavian (1998).

18 Order of autoregression has been determined on the basis of Schwarz criterion. The Schwarz criterion uses a function of the residual sum of squares together with a large number of parameters. Specifically, the Schwarz information criterion minimizes the expression: T * log (RSS) + K * (log T), where T is the number of observations, RSS is the sum of the squared residuals, and K is the number of regressors. Lagged terms provide an explanation of the short-run deviations from the long-run equilibrium for the two test equations.

19 Fama and French (1987) stated that if mispricing is governed only by market factors then actual basis (i.e., $F_t - S_t$) should predict the theoretical basis (i.e., $S_{t,T} - S_t$) and if β is positive and significant in Equation (3), it implies that the variance of actual basis results in correcting the spot price deviation from its equilibrium.

$$S_{t,T} - S_t = \alpha + \beta\,(F_t - S_t) + \mu_{t,T} \qquad \text{...(3)}$$

where,

$S_{t,T}$ = Theoretical futures price of the underlying asset at time t with maturity date T

S_t = Current market price of the underlying asset

α = Constant term

F_t = Current futures price

$\mu_{t,T}$ = Random error term

whereas arbitrage opportunities in a highly liquid market like India[20] are not expected to persist for a longer duration. Therefore, first lag of both variables may be sufficient to capture arbitrage opportunities between two markets. In Equation (4), in addition to the variables defined in Equation (2), $R_{f,\,t-1}$ represents the lagged futures returns, and $(R_{f,\,t} - R_{s,\,t})$ symbolizes basis at time t.

$$R_{s,t} = \alpha_0 + \sum_{i=1}^{p} \alpha_i R_{s,t-i} + \beta_1 R_{f,t} + \beta_2 R_{f,t-1} + \beta_3 \left(R_{f,t} - R_{s,t}\right) + \varepsilon_t \qquad ...(4)$$

Estimated value of β_1 will be the hedge ratio, which will guide the hedgers to decide upon the optimum amount of positions in futures market in order to hedge the current cash market holdings. In the presence of efficient trading system, strong and stable long-run relationship between the two markets will help the hedge ratio to be equal to or less than one (providing partial hedging), assuming that the hedger is a loss averter not a risk averter. The estimation procedure, as laid down in Equation (4), may be economically justifiable, because Kamara and Siegel (1987), Myers (1991) and Holmes (1995) suggested that as traders lack perfect foresight with respect to cash and futures price relationship and the hedge ratio varies with time-to-expiry,[21] the hedge ratio estimated in *ex ante* setting[22] may be more efficient than the hedge ratio estimated in *ex post* setting.

The literature on financial econometrics has further observed that stock returns suffer from the problem of volatility clustering, which implies that an information set continues to affect the stock return volatility for a few days in future. In other words, volatility clustering implies that large price changes will be followed by large price changes, and small price changes will be followed by small price changes.

In Equation (4), if the variance of error term is constant,[23] the hedge ratio estimation through OLS method will be valid; however, a vast amount of academic literature has evidenced that stock returns are heteroscedastic in nature. Therefore, Autoregressive Conditional Heteroscedasticity (ARCH) model may be a better procedure to obtain robust statistical estimations. In the ARCH model (first introduced by Engle, 1982), the mean equation is specified in the baseline scenario by an AR(p) process, and other endogenous variables such as in Equation (4) and the conditional variance will be regressed on constant (ω) and lagged values of squared error terms (ε^2_{t-p}), as shown in Equation (5),

[20] *See* Monthly Derivatives Market Updates published by National Stock Exchange of India (www.nseindia.com).

[21] *See* Kroner and Sultan (1993), Park and Switzer (1995), Lien and Tse (1998), Harris and Shen (2003), Poomimars *et al.* (2003), Floros and Vougas (2004), Pattarin and Ferretti (2004), Yang and Allen (2004), Kofman and McGlenchy (2005), Floros and Vougas (2006), Hatemi and Roca (2006), Bhaduri and Durai (2007), and Lee and Yoder (2007).

[22] In *ex ante* setting, historical returns contain significant information for the prospective price movements in the market (Holmes, 1995).

[23] Lagrange Multiplier test's null hypothesis states that variance of error term is homoscedastic. Therefore, rejection of null hypothesis will require the researcher to apply appropriate models of GARCH family.

$$h_t = \omega + \alpha_1\varepsilon^2_{t-1} + \alpha_2\varepsilon^2_{t-2} + \ldots\ldots\ldots + \alpha_p\varepsilon^2_{t-p} \qquad ...(5)$$

This ARCH model was generalized by Bollerslev (1986), and it resulted in Generalized ARCH class of models called GARCH (*p*, *q*) in which conditional variance depends not only on the squared residuals of the mean equation, but also on its own past values. The GARCH (*p*, *q*) model is given by Equation (6):

$$h_t = \omega + \sum_{i=1}^{p} \alpha_i \varepsilon^2_{t-i} + \sum_{j=1}^{q} \beta_j h_{t-j} + \upsilon_t \qquad ...(6)$$

where h_t is the conditional volatility, α_i is the coefficient of the ARCH term with order *i* to *p*, and β_j is the coefficient of the GARCH term with order *j* to *q*. The conditional volatility, as defined in Equation (6), is determined by three effects, namely, the intercept term given by ω, the ARCH term expressed by $\alpha_i\varepsilon^2_{t-i}$ and the forecasted volatility from the previous period called GARCH component expressed by $\beta_j h_{t-j}$. The parameters ω and α should be greater than 0 and β_j should be positive in order to ensure that conditional variance (h_t) is non-negative. Besides this, it is necessary that $\alpha_i + \beta_j \leq 1$, which secures covariance stationarity of conditional variance. A straightforward interpretation of the estimated coefficients in Equation (6) is that the constant term is the long-term average volatility, whereas, α_i and β_j represent how volatility is affected by current and past information set(s) respectively. Moreover, the magnitude of parameters α_i and β_j determines the short-run dynamics of resulting time series volatility. Large β_j shows that shocks to the conditional variance take a long time to die out, thus volatility may persist for longer time periods. Large GARCH error coefficient indicates that volatility reacts quite intensely to market movements. Therefore, if variance of error term in Equation (4) is not constant, Equation (6) would be attached to Equation (4), hence the estimation of hedge ratio (β_1) would be subject to the nature of stock/index return's volatility.

Furthermore, Nelson (1991), by taking into account the asymmetric relationship between conditional volatility and conditional mean, proposed an Exponential GARCH (EGARCH) model, which is based upon the logarithmic expression of conditional volatility in cash and futures market returns. Therefore, if the stock returns are asymmetric and the interaction between old and new information observes leverage effect, EGARCH model (i.e., Equation 7) may help to estimate an improved hedge ratio as compared to that estimated through GARCH process in Equation (6).

$$h_t = \gamma_1 + \gamma_2 \left| \frac{\varepsilon_{t-1}}{h_{t-1}} \right| + \gamma_3 \frac{\varepsilon_{t-1}}{h_{t-1}} + \gamma_4 h_{t-1} \qquad ...(7)$$

Equation (7) reports the leverage relationship between old and new information, but in the speculative markets, besides the leverage effect, it has been observed that traders react heterogeneously to positive and negative news. For instance, Karpoff (1987), in a survey on relationship between information arrival (trading volume as proxy for information arrival) and behavior of stock market volatility, has reported that volatility in the declining market is always higher than in the rising market. Therefore, it would be more appropriate (if conditional volatility behaves differently to positive and negative news) to segregate the impact of both positive and negative news, which can be done by specifying the variance equation in Threshold ARCH (TARCH) framework and then estimate the optimal hedge ratio in the mean equation.

Equation (8) lays down the variance equation of TARCH model, where Equation (6) is modified to include $\varepsilon^2_{t-i}\xi_{t-i}$, which is a dummy for negative news having value one, if there is negative news and zero otherwise. Therefore, an appropriate GARCH methodology would be able to capture the stylized behavior of conditional volatility of cash market returns, hence the estimated hedge ratio will be statistically robust.

$$h_t = \omega + \sum_{i=1}^{p} \alpha_i \varepsilon^2_{t-i} + \sum_{i=1}^{p} \alpha_k \varepsilon^2_{t-i} \xi_{t-i} + \sum_{j=1}^{q} \beta_j h_{t-j} + \upsilon_t \quad \text{...(8)}$$

where,

$\xi_{t-i} = 1$, if $\varepsilon_{t-i} < 0$

$\xi_{t-i} = 0$, if $\varepsilon_{t-i} > 0$

Equation (4) estimated through OLS, GARCH, EGARCH or TARCH procedures may provide better estimate of the hedge ratio, but optimality of hedge ratio will still be doubtful because both markets observe significant lead-lag relationship in terms of volatility spillover and information dissemination. Therefore, estimating an optimal hedge ratio by regressing only the cash market returns on lagged returns of both futures and cash market may be biased because the other way round is also true as volatility spillover is bidirectional and continuous (Wahab and Lashgari, 1993; Chan and Lien, 2001; Chen *et al.*, 2002; Lin *et al.*, 2002 and 2003; Lien *et al.*, 2003; Mukherjee and Mishra, 2006; and Thomas, 2006).

Therefore, in the present case, either Vector Autoregression (VAR) model (when returns of both markets under consideration are significantly auto- and cross-correlated) or Vector Error Correction Model (VECM) (when both markets are cointegrated) may provide efficient speculative forecasts and robust hedge ratio may be estimated. VAR model simultaneously regresses the lagged returns of both variables, whereas VECM, in addition to lagged returns, also considers the error correction term (if both series are cointegrated). Hence, both methodologies estimate an optimal hedge ratio by considering theoretical relationship between the two markets (i.e., lead-lag in the short run and cointegration in the long run), which confirms the volatility spillover between the two markets through arbitrage process. Equations (9) and (10) specify the estimation process of VAR methodology and Equations (11) and (12) present the estimation procedure of VECM. In this study, the hedge ratio, on the basis of VAR and VECM, has been computed as $\sigma_{s,f}/\sigma^2_f$ where $\sigma_{s,f} = \text{cov}(\varepsilon_{f,t}, \varepsilon_{s,t})$ and $\sigma^2_f = \text{var}(\varepsilon_{f,t})$.

$$R_{s,t} = \sum_{i=1}^{M} \alpha_i R_{s,t-i} + \sum_{j=1}^{N} \beta_j R_{f,t-j} + \varepsilon_{st} \quad \text{...(9)}$$

$$R_{f,t} = \sum_{k=1}^{O} \alpha_k R_{s,t-k} + \sum_{l=1}^{P} \beta_l R_{f,t-l} + \varepsilon_{ft} \quad \text{...(10)}$$

$$R_{f,t} = \alpha_{0f} + \sum_{i=1}^{p} \alpha_{if} \left(F_{t-i} - S_{t-i}\right) + \sum_{j=1}^{q} \beta_f R_{f,t-j} + \sum_{k=1}^{m} \beta_f R_{s,t-k} + \varepsilon_{ft} \quad \text{...(11)}$$

$$R_{s,t} = \alpha_{0s} + \sum_{i=1}^{p} \alpha_{is} \left(F_{t-i} - S_{t-i}\right) + \sum_{l=1}^{n} \beta_s R_{s,t-l} + \sum_{h=1}^{o} \beta_s R_{f,t-h} + \varepsilon_{st} \quad \text{...(12)}$$

In a nutshell, the present study estimates optimal hedge ratio in different statistical and economic theory frameworks, and hence aims to propose efficient hedge ratio estimation methodology, which is statistically as well as theoretically robust. After estimating the optimal hedge ratio through the above-discussed six statistical procedures (i.e., OLS, GARCH, EGARCH, TARCH, VAR and VECM), the hedging effectiveness of all hedge ratios will be compared and the optimal hedge ratio, which reduces the portfolio variance to minimum level, would be proposed as the efficient hedge ratio. The efficiency of optimal hedge ratio will be measured as percentage decline in portfolio variance, as shown in Equation (13), where Var (*U*) and Var (*H*) represent variance of unhedged and hedged portfolios, respectively. σ_s and σ_f are standard deviations of the cash and futures returns respectively, $\sigma_{s,f}$ represents the covariability of the cash and futures returns, and h^* is the optimal hedge ratio.

$$\frac{\mathrm{Var}(U) - \mathrm{Var}(H)}{\mathrm{Var}(U)} \quad \text{...(13)}$$

$$\mathrm{Var}(U) = \sigma_s^2 \quad \text{...(14)}$$

$$\mathrm{Var}(H) = \sigma_s^2 + h^{*2}\sigma_f^2 - 2h^* \sigma_{s,f} \quad \text{...(15)}$$

Analysis and Discussion

Before discussing the optimal hedge ratio estimation results obtained from the various econometric procedures and comparing their efficiency in reducing the portfolio risk, it is important to discuss the time series properties of the series under examination. The results presented in Table 3 indicate important information relating to the summary statistics of futures and cash markets and joint comovement in the two markets (i.e., basis). Table 3 shows that returns of both futures and cash markets are significantly skewed (negatively skewed in most of the cases) and their coefficients of kurtosis are significantly different from three, which implies that futures and cash market returns do not conform to normal distribution. The null hypothesis that futures and cash market returns follow normal distribution is further tested through Jarque-Bera test. The coefficient of Jarque-Bera test is statistically significant, which rejects the null hypothesis for all indices as well as individual stock futures and cash market returns. Finding asymmetric returns in futures and cash markets is not a new observation and summary statistics in the current study are consistent with the findings of Kendall and Hill (1953), Fama (1965), Stevenson and Bear (1970), Chen (1996), Reddy (1997), and Kamath *et al.* (1998).

Rejection of the null hypothesis that returns of speculative assets do not follow normal distribution suggests that information dissemination process in these markets may not be efficient and returns are not symmetrically distributed among buyers and sellers.

Table 3: Descriptive Statistics

Symbols	Variables	Count	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
BANKNIFTY	FUTURES	385	0.001335	0.018441	–0.402322	4.926330	69.73120*
	CASH	385	0.001303	0.017815	–0.342960	4.806104	59.71997*
	BASIS	385	0.000145	0.004792	–1.331375	7.626209	455.87280*
CNXIT	FUTURES	833	0.001543	0.018978	–0.453098	16.481910	6,337.15900*
	CASH	833	0.001540	0.018263	–0.150685	10.599000	2,007.37800*
	BASIS	833	9.52E–05	0.004863	–0.971186	10.698060	2,187.76700*
NIFTY	FUTURES	998	0.001283	0.016032	–1.335249	16.589760	7,976.22900*
	CASH	998	0.001285	0.014715	–1.118830	12.022160	3,593.07000*
	BASIS	998	–0.001852	0.004742	–1.336837	7.776468	1,245.96900*
ABB	FUTURES	417	0.002772	0.022791	–0.339925	7.085139	297.9909*
	CASH	417	0.002768	0.021458	–0.280058	5.979046	159.64920*
	BASIS	417	0.003975	0.038626	–0.995076	10.685340	1,095.06200*
ACC	FUTURES	998	0.002074	0.022250	–0.250975	6.084294	397.91660*
	CASH	998	0.001858	0.021621	–0.183568	5.662628	294.39330*
	BASIS	998	0.012291	0.046800	–0.793499	9.895391	2,040.14800*
ALBK	FUTURES	423	0.000294	0.021564	–0.223252	4.700786	54.36834*
	CASH	423	0.000232	0.021425	–0.405819	5.169430	94.33782*
	BASIS	423	0.001232	0.014579	–3.247397	13.339290	2,621.38200*
ALOKTEXT	FUTURES	395	0.000134	0.026311	0.065873	5.190530	79.25971*
	CASH	395	0.000137	0.026282	0.017793	5.279955	85.57444*
	BASIS	395	0.001771	0.010369	–2.754389	15.911630	3,243.22800*

Table 3 (Cont.)

Symbols	Variables	Count	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
ANDHRABANK	FUTURES	833	0.000810	0.029950	–0.338393	8.411993	1,032.49300*
	CASH	833	0.000827	0.029366	–0.283542	8.193922	947.48250*
	BASIS	833	0.002679	0.007080	–1.767211	8.270047	1,397.54900*
ARVINDMILLS	FUTURES	813	0.000146	0.030516	–0.279557	5.144003	166.30440*
	CASH	813	0.000154	0.029736	–0.298970	5.452913	215.93000*
	BASIS	813	0.004382	0.004635	–0.294555	5.244214	182.36760*
ASHOKLEY	FUTURES	422	0.001817	0.025420	–0.181066	5.608429	121.94110*
	CASH	422	0.001824	0.025064	–0.127605	5.270487	91.78925*
	BASIS	422	0.003194	0.008299	–3.217242	15.924400	3,665.11600*
AUROPHARMA	FUTURES	406	0.002081	0.025001	0.479721	4.715901	65.38025*
	CASH	406	0.002089	0.024749	0.678356	6.310551	216.54030*
	BASIS	406	0.004288	0.006542	–2.809096	27.341150	10,556.94000*
BAJAJAUTO	FUTURES	998	0.001639	0.019676	–0.104925	6.148982	414.17510*
	CASH	998	0.001642	0.019678	–0.040934	5.004078	167.29100*
	BASIS	998	–0.001049	0.008782	–1.911327	8.652267	1,936.15400*
BANKBARODA	FUTURES	833	0.000597	0.033301	–0.823895	17.862070	7,760.65700*
	CASH	833	0.000612	0.031868	–0.490668	11.580420	2,588.77900*
	BASIS	833	0.001931	0.008273	–2.815133	18.320020	9,246.40300*
BANKINDIA	FUTURES	833	0.001596	0.034389	–0.166660	6.004010	317.06680*
	CASH	833	0.001621	0.034037	–0.074083	5.676542	249.40810*
	BASIS	833	0.002404	0.006736	–1.585889	8.524413	1,408.44000*
BEL	FUTURES	976	0.001947	0.025039	0.060880	7.305953	754.61290*
	CASH	976	0.001950	0.024119	0.138879	7.309824	758.50370*
	BASIS	976	0.003505	0.005707	–0.755653	5.499208	346.89020*
BHEL	FUTURES	998	0.002589	0.024581	–1.186682	23.851820	18,314.60000*
	CASH	998	0.002591	0.024130	–0.620137	14.831310	5,884.79300*
	BASIS	998	–0.000248	0.006504	–1.562464	11.291070	3,264.58400*
BILT	FUTURES	406	–2.81E–05	0.025048	–0.579796	8.185470	477.62100*
	CASH	406	–3.29E–50	0.024139	–0.678891	8.284907	503.67370*
	BASIS	406	0.003183	0.005823	–1.154101	6.462803	292.97640*
BONGAIREFN	FUTURES	406	–0.001709	0.025518	–0.442867	8.706698	564.18650*
	CASH	406	–0.001716	0.024594	–0.564479	9.040376	638.78510*
	BASIS	406	0.001834	0.014850	–3.319707	13.764680	2,705.99200*

Table 3 (Cont.)

Symbols	Variables	Count	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
BPCL	FUTURES	998	0.000383	0.024143	–0.185078	6.791118	603.35710*
	CASH	998	0.000410	0.023929	0.084930	5.798982	326.97260*
	BASIS	998	–0.001918	0.010126	–3.209833	26.264180	24,219.55000*
CANBANK	FUTURES	833	0.000936	0.030764	–0.250610	6.433211	417.82440*
	CASH	833	0.000957	0.030920	–0.065459	6.402834	402.49230*
	BASIS	833	0.001075	0.008502	–2.692085	15.376310	6,322.55200*
CENTURYTEXT	FUTURES	422	0.002684	0.035582	–0.369469	6.724674	253.53810*
	CASH	422	0.002677	0.034392	–0.396010	6.884538	276.35600*
	BASIS	422	0.004385	0.004284	–0.641326	5.113970	107.50560*
CESC	FUTURES	406	0.001330	0.027587	–0.869823	9.273369	716.95420*
	CASH	406	0.001326	0.027025	–1.006838	10.940870	1,135.31700*
	BASIS	406	0.003612	0.005945	–1.289694	6.360096	303.54400*
CHAMBLFERT	FUTURES	406	0.000521	0.024639	–0.390165	6.468803	213.85220*
	CASH	406	0.000525	0.023743	–0.586453	6.953154	287.63630*
	BASIS	406	0.000951	0.014609	–2.478882	8.652594	956.32000*
COLGATE	FUTURES	422	0.001556	0.024736	0.873068	11.77748	1,408.30300*
	CASH	422	0.001528	0.023366	1.124075	12.49708	1,674.79100*
	BASIS	422	0.002442	0.006500	–2.458244	14.08489	2,585.56800*
CORPBANK	FUTURES	385	–9.56E–05	0.029089	–0.310687	8.409757	475.66060*
	CASH	385	–9.44E–05	0.028359	–0.231358	7.591893	341.68090*
	BASIS	385	0.002224	0.007254	–0.899296	4.416888	85.01406*
CUMMINSIND	FUTURES	380	0.001888	0.029101	0.340740	5.301170	91.196840*
	CASH	380	0.001888	0.027654	0.349189	5.177467	82.79397*
	BASIS	380	0.003775	0.005524	–0.891310	6.370101	230.14250*
DIVISLAB	FUTURES	406	0.002855	0.027671	–0.156406	6.595236	220.31540*
	CASH	406	0.002849	0.026382	–0.243415	7.151616	295.58360*
	BASIS	406	0.005037	0.006216	1.429376	26.811890	9,730.10600*
ESCORTS	FUTURES	395	0.000763	0.038772	–0.039455	4.863097	57.23151*
	CASH	395	0.000773	0.037868	0.051479	5.058868	69.94029*
	BASIS	395	0.006151	0.038586	–0.134932	5.234083	83.34425*
ESSAROIL	FUTURES	406	0.001044	0.041188	0.138441	7.144109	291.81760*
	CASH	406	0.001034	0.040439	0.167222	7.628565	364.30840*
	BASIS	406	0.005228	0.004320	–0.135010	3.921563	15.60036*

Table 3 (Cont.)

Symbols	Variables	Count	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
FEDERALBANK	FUTURES	406	0.000814	0.027951	–0.343400	7.535135	355.9122*
	CASH	406	0.000790	0.027611	–0.271982	8.000690	428.0390*
	BASIS	406	0.002999	0.007755	–2.182783	11.188240	1,456.6170*
GAIL	FUTURES	813	0.000730	0.029285	–0.076069	29.402120	23,614.1000*
	CASH	813	0.000787	0.028511	–0.096079	24.975980	16,360.9700*
	BASIS	813	–0.001980	0.010168	–1.724453	7.245408	1,013.4870*
GLAXO	FUTURES	422	0.001218	0.023397	–0.068218	6.968143	277.1973*
	CASH	422	0.001169	0.021536	–0.144371	5.917356	151.1171*
	BASIS	422	0.000309	0.008384	–1.374097	5.874785	278.1149*
GNFC	FUTURES	406	0.000642	0.029120	–0.021057	7.329326	317.1002*
	CASH	406	0.000638	0.028522	0.015836	7.404770	328.2341*
	BASIS	406	0.003714	0.008721	–3.572083	18.469840	4,911.8420*
GRASIM	FUTURES	998	0.002180	0.022067	0.279324	7.077563	704.3638*
	CASH	998	0.002198	0.021803	0.359303	7.023161	694.5339*
	BASIS	998	0.001351	0.005973	–0.736194	4.074133	138.1268*
HCLTCH	FUTURES	976	0.001387	0.027283	–0.396541	9.931323	1,979.3370*
	CASH	976	0.001409	0.026749	–0.516477	8.857187	1,438.5280*
	BASIS	976	–0.000405	0.007440	–4.659567	62.555080	1,47,768.5700*
HDFC	FUTURES	998	0.001524	0.021535	0.457972	10.871270	2,611.2630*
	CASH	998	0.001522	0.021993	0.325851	6.623006	563.4911*
	BASIS	998	–0.001091	0.006983	–1.932181	9.850296	2,572.3380*
HDFCBANK	FUTURES	833	0.001627	0.021293	–0.900584	33.229900	31,830.7100*
	CASH	833	0.001626	0.021872	0.163143	31.954910	29,102.7000*
	BASIS	833	–0.001394	0.007019	–1.926467	16.239570	6,599.1420*
HEROHONDA	FUTURES	976	0.001120	0.021874	–0.037283	4.855592	140.2505*
	CASH	976	0.001124	0.022953	–0.059975	4.401217	80.43041*
	BASIS	976	–0.002607	0.011626	–2.880215	14.441400	6,672.9180*
HINDLEVER	FUTURES	998	0.000174	0.020556	–0.411778	8.205080	1,154.8150*
	CASH	998	0.000175	0.020382	–0.300527	7.919760	1,021.5070*
	BASIS	998	–0.000350	0.009383	–3.797757	22.523230	18,248.7700*
HINDPETRO	FUTURES	998	–9.67E–05	0.024773	–0.247158	7.106269	711.3159*
	CASH	998	–9.14E–05	0.023750	–0.291095	6.565608	542.7666*
	BASIS	998	0.001062	0.009080	–3.424464	19.646240	13,473.2100*

Table 3 (Cont.)

Symbols	Variables	Count	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
ICICIBANK	FUTURES	976	0.001825	0.022797	–0.003587	6.651226	542.14770*
	CASH	976	0.001827	0.022909	0.125677	5.805752	322.70720*
	BASIS	976	–0.002242	0.010131	–1.508705	5.872128	705.72460*
IDBI	FUTURES	422	–0.000251	0.030504	–0.000706	6.125992	171.82130*
	CASH	422	–0.000242	0.029766	0.018229	6.363526	198.94910*
	BASIS	422	0.003765	0.005785	–2.061354	11.109350	1,455.16500*
IDFC	FUTURES	341	0.000337	0.025504	0.519285	6.892131	230.56300*
	CASH	341	0.000335	0.025223	0.578860	6.718258	215.48020*
	BASIS	341	0.001789	0.008195	–2.317441	10.577660	1,121.08200*
IFCI	FUTURES	395	–0.000170	0.040209	0.206555	6.082381	159.18060*
	CASH	395	–0.000182	0.038698	0.139327	6.106062	160.06170*
	BASIS	395	0.008117	0.005607	–0.311999	3.920426	20.35169*
INDUSIND-BANK	FUTURES	406	–0.000437	0.037144	–0.301624	7.088246	288.89710*
	CASH	406	–0.000453	0.036060	–0.237605	7.189613	300.75600*
	BASIS	406	0.004320	0.005991	–1.431988	6.732466	374.42770*
IOB	FUTURES	422	0.001046	0.029337	–0.206758	5.348146	99.95746*
	CASH	422	0.001059	0.028689	0.039968	5.312882	94.17304*
	BASIS	422	0.002506	0.009047	–2.329941	11.059530	1,523.95500*
IOC	FUTURES	813	0.000257	0.026377	–0.741857	14.018380	4,187.15800*
	CASH	813	0.000267	0.025008	–0.300557	9.565449	1,472.42600*
	BASIS	813	0.000806	0.008691	–3.783534	30.405570	27,382.03000*
IPCL	FUTURES	976	0.001188	0.028615	–0.348666	21.740130	14,301.60000*
	CASH	976	0.001196	0.027993	–0.264025	20.899990	13,041.33000*
	BASIS	976	0.003118	0.008364	–4.065384	29.140240	30,476.48000*
JETAIRWAYS	FUTURES	447	–0.001671	0.024585	–0.966197	11.332460	1,362.68000*
	CASH	447	–0.001673	0.023963	–0.292208	8.809893	635.04540*
	BASIS	447	–0.000706	0.007656	–1.420026	6.720142	407.98710*
JINDALSTEL	FUTURES	422	0.001886	0.027820	–1.290973	13.932830	2,218.89900*
	CASH	422	0.001911	0.027083	–1.226843	12.896870	1,828.11300*
	BASIS	422	0.004215	0.005885	0.293948	6.778386	257.10040*
JPHYDRO	FUTURES	424	–0.000108	0.025078	–0.222276	7.423126	349.12290*
	CASH	424	–0.000116	0.024048	–0.414247	7.518913	372.89000*
	BASIS	424	0.005721	0.005045	–0.267651	5.494220	114.96900*

Table 3 (Cont.)

Symbols	Variables	Count	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
JSTAINLESS	FUTURES	406	0.000387	0.035912	0.308638	8.646619	545.82200*
	CASH	406	0.000410	0.035034	0.373328	9.414194	705.41450*
	BASIS	406	0.004630	0.005711	–1.290295	7.801603	502.67600*
KTKBANK	FUTURES	395	0.001534	0.032399	0.742804	8.116029	467.10040*
	CASH	395	0.001539	0.031147	0.760213	7.596209	385.73110*
	BASIS	395	0.002609	0.010235	–2.662576	10.474270	1,386.15300*
LICHSGFIN	FUTURES	422	–0.000959	0.022164	–0.353068	6.924634	279.59930*
	CASH	422	–0.001005	0.021463	–0.366455	6.390991	211.63260*
	BASIS	422	0.002956	0.009162	–2.581933	11.744530	1,813.41000*
MARUTI	FUTURES	869	0.001992	0.025530	0.143740	5.475066	224.80300*
	CASH	869	0.001994	0.025618	0.219604	5.094221	165.78590*
	BASIS	869	0.000990	0.005719	–0.766788	5.023050	233.34790*
MATRIXLABS	FUTURES	422	0.000493	0.028562	0.516713	9.585583	781.36600*
	CASH	422	0.000486	0.027217	0.954753	10.804310	1,135.06500*
	BASIS	422	0.000521	0.020014	–5.562085	36.577050	21,999.66000*
MRPL	FUTURES	422	–0.000298	0.028653	–0.124371	7.606824	374.25590*
	CASH	422	–0.000271	0.027545	–0.047958	7.832747	410.82820*
	BASIS	422	0.004505	0.005729	–1.228438	5.230728	193.63440*
MTNL	FUTURES	998	0.000395	0.026942	–0.004390	6.994797	663.60670*
	CASH	998	0.000395	0.026911	0.103027	6.617215	545.85200*
	BASIS	998	0.002487	0.006506	–2.130174	11.437590	3,715.19800*
NAGARFERT	FUTURES	395	–0.000324	0.032234	–0.466661	8.717735	552.40050*
	CASH	395	–0.000328	0.030799	–0.380586	8.194810	453.68110*
	BASIS	395	0.007119	0.005592	–1.255557	9.429140	784.06740*
NATIONALUM	FUTURES	976	0.000882	0.028790	–0.637795	9.188547	1,623.62600*
	CASH	976	0.000915	0.027043	–0.614264	7.778732	990.05290*
	BASIS	976	–0.000919	0.011090	–1.996910	9.643297	2,443.41600*
NDTV	FUTURES	406	0.000423	0.035213	–0.698990	5.914259	176.73270*
	CASH	406	0.000426	0.034415	–0.702015	5.918178	177.40610*
	BASIS	406	0.005304	0.004734	0.387026	8.847174	588.50720*
NEYVELILIG	FUTURES	422	–0.000477	0.029089	–0.372302	11.015270	1,139.38200*
	CASH	422	–0.000473	0.027605	–0.255497	11.875590	1,389.73700*
	BASIS	422	0.004036	0.005690	–1.337218	8.289599	617.74600*

Table 3 (Cont.)

Symbols	Variables	Count	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
NICOLASPIR	FUTURES	422	0.000505	0.026606	0.358507	8.103587	467.02590*
	CASH	422	0.000490	0.024957	0.259100	7.086441	298.34570*
	BASIS	422	0.002254	0.007874	–1.570145	7.258059	492.20120*
NTPC	FUTURES	534	0.001108	0.018365	0.060440	4.909661	81.46655*
	CASH	534	0.001108	0.018242	0.100341	4.681064	63.77407*
	BASIS	534	0.002581	0.004999	–0.770315	4.737951	120.01690*
ORIENTBANK	FUTURES	833	0.000296	0.030977	–0.995533	18.057810	8,007.27700*
	CASH	833	0.000326	0.030432	–0.808975	16.587960	6,499.15300*
	BASIS	833	0.001829	0.007996	–3.585844	24.465330	17,777.38000*
PATNI	FUTURES	422	0.000557	0.024456	0.774594	10.177150	947.94380*
	CASH	422	0.000557	0.023896	1.170232	11.780440	1,451.92300*
	BASIS	422	0.003218	0.007121	–5.897579	78.739160	103,311.70000*
PNB	FUTURES	833	0.001268	0.029463	–0.389100	8.349188	1,014.15700*
	CASH	833	0.001289	0.028943	–0.294956	7.392712	681.80770*
	BASIS	833	–0.000638	0.011536	–3.226099	16.898080	8,149.08400*
POLARIS	FUTURES	976	0.000140	0.034277	–0.519652	7.174737	752.68250*
	CASH	976	0.000134	0.033443	–0.472296	7.494669	857.83480*
	BASIS	976	0.004670	0.004816	–0.505143	4.977865	200.59360*
REL	FUTURES	699	–0.000499	0.027611	–2.495871	48.081560	59,917.84000*
	CASH	699	–0.000505	0.025437	–1.848650	37.692880	35,452.87000*
	BASIS	699	0.000686	0.009461	–3.820795	23.251760	13,645.87000*
RELCAPITAL	FUTURES	422	0.002794	0.034957	0.148279	9.839599	824.09670*
	CASH	422	0.002788	0.034579	0.266310	10.286760	938.60790*
	BASIS	422	0.004377	0.004117	–1.300050	8.519489	654.54440*
RELIANCE	FUTURES	998	0.001450	0.021022	–1.941301	23.321100	17,798.58000*
	CASH	998	0.001453	0.021628	–2.891479	40.212210	58,973.11000*
	BASIS	998	0.002935	0.005287	–2.573320	25.216410	21,625.69000*
SBIN	FUTURES	998	0.001474	0.022421	–0.845029	9.828168	2,057.55100*
	CASH	998	0.001479	0.021559	–0.760732	8.368103	1,294.54700*
	BASIS	998	0.003286	0.005472	–1.691051	9.358685	2,156.99000*
SCI	FUTURES	976	0.000979	0.029597	–0.681709	12.878960	4,044.40800*
	CASH	976	0.000984	0.029558	–0.277285	14.136590	5,056.13200*
	BASIS	976	0.002817	0.008808	–3.570780	23.689750	19,482.08000*

Table 3 (Cont.)

Symbols	Variables	Count	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
SRF	FUTURES	395	0.000799	0.041022	0.135958	7.368090	315.24540*
	CASH	395	0.000791	0.040056	0.274910	7.632840	358.22400*
	BASIS	395	0.004205	0.005249	–1.509533	7.621817	501.58350*
STAR	FUTURES	395	0.001083	0.032332	0.729723	9.359736	700.73370*
	CASH	395	0.001098	0.030201	0.793652	7.658975	398.71270*
	BASIS	395	0.003025	0.011056	–3.623565	24.971270	8,809.44600*
SUNPHARMA	FUTURES	422	0.001783	0.018775	–0.167620	4.558419	44.68023*
	CASH	422	0.001744	0.018986	–0.146669	5.084428	77.90977*
	BASIS	422	–0.006860	0.009731	–1.773672	8.085354	675.98190*
SYNDIBANK	FUTURES	813	0.001240	0.032792	–0.214321	12.098460	2,810.46300*
	CASH	813	0.001248	0.032233	–0.162561	10.616960	1,968.94600*
	BASIS	813	0.001916	0.009703	–2.613639	13.821780	4,892.74700*
TATACHEM	FUTURES	422	0.000909	0.022666	0.114437	8.905212	614.07880*
	CASH	422	0.000891	0.020121	0.051186	6.830779	258.21740*
	BASIS	422	–0.002017	0.016568	–2.698518	10.487170	1,497.84800*
TATAMOTORS	FUTURES	998	0.001705	0.024067	–0.391477	5.661021	319.94440*
	CASH	998	0.001716	0.023699	–0.219446	4.416916	91.49484*
	BASIS	998	0.000807	0.007141	–2.113637	9.452582	2,474.44300*
TATAPOWER	FUTURES	998	0.001611	0.025291	–0.940810	13.842040	5,035.33700*
	CASH	998	0.001618	0.024284	–0.975664	12.143870	3,635.13200*
	BASIS	998	0.000236	0.009586	–3.064836	17.891880	10,784.26000*
TATATEA	FUTURES	998	0.001422	0.021926	–0.293821	7.626037	904.25210*
	CASH	998	0.001423	0.021389	–0.245959	7.387312	810.47950*
	BASIS	998	0.002475	0.006628	–1.322060	6.407631	773.58810*
TITAN	FUTURES	406	0.002818	0.034111	0.611560	8.413550	521.07650*
	CASH	406	0.002810	0.033619	0.766275	9.415784	736.06100*
	BASIS	406	0.004238	0.004833	–1.334417	7.068273	400.47710*
TVSMOTORS	FUTURES	406	0.000505	0.030824	0.032698	5.198335	81.82514*
	CASH	406	0.000499	0.029622	0.033343	5.344065	93.02620*
	BASIS	406	0.003239	0.007113	–2.239002	11.241380	1,488.20800*
UNIONBANK	FUTURES	833	0.001126	0.030345	–0.293890	6.256172	379.99180*
	CASH	833	0.001157	0.030585	–0.209484	6.577444	450.29330*
	BASIS	833	0.002051	0.007399	–1.948479	9.848563	2,155.00900*

Table 3 (Cont.)

Symbols	Variables	Count	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
UTIBANK	FUTURES	422	0.001748	0.024848	–0.134632	4.770174	56.37252*
	CASH	422	0.001702	0.025921	–0.163013	4.990935	71.56621*
	BASIS	422	–0.000649	0.008231	–2.207599	14.171950	2,537.38700*
VIJAYABANK	FUTURES	422	–0.000525	0.025694	0.487474	7.548503	380.49290*
	CASH	422	–0.000541	0.025697	0.822026	9.802587	861.19810*
	BASIS	422	0.004378	0.005747	–0.701811	4.744345	88.14346*
WOCKPHARMA	FUTURES	422	9.87E–05	0.023289	–0.353951	4.947124	75.47499*
	CASH	422	5.37E–05	0.022064	–0.194878	4.511717	42.85407*
	BASIS	422	0.004169	0.006388	–2.119171	11.275960	1,520.16800*

Significantly skewed returns imply that extremely divergent risk perceptions for same information set persist in the market, which may not allow futures and cash markets returns to represent their cost-of-carry and intrinsic value, respectively. It also indicates that the two markets do not adequately discount the risk premium component contained in the new information set traveled to the market. Asymmetry in the cash and futures markets returns is not an unexpected phenomenon because traders with varied trading interests interact in both markets and react heterogeneously to different news. For instance, the risk averse nature of traders in a speculative asset market may be a prominent cause for the asymmetric returns (Moolman, 2004) because due to high degree of volatility in speculative markets, both optimistic and pessimistic views of traders to new information set(s) cause unexpected variations in prices (Diagler and Wiley, 1999). Furthermore, in speculative markets like stock, derivatives and commodity markets, it has been observed that the volume on uptick (positive news) is always higher than the volume on downtick (pessimistic news), because in bull market, traders consider every dip in the stock/index as an opportunity to buy, which in turn causes speculative asset's returns to behave asymmetrically (for details see, Karpoff, 1987).

In addition, basis (which is a proxy for joint dynamics between futures and cash markets) also shows asymmetric behavior, as basis is significantly skewed and its coefficient of kurtosis significantly differs from three. An important observation in the summary statistics of basis is that it is negatively skewed for all indices as well as individual stocks (except for DIVISLAB, JINDALSTEL and NDTV), which implies that more or less futures are in backwardation state, which may offer significant arbitrage opportunities to traders, as found by Vipul (2005). However, since the mean value of basis is meager (approximately close to zero), available arbitrage opportunities do not seem to persist for a longer duration. This observation supports the sample selection criterion because the sample under study covers the period when Indian equity futures market began observing phenomenal growth in trading volume; thus sample selection criterion conforms to the market completion hypothesis, which suggests that in a liquid market arbitrage opportunities do not last long.

In addition, the negatively skewed basis provides important information relating to the exploitation of arbitrage opportunities and reestablishment of equilibrium between the two markets. Kawaller *et al.* (1987), Ng (1987), Stoll and Whaley (1990), Chan (1992), Wahab and Lashgari (1993), Martikainen *et al.* (1995), Arshanapalli and Doukas (1997), Jong and Donders (1998), Pizzi *et al.* (1998), Booth *et al.* (1999), Min and Najand (1999), Tse (1999), Frino *et al.* (2000), Chan and Lien (2001), Chen *et al.* (2002), Lin *et al.* (2002), Thenmozhi (2002), Lin *et al.* (2003), Lien *et al.* (2003), Covrig *et al.* (2004), Kenourgios (2004), Pattarin and Ferretti (2004), So and Tse (2004), Zong *et al.* (2004), Mukherjee and Mishra (2006), and Thomas (2006) were a few prominent works, which found that during long run, both markets are in equilibrium, however, exploitable arbitrage opportunities were available during short run, reflected in the form of lead-lag relationship between the two markets, which may be a result of the presence of various market frictions, as observed by Stoll and Whaley (1990).

The type of traders in two markets may be a potential factor affecting the theoretical distribution of speculative asset's returns. It is an established fact that Indian cash market is predominantly run by foreign as well as domestic institutional investors, and retail investors play little role in market movements. On the other hand, in futures market, retail investors' participation is very significant and institutional investors have little role to play.[24] Therefore, asymmetric profile of investors in both the markets may be a strong determinant of significant asymmetry in basis, because institutional investors base their trading decision on sophisticated analysis undertaken by a team of professionals, whereas retail traders base their decision on firm-specific or insider information (Thomas, 2006), which will be slightly stale or late; consequently the timing of trading by two group of investors will be different, hence new information will take time to die out and will cause asymmetric jumps in the conditional volatility of both the markets.

Moreover, exploitation of available arbitrage opportunities to secure reward out of market disequilibrium causes mean reversion in basis, which implies that increase in spread on account of reaction by different market agents reverts to its intrinsic value because basis, like any financial time series, possesses asymptotic property. Therefore, stationary basis is presumed to observe mean reverting behavior because when spread between two prices is different from cost-of-carry, arbitrageur's participation will correct the deviation and the basis will start representing the cost-of-carry of the underlying asset (Theobald and Yallup, 2001; Zeng, 2001; Monoyios and Sarno, 2002; and Pattarin and

[24] Retail participants drive approximately 60% of the total trading volume in the Indian equity futures market, however, the participation of institutional traders approximates to only 10% of the total trading volume. For reference, *see* Monthly Derivatives Market Update published by National Stock Exchange of India (www.nseindia.com).

Ferretti, 2004). Thus, mean reverting behavior and negative correlation between basis and time-to-expiry of a contract may be another potential reason for negatively skewed basis.

In addition, positive mean value of returns for all indices and most of the individual stocks in both markets may be due to the sample selection bias because the sample period under study observed steady bull run in the Indian equity market, and this was the period when major sources of FDI and FII (viz., the US, the UK and Japan) were aggressively attracted towards the mushroom growth in the Indian economy; consequently, there was huge buying pressure in the market, which was reflected in the phenomenal growth of Indian stock market indices like SENSEX and Nifty, which grew from 3,400 to 13,800 and 1,100 to 4,000 respectively, during the sample period.[25]

In addition to the theoretical distributional properties of futures and cash markets, another important observation can be drawn from unit root test results, which suggests that returns in both futures and cash markets are significantly predictable, thus refuting the null hypothesis of Efficient Market Theory that returns in speculative markets follow the random walk model.[26] Random walk model requires that price changes in speculative markets should be a function of new information set, and the asset prices immediately discount all relevant information as it becomes available, which implies weak form efficiency of the speculative asset (for details, see Fama, 1970). However, stationary futures and cash market returns suggest that information dissemination efficiency in Indian equity futures and cash markets is weak and informed traders can frame market strategies to exploit arbitrage and/or speculative opportunities as they become available. These findings are consistent with earlier works on similar hypothesis in the Indian capital market by Barua (1981), Sharma (1983), Gupta (1985), Rao (1988), Chaudhuri (1991), Reddy (1997), Mishra (1999), Anshuman and Goswami (2000), Ranjan and Padhye (2000), Pant and Bishnoi (2001), Nath (2002), Marisetty (2003), Mangala and Mittal (2005), and Gupta and Singh (2006a).

Furthermore, stationary behavior of one additional variable that is 'basis' provides important information relating to the joint dynamics of Indian futures and cash markets. As the cost-of-carry model (which is followed to determine the price of futures contracts) suggests, price of a futures contract at any time should be the sum of the spot price of the underlying asset traded in the cash market and the risk premium of holding such an asset. Therefore, on maturity date when risk premium ceases, both markets would converge. Stationary behavior and low mean of basis in Tables 2 and 3 respectively confirm that both markets observe stable and strong comovement over the contract cycle, which implies that both markets are in long-run equilibrium; however, exploitable arbitrage opportunities may be available only during very short run. These findings are consistent with Fortenbery and Zapata (1997), Alexander (1999), Neuberger (1999), Sahadevan (2002), Lin *et al*. (2003),

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25 Source: www.bseindia.com for SENSEX and www.nseindia.com for Nifty.

26 For reference on testing the random walk hypothesis by applying the stationarity tests, *see* Crowder and Phengpis (2005) and Evans (2006).

Kumar (2004), and Pattarin and Ferretti (2004). Fortenbery and Zapata (1997) and Kumar (2004) further mentioned that the absence of stationary and predictable basis may be a result of either immaturity of the market(s) and/or inappropriate regulatory framework.

Stationary basis and strong comovement between futures and cash markets, during long run,[27] motivate authors to modify the minimum variance hedge ratio estimation model, that was originally proposed by Ederington (1979) (as given in Equation 1) to include the first lag of futures returns and basis, and the original model is modified to Equation (4), which helps traders predict future spot price movements on the basis of current futures price and lags of spot price itself. Estimation of hedge ratio through Equation (4) (with appropriate estimation procedures like OLS, GARCH, EGARCH and TARCH) though theoretically seems better than that proposed by Ederington (1979), results of variance reduction through different optimal hedge ratios estimated by applying six econometric methodologies in the present study favor the estimation of optimal hedge ratio either through VAR or VECM.

Hedge ratios estimated through VAR methodology are the lowest for three indices (namely Bank Nifty, CNXIT and Nifty), as compared to those estimated through other methodologies, and the time-varying hedge ratios estimated through GARCH, EGARCH or TARCH methodologies are the highest (Table 4), which imply that ignoring the theoretical relationship between the series under examination escalates the hedging cost, which is later reflected in the lower portfolio value. These findings support the theoretical relationship between the two markets, because CNXIT and Nifty show significant bidirectional causality, whereas cash market returns significantly cause futures market returns in the case of Bank Nifty. Moreover, the causal relationship between the two markets with the aid of impulse response analysis could further be interpreted in terms of lead-lag relationship between the two markets.

It has been observed that in the case of Bank Nifty and Nifty, cash market leads futures market and in the case of CNXIT, futures market leads cash market. Furthermore, in the case of Bank Nifty, it depends upon the futures market to correct the market disequilibrium, whereas in the case of Nifty, the error correction term is significant for both the markets, but the magnitude of the coefficient of the error correction term suggests that in order to reestablish market equilibrium, futures market has to make double adjustment in comparison to that by the cash market. The finding that cash market leads futures market in India is not a new observation and is consistent with the findings of earlier studies like Gupta and Singh (2006b), Mukherjee and Mishra (2006) and Thomas (2006).

[27] In order to determine the long-run relationship between futures and cash markets, the cointegration procedure proposed by Johansen and Juselius (1990) has been undertaken and the results of λ_{max} and λ_{trace} tests suggest that both markets are in equilibrium during the long run. In order to save space, results of cointegration tests are not presented in this paper but are available on demand.

Furthermore, out of the 84 individual stocks under examination, 54 (64.28%) and 9 (10.71%) stocks favor the optimal hedge ratio estimated through VAR and VECM respectively, 15 (17.86%) and 4 (4.76%) stocks support OLS and GARCH hedge ratios respectively, whereas 5 (5.95%) stocks each favor the hedge ratio estimated each through EGARCH and TARCH methodology.[28] Out of the total number of stocks under examination, approximately 93% favors constant hedge ratio, and out of the stocks favoring constant hedge ratio, 81% favors the optimal hedge ratio estimated through VAR or VECM, which is consistent with the results of optimal hedge ratio for indices.

Besides the percentage reduction in portfolio variance, measuring the efficiency of estimated hedge ratios obtained through six different procedures has been evaluated on the basis of mean returns of hedged portfolio. Mean returns of hedged portfolio have been estimated from Equation (16), where $R_{h,t}$ is returns of hedged portfolio, $S_t - S_{t-1}$ is cash market returns, h^* is the optimal hedge ratio, and $F_t - F_{t-1}$ is futures market returns. Summarized results of mean returns of hedged portfolio, presented in Table 5, indicates that a portfolio in which optimal hedge ratio was estimated either through VAR or VECM methodologies could generate the highest mean returns in the case of 54.01% (including three indices) and 22.99% portfolios, respectively. However, the mean returns were lowest in the case of 57.48% hedged portfolios, whose optimal hedge ratio was estimated through any of the GARCH family models.

$$R_{h,t} = (S_t - S_{t-1}) - h^*(F_t - F_{t-1}) \qquad \text{...(16)}$$

Therefore, theoretical relationship between the two markets seems to be a significant factor contributing to the efficiency of optimal hedge ratio. Hence, finding VAR or VECM hedge ratios better than time-varying hedge ratios estimated through GARCH, EGARCH and TARCH is justifiable, and this result is consistent with the findings of Castelino (1992), Park and Switzer (1995), Koutmos and Pericli (1998), Alexander (1999), Poomimars *et al.* (2003), Alizadeh and Nomikos (2004), Floros and Vougas (2004), Pattarin and Ferretti (2004), Yang and Allen (2004), Lien and Shrestha (2005), Floros and Vougas (2006), Bhaduri and Durai (2007), and Bhargava and Malhotra (2007).

In addition, overall, the results of the current study favor constant hedge ratio, which is consistent with the findings of Lien (2005), who suggested that hedge ratio based upon OLS (despite the violation of statistical properties) will outperform the time-varying hedge ratio, except when major structural changes take place in the market. Moreover, Ferguson and Leistikow (1998) by applying Dickey-Fuller test, mentioned that rejection of constant hedge ratio hypothesis may be a result of inadequate data points, therefore, hedge ratio computed over the long run will be stationary. Since the sample period did not observe any structural changes in Indian cash and futures markets and the sample period contains sufficient data points (Nath, 2003) drawn out of liquid market, the results of the present study are consistent with the findings of Grammatikos and Saunders (1983), McNew and Fackler (1994), Ferguson and Leistikow (1998), Lo *et al.* (2002), and Lien (2005).

[28] The total number of optimal hedge ratios (92) exceeds the total number of stocks (84) because seven stocks, namely, HEROHONDA, IDBI, IPCL, KTKBANK, ORIENTBANK, RELCAPITAL and SCI, have optimal hedge ratio for more than one methodology.

Furthermore, many empirical findings have suggested that Ederington's optimal hedge ratio performs better in the *ex post* setting rather than in *ex ante* setting, which implies that Ederington's efficient hedge ratio should be calculated by considering data for futures and cash markets for the same period. However, as mentioned earlier, the required number of lags of cash market returns (on the basis of Schwarz Information Criterion) and one lag of each futures returns and basis have been included in Equation (4) to efficiently forecast the cash market changes. Therefore, the optimal OLS hedge ratio (Table 4) does not suffer from the criticisms of Ederington's hedge ratio by Figlewski (1984), Kamara and Siegel (1987), Myers (1991), Holmes (1995), Alexander (1999) Neuberger (1999), Arias *et al.* (2000), Lien (2000), Giaccotto *et al.* (2001), and Lo *et al.* (2002).

Findings of this study are equally important for traders, regulatory bodies, practitioners and academicians, because this study comments upon the theoretical relationship between the two markets and interprets such relationship in economic terms to reduce the

Table 4: Optimal Hedge Ratios

S. No.	Symbols	OLS	GARCH	TARCH	EGARCH	VAR	VECM
1.	BANKNIFTY	0.954325	0.976778	0.979427^{H}	0.976822	0.945011^{L}	0.954110
2.	CNXIT	0.958219	0.982394	0.983521	0.991445^{H}	0.956613^{L}	0.958691
3.	NIFTY	0.907241	0.920750	0.921465^{H}	0.921447	0.904111^{L}	0.913727
4.	ABB	0.912704	0.935855	0.952362	0.953889^{H}	0.904726^{L}	0.910182
5.	ACC	0.954642	0.957348	0.975383	0.976054^{H}	0.950969^{L}	0.953824
6.	ALBK	0.946337	NA	NA	NA	0.948235^{H}	0.933401^{L}
7.	ALOKTEXT	0.958443^{L}	0.973128	0.981862^{H}	0.980272	0.962647	0.972321
8.	ANDHRABANK	0.974391	0.980668	0.982491	0.982571^{H}	0.970474^{L}	0.978616
9.	ARVINDMILLS	0.969002	0.970021	0.973318^{H}	0.972296	0.963478	0.963178^{L}
10.	ASHOKLEY	0.965287	0.986265^{H}	0.982336	0.976827	0.960472^{L}	0.962431
11.	AUROPHARMA	0.943356	NA	NA	NA	0.943692^{H}	0.938530^{L}
12.	BAJAJAUTO	0.960501	0.997923	1.001164^{H}	0.994442	0.955667^{L}	0.962976
13.	BANKBARODA	0.945734	0.962970	0.977531^{H}	0.976293	0.945709^{L}	0.951251
14.	BANKINDIA	0.982385	0.990092	0.994005^{H}	0.993629	0.976964^{L}	0.985451
15.	BEL	0.953256^{H}	NA	NA	NA	0.948546^{L}	0.953236
16.	BHEL	0.958345^{H}	NA	NA	NA	0.957845	0.953114^{L}
17.	BILT	0.941232	0.952642	0.962219^{H}	0.961004	0.936157^{L}	0.937734
18.	BONGAIREFN	0.925423	0.933928	0.908194^{L}	0.934694	0.919504	0.943417^{H}
19.	BPCL	0.945423	0.963960	0.987400	0.998869^{H}	0.942187^{L}	0.958599
20.	CANBANK	0.984180	0.991028	0.993827	1.002752^{H}	0.980598^{L}	0.981850

Table 4 (Cont.)

S. No.	Symbols	OLS	GARCH	TARCH	EGARCH	VAR	VECM
21.	CENTURYTEXT	0.963095^{H}	NA	NA	NA	0.960754^{L}	0.962317
22.	CESC	0.947205	0.949122	0.958047^{H}	0.954839	0.941882	0.938909^{L}
23.	CHAMBLFERT	0.922341	NA	NA	NA	0.916986^{L}	0.933672^{H}
24.	COLGATE	0.927758	0.956610	0.966530^{H}	0.966530^{H}	0.916193^{L}	0.929679
25.	CORPBANK	0.962303	0.968125	0.969059^{H}	0.966842	0.951816^{L}	0.957046
26.	CUMMINSIND	0.938138^{H}	NA	NA	NA	0.932345^{L}	0.936126
27.	DIVISLAB	0.956411	0.965586	0.973834	0.976852^{H}	0.931019^{L}	0.953682
28.	ESCORTS	0.968391^{H}	NA	NA	NA	0.964717^{L}	0.966340
29.	ESSAROIL	0.969641^{H}	NA	NA	NA	0.968545	0.966547^{L}
30.	FEDERALBANK	0.956336	0.959471^{H}	0.954741	0.958261	0.951219	0.938818^{L}
31.	GAIL	0.957567	0.967431^{H}	0.965953	0.960674	0.954746^{L}	0.958083
32.	GLAXO	0.897584	0.910195	0.939107	0.942953^{H}	0.887324^{L}	0.888758
33.	GNFC	0.965649	NA	NA	NA	0.960971^{L}	0.968097^{H}
34.	GRASIM	0.970778	NA	NA	NA	0.968321^{L}	0.973551^{H}
35.	HCLTCH	0.966956	0.991114	0.992009	0.997673^{H}	0.963477^{L}	0.971265
36.	HDFC	1.001205	1.020666	1.020784	1.028577^{H}	0.994144^{L}	0.995631
37.	HDFCBANK	1.009090	1.015543	1.017352	1.019549^{H}	1.004205^{L}	1.009169
38.	HEROHONDA	0.999769	NA	NA	NA	0.999800^{H}	0.978935^{L}
39.	HINDLEVER	0.965539	0.987412	0.992936^{H}	0.988889	0.960892^{L}	0.968040
40.	HINDPETRO	0.932271	0.939642	0.938635	1.000936^{H}	0.926845^{L}	0.939635
41.	ICICIBANK	0.953019^{L}	0.975379^{H}	0.975163	0.971114	0.954736	0.960489
42.	IDBI	0.964884	0.975507	0.977574^{H}	0.975595	0.959912^{L}	0.964816
43.	IDFC	0.963684	0.975763	0.978087^{H}	0.975652	0.954968	0.939510^{L}
44.	IFCI	0.957699	0.960395	0.960784	0.961568^{H}	0.951049^{L}	0.960012
45.	INDUSINDBANK	0.958858	0.960619	0.970285^{H}	0.970269	0.954756	0.953694^{L}
46.	IOB	0.963501	0.982740^{H}	0.976422	0.969685	0.954705^{L}	0.963392
47.	IOC	0.926873	0.940523	0.942203^{H}	0.928559	0.923865^{L}	0.929784
48.	IPCL	0.968143^{H}	0.963934	0.965591	0.966184	0.965701	0.960829^{L}
49.	JETAIRWAYS	0.949671	0.939650^{L}	0.964825	0.975767^{H}	0.941893	0.954784
50.	JINDALSTEL	0.960258^{H}	NA	NA	NA	0.952262^{L}	0.952657
51.	JPHYDRO	0.948162^{H}	NA	NA	NA	0.937365	0.936154^{L}
52.	JSTAINLESS	0.960963	0.960704	0.967406^{H}	0.966743	0.953477^{L}	0.955825

Table 4 (Cont.)

S. No.	Symbols	OLS	GARCH	TARCH	EGARCH	VAR	VECM
53.	KTKBANK	0.950089H	NA	NA	NA	0.947965	0.947531L
54.	LICHSGFIN	0.935007H	NA	NA	NA	0.929800	0.920178L
55.	MARUTI	0.990548	0.992219	1.000960H	0.999270	0.989256L	0.992867
56.	MATRIXLABS	0.899863	0.922476	0.940174H	0.906115	0.903317	0.899701L
57.	MRPL	0.949350	0.953326	0.952727	0.962575H	0.943742L	0.950182
58.	MTNL	0.984175	0.992940H	0.985609	0.987772	0.981108L	0.984754
59.	NAGARFERT	0.948359	NA	NA	NA	0.940287L	0.954510H
60.	NATIONALUM	0.920248H	0.916345	0.916534	0.916414	0.912135L	0.918957
61.	NDTV	0.972484	0.971805	0.985647H	0.981297	0.964819L	0.970361
62.	NEYVELILIG	0.940307H	NA	NA	NA	0.932623L	0.936333
63.	NICOLASPIR	0.911381	0.920017	0.934407	0.948092H	0.905843L	0.908916
64.	NTPC	0.968335H	NA	NA	NA	0.963719L	0.965639
65.	ORIENTBANK	0.969299	0.953482L	0.968998	0.968893	0.961077	0.970264H
66.	PATNI	0.935187H	NA	NA	NA	0.920845L	0.929961
67.	PNB	0.963860	0.961331	0.960765	0.959728	0.958686L	0.977065H
68.	POLARIS	0.972154	0.970692	0.974387	0.974904H	0.969881	0.967509L
69.	REL	0.907802	0.960732	0.972070H	0.970936	0.901684L	0.913750
70.	RELCAPITAL	0.978211	0.973013L	0.976443	0.979334H	0.979300	0.976862
71.	RELIANCE	0.994086	0.980958	0.978266L	0.980839	0.995285H	0.988868
72.	SBIN	0.953816	0.955742	0.955413	0.956528	0.950890L	0.958962H
73.	SCI	0.975516	0.967939L	0.970005	0.970645	0.972781	0.978573H
74.	SRF	0.970648	0.979503	0.978219	0.981196H	0.967064	0.963270L
75.	STAR	0.888055	NA	NA	NA	0.893274H	0.881545L
76.	SUNPHARMA	0.911938	0.932685	0.933352H	0.929106	0.907949L	0.926307
77.	SYNDIBANK	0.969323	0.987456	0.990526H	0.989387	0.965842L	0.969212
78.	TATACHEM	0.837807	0.918946	0.902495	0.923732H	0.818968L	0.849541
79.	TATAMOTORS	0.967558	0.988508	0.981823	0.992923H	0.961909	0.955582L
80.	TATAPOWER	0.932961L	0.955435	0.961104H	0.958351	0.934184	0.941624
81.	TATATEA	0.958970	0.962644	0.964136	0.965601H	0.954237L	0.960587
82.	TITAN	0.977876H	NA	NA	NA	0.975998	0.972918L
83.	TVSMOTORS	0.935610	0.946936	0.951129	0.953403H	0.935741	0.934675L
84.	UNIONBANK	0.993981	0.997009	0.998034H	0.992475	0.990109L	0.995370
85.	UTIBANK	0.999688	1.023904H	1.017679	1.019552	0.994333L	1.013133
86.	VIJAYABANK	0.985474	0.974782L	0.983783	0.987734H	0.975170	0.976661
87.	WOCKPHARMA	0.932771	0.945409	0.948700	0.952743H	0.923674L	0.926119

Note: NA = Methodology not applicable; H = Highest hedge ratio and L = Lowest hedge ratio.

Table 5: Mean Returns of Hedged Portfolio							
Mean Returns of Hedged Portfolio	OLS	GARCH	TARCH	EGARCH	VAR	VECM	Total
Highest	6 (6.90%)	3 (3.45%)	6 (6.90%)	5 (5.75%)	47 (54.01%)	20 (22.99%)	**87 (100%)**
Lowest	13 (14.94%)	9 (10.34%)	20 (22.99%)	21 (24.15%)	14 (16.09%)	10 (11.49%)	**87 (100%)**

portfolio risk. The authors have found that hedging through index futures reduces portfolio variance by approximately 96%, whereas in the case of individual stocks, the reduction in portfolio variance ranges from 79% in the case of SUNPHARMA to 98.50% in the case of TITAN (Table 6). Therefore, it is evident from the above discussion that

Table 6: Variance Reduction							
S. No.	Symbols	OLS	GARCH	TARCH	EGARCH	VAR	VECM
1.	BANKNIFTY	0.950805	0.949675	0.949471^{L}	0.949672	0.950957^{H}	0.950811
2.	CNXIT	0.955930	0.954402	0.954300	0.953505^{L}	0.955987^{H}	0.955912
3.	NIFTY	0.961293	0.960842	0.960806^{L}	0.960807	0.961336^{H}	0.961131
4.	ABB	0.900701	0.899106	0.897230	0.897026^{L}	0.900970^{H}	0.900802
5.	ACC	0.960924	0.960904	0.960377	0.960344^{L}	0.960926	0.960927^{H}
6.	ALBK	0.914810	NA	NA	NA	0.914822^{H}	0.914537^{L}
7.	ALOKTEXT	0.916689^{H}	0.916412	0.916042^{L}	0.916121	0.916654	0.916438
8.	ANDHRABANK	0.964682	0.964494	0.964424	0.964421^{L}	0.964759^{H}	0.964565
9.	ARVINDMILLS	0.980852	0.980843	0.980797^{L}	0.980813	0.980866^{H}	0.980865
10.	ASHOKLEY	0.940281	0.939434^{L}	0.939661	0.939927	0.940347^{H}	0.940326
11.	AUROPHARMA	0.921277	NA	NA	NA	0.921282^{H}	0.921186^{L}
12.	BAJAJAUTO	0.906473	0.904454	0.904147^{L}	0.904760	0.906530^{H}	0.906426
13.	BANKBARODA	0.963128	0.962557	0.961570^{L}	0.961672	0.963129^{H}	0.963016
14.	BANKINDIA	0.967079	0.966877	0.966728^{L}	0.966744	0.967149^{H}	0.967013
15.	BEL	0.960165^{L}	NA	NA	NA	0.960236^{H}	0.960165^{L}
16.	BHEL	0.945072^{L}	NA	NA	NA	0.945076	0.945088^{H}
17.	BILT	0.953608^{H}	0.953465	0.953128^{L}	0.953181	0.953582	0.953596
18.	BONGAIREFN	0.892829	0.892484	0.893052^{H}	0.892445	0.892978	0.891914^{L}
19.	BPCL	0.888247	0.887473	0.885493	0.884116^{L}	0.888311^{H}	0.887769
20.	CANBANK	0.957005^{H}	0.956946	0.956895	0.956629^{L}	0.956999	0.957004
21.	CENTURYTEXT	0.957477^{L}	NA	NA	NA	0.957557^{H}	0.957505
22.	CESC	0.958038^{L}	0.958081	0.958180^{H}	0.958164	0.957878	0.957764
23.	CHAMBLFERT	0.905836	NA	NA	NA	0.905865^{H}	0.905572^{L}

Table 6 (Cont.)

S. No.	Symbols	OLS	GARCH	TARCH	EGARCH	VAR	VECM
24.	COLGATE	0.934594	0.932727	0.931654^{L}	0.931654^{L}	0.934818^{H}	0.934527
25.	CORPBANK	0.947591	0.947394	0.947355^{L}	0.947443	0.947767^{H}	0.947708
26.	CUMMINSIND	0.968903	NA	NA	NA	0.968901^{L}	0.968910^{H}
27.	DIVISLAB	0.941778	0.941067	0.940269	0.939940	0.942781^{H}	0.941954
28.	ESCORTS	0.942228^{L}	NA	NA	NA	0.942369^{H}	0.942310
29.	ESSAROIL	0.981288^{H}	NA	NA	NA	0.981280	0.981259^{L}
30.	FEDERALBANK	0.941067	0.941070	0.941058	0.941071^{H}	0.941020	0.940683^{L}
31.	GAIL	0.950459	0.950182^{L}	0.950236	0.950394	0.950500^{H}	0.950449
32.	GLAXO	0.922377	0.921788	0.919022	0.918505^{L}	0.922579^{H}	0.922566
33.	GNFC	0.966496	NA	NA	NA	0.966500^{H}	0.966476^{L}
34.	GRASIM	0.959930	NA	NA	NA	0.959938^{H}	0.959907^{L}
35.	HCLTCH	0.915811	0.913782	0.913684	0.913022^{L}	0.916003^{H}	0.915538
36.	HDFC	0.925591	0.924538	0.924529	0.923902^{L}	0.925793^{H}	0.925759
37.	HDFCBANK	0.917565	0.917222	0.917112	0.916970^{L}	0.917773^{H}	0.917562
38.	HEROHONDA	0.910895^{H}	NA	NA	NA	0.910895^{H}	0.910436^{L}
39.	HINDLEVER	0.927895	0.926948	0.926554^{L}	0.926849	0.927971^{H}	0.927836
40.	HINDPETRO	0.933186	0.933029	0.933057	0.927141^{L}	0.933227^{H}	0.933029
41.	ICICIBANK	0.889314^{H}	0.888583^{L}	0.888594	0.888799	0.889293	0.889180
42.	IDBI	0.978009^{H}	0.977893	0.977843^{L}	0.977892	0.977982	0.978009^{H}
43.	IDFC	0.916576	0.916014	0.915872^{L}	0.916021	0.916796	0.916804^{H}
44.	IFCI	0.977300	0.977256	0.977248	0.977231^{L}	0.977342^{H}	0.977263
45.	INDUSINDBANK	0.980403	0.980408^{H}	0.980322^{L}	0.980323	0.980364	0.980348
46.	IOB	0.948590	0.947760^{L}	0.948118	0.948408	0.948711^{H}	0.948592
47.	IOC	0.918249	0.917490	0.917368^{L}	0.918178	0.918360^{H}	0.918122
48.	IPCL	0.975016	0.975016	0.975021^{H}	0.975021^{H}	0.975021^{H}	0.974993^{L}
49.	JETAIRWAYS	0.917958	0.918183^{H}	0.917216	0.916380^{L}	0.918151	0.917762
50.	JINDALSTEL	0.952676^{L}	NA	NA	NA	0.952778^{H}	0.952776
51.	JPHYDRO	0.947974^{L}	NA	NA	NA	0.948185	0.948193^{H}
52.	JSTAINLESS	0.974178^{H}	0.974177	0.974161	0.974167	0.974089^{L}	0.974130
53.	KTKBANK	0.971422^{L}	NA	NA	NA	0.971429^{H}	0.971429^{H}
54.	LICHSGFIN	0.928263^{H}	NA	NA	NA	0.928256	0.928092^{L}
55.	MARUTI	0.967303	0.967288	0.967120^{L}	0.967164	0.967311^{H}	0.967281

Table 6 (Cont.)

S. No.	Symbols	OLS	GARCH	TARCH	EGARCH	VAR	VECM
56.	MATRIXLABS	0.894986^{H}	0.894504	0.893340^{L}	0.894965	0.894985	0.894985
57.	MRPL	0.977623	0.977616	0.977619	0.977467^{L}	0.977575	0.977625^{H}
58.	MTNL	0.969045^{H}	0.968952	0.969040	0.969025^{L}	0.969041	0.969043
59.	NAGARFERT	0.966231	NA	NA	NA	0.966320^{H}	0.966067^{L}
60.	NATIONALUM	0.934873^{L}	0.934961	0.934958	0.934960	0.935018^{H}	0.934906
61.	NDTV	0.977256	0.977264	0.976901^{L}	0.977058	0.977296^{H}	0.977279
62.	NEYVELILIG	0.960659^{L}	NA	NA	NA	0.960766^{H}	0.960731
63.	NICOLASPIR	0.922389	0.922100	0.921241	0.919987^{L}	0.922486^{H}	0.922441
64.	NTPC	0.951203^{H}	NA	NA	NA	0.951177^{L}	0.951193
65.	ORIENTBANK	0.965351	0.965225	0.965354 H	0.965354^{H}	0.965350	0.965342^{L}
66.	PATNI	0.895364	NA	NA	NA	0.895466^{H}	0.895451^{L}
67.	PNB	0.948692	0.948722	0.948727	0.948735	0.948740^{H}	0.948319^{L}
68.	POLARIS	0.985904	0.985912	0.985883	0.985876^{L}	0.985915^{H}	0.985914
69.	REL	0.944228	0.939366	0.937466^{L}	0.937670	0.944364^{H}	0.944011
70.	RELCAPITAL	0.983954	0.983895^{L}	0.983940	0.983960^{H}	0.983960^{H}	0.983944
71.	RELIANCE	0.959559	0.959054	0.958910	0.959048^{L}	0.959589	0.959398
72.	SBIN	0.976294	0.976275	0.976278	0.976264	0.976308	0.976224^{L}
73.	SCI	0.943282	0.943308	0.943312^{H}	0.943312^{H}	0.943304	0.943238^{L}
74.	SRF	0.989289^{H}	0.989217	0.989237	0.989184^{L}	0.989271	0.989223
75.	STAR	0.889724	NA	NA	NA	0.889609^{L}	0.889779^{H}
76.	SUNPHARMA	0.786826	0.785804	0.785757^{L}	0.786040	0.786926^{H}	0.786207
77.	SYNDIBANK	0.962099	0.961565	0.961407^{L}	0.961468	0.962124^{H}	0.962100
78.	TATACHEM	0.841057	0.827893	0.831913	0.826595^{L}	0.841723^{H}	0.840187
79.	TATAMOTORS	0.955779	0.955117^{L}	0.955426	0.954862	0.955803^{H}	0.955751
80.	TATAPOWER	0.937454^{H}	0.936746	0.936394^{L}	0.936574	0.937443	0.937311
81.	TATATEA	0.959963	0.959924	0.959900	0.959872^{L}	0.959971^{H}	0.959949
82.	TITAN	0.984268^{H}	NA	NA	NA	0.984265	0.984244^{L}
83.	TVSMOTORS	0.961840	0.961870^{H}	0.961811	0.961763^{L}	0.961842	0.961825
84.	UNIONBANK	0.966330	0.966302	0.966288^{L}	0.966337	0.966339^{H}	0.966319
85.	UTIBANK	0.892742	0.891582^{L}	0.891983	0.891870	0.892852^{H}	0.892231
86.	VIJAYABANK	0.948245	0.948377^{H}	0.948281	0.948188^{L}	0.948376	0.948371
87.	WOCKPHARMA	0.940480	0.939911	0.939704	0.939417^{L}	0.940670^{H}	0.940637

Note: NA = Methodology not applicable; H = Highest hedge ratio and L = Lowest hedge ratio.

strong and stable comovement between Indian equity futures and cash markets has helped traders to significantly reduce portfolio variance, subject to the coefficient of determination between the two markets, which is consistent with the findings of Ederington (1979).

Since the efficiency of optimal hedge ratio is subject to strong and stable comovement between futures and cash markets, these results can help the Securities and Exchange Board of India (SEBI) in policy framing.[29] Therefore, prior to announcing any policy changes, SEBI should give due consideration to their potential impact on the cost-of-carry relationship between the two markets, because any reform in the Indian capital market will affect the hedging efficiency of derivatives market. Thus, SEBI should make efforts to strengthen the relationship between the two markets by removing various imperfections in the Indian derivatives markets.

Conclusion

The past one-and-a-half decades have brought about a sea change in the Indian capital market, such as screen-based trading replaced open outcry trading system; demat accounts replaced share certificates; floor trading has been replaced by Internet trading; badla trading is banned; compulsory rolling settlement was introduced; fixed price issues were replaced by partial or complete book building issues in primary issue market; and establishment of interconnected stock exchanges. One of the most important reforms in the Indian capital market has been the introduction of equity derivatives (futures and options) as efficient price discovery and hedging instruments.

The success of derivatives trading in the Indian capital market can be adjudged from the fact that index and individual stock futures contracts have been continuously rated amongst the top five exchanges (in terms of trading volume) in the world.[30] Volume explosion in the futures market has been a subject of interest for practitioners, traders, regulatory bodies and academicians because huge volume in the market, especially through retail traders (because retail traders contribute approximately 60% of total trading volume in Indian derivatives market), raises many questions relating to the information dissemination efficiency of futures markets as well as the change in price discovery efficiency of cash market, after the introduction of futures trading, hedging, arbitrage efficiency of futures market, and another important question whether futures trading has stabilized or destabilized the cash market.

[29] Reduction in tick size of TSE 35 Index Participation Units from 0.60% to 0.25% of the prevailing price improved its price discovery efficiency in Canada, which implies that improvements in contract specifications improve price discovery efficiency of the asset. Furthermore, Jiang *et al.* (2001) found that contemporaneous relationship between futures and cash markets strengthened with the removal of short-selling restrictions in the Hong Kong cash market, particularly when the market was undergoing a bear phase and the underlying asset was relatively overpriced. Therefore, irrational trading specifications of the futures contracts is responsible for violation of the common notion that an asset which involves zero investment will always be a better price discovery vehicle (Beaulieu *et al.*, 2003).

[30] For reference, *see,* Monthly Derivatives Market Updates, published by National Stock Exchange of India (www.nseindia.com).

All these issues have been adequately answered in developed markets as well as emerging markets, but hedging efficiency of the Indian equity futures market has not yet been given due attention. To the best of the researcher's knowledge, Bhaduri and Durai's (2007) has been the only work, which examined the hedging efficiency of Indian equity futures market, but the scope of the study was restricted to the investigation of hedging efficiency of only Nifty futures. Therefore, the present study has been an attempt to fill the gap in literature by examining the hedging efficiency of both index as well as individual stock futures contracts traded on the National Stock Exchange of India over the sample period January 2003 to December 2006.

The study finds asymmetric and significantly kurtic futures and cash market returns, which refute the null hypothesis that in a highly liquid speculative market, returns are symmetrically distributed among buyers and sellers. Furthermore, both futures and cash markets returns have been found to be stationary, which rejects the hypothesis that in a liquid stock market, successive price movements are random, which implies that information dissemination process in both futures and cash markets is weak. In addition, joint dynamics of both the markets (i.e., basis) has been found to be stationary, which implies that stable long-run relationship persists between the two markets, which has later been confirmed by Johansen and Juselius (1990) cointegration test results.

After examining the nature of series under consideration and the relationship between the two markets, the hedging efficiency of both index as well as individual stock futures contracts has been investigated in the minimum variance hedge ratio framework, as suggested by Ederington (1979). The original model has been modified to accommodate the theoretical relationship between the two markets and the optimal hedge ratio was estimated through six econometric procedures (subject to the fitness of the model), namely, OLS, GARCH, TARCH, EGARCH, VAR and VECM. The study finds that hedge ratio estimated through VAR or VECM could reduce the portfolio variance to the maximum extent, whereas other methodologies, by considering the stylized features of futures and cash markets, estimated higher hedge ratios, requiring higher initial investment, which is later reflected in the reduced portfolio value.

The results of the present study are consistent with the findings of Castelino (1992), Park and Switzer (1995), Koutmos and Pericli (1998), Alexander (1999), Poomimars *et al.* (2003), Alizadeh and Nomikos (2004), Floros and Vougas (2004), Pattarin and Ferretti (2004), Yang and Allen (2004), Lien and Shrestha (2005), Floros and Vougas (2006), Bhaduri and Durai (2007), and Bhargava and Malhotra (2007), who found that ignoring the theoretical relationship between the futures and cash markets would escalate the hedge ratio. In addition, the hedge ratio estimated through OLS (despite the violation of statistical properties) provides better hedging than the hedge ratios estimated through either of the conditional heteroscedasticity models applied in the study.

The study also finds that hedging through index futures in India reduces portfolio variance by 96%; however, hedging through individual stock futures reduces portfolio variance in the range of 79% to 98.50%, subject to the strength of liaison and stable comovement between the two markets, which is consistent with the findings of Ederington (1979). The findings of the study are important for traders because it suggests that hedgers should hedge (either straight or cross hedge) through liquid futures contracts so that they can avoid hedging cost escalations and they should estimate the long-run hedge ratio on the basis of cost-of-carry relationship between the two markets. ❖

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