Fitness of Cost of Carry Model in the Indian Equity Futures Market

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Abstract

Present study aims to examine the suitability of Cost of Carry Model (COC) for pricing the index futures contracts in the Indian market conditions. Using daily data of Nifty and near month Nifty futures contracts for five and half years (January 2004 to May 2009); it has been observed that COC does not fit in the Indian market conditions. Over the period, Nifty futures contracts have been found to be traded at discount and offering significant arbitrage opportunities. Moreover, by using Hemler and Longstaff (1991) model, it has been found that two assumptions of COC (i.e. non stochastic interest rates and volatility of the underlying asset does not explain the price discovery process of index futures contracts) are refuted. In addition to stochastic interest rates and volatility of the underlying index, restrictions on the exposure of institutional traders may be another important factor responsible for unsuitability of COC in the Indian market conditions because these restrictions won't allow them to open sufficient amount of positions so as to unwind the price spreads between two markets.

1.0 Introduction

In India, after strong deliberations, equity derivatives were introduced in 2000 starting with index futures and followed by index options, individual stock options and individual stock futures in 2001. The objective of introducing equity derivatives in the Indian capital market was to make available hedging instruments to hedgers, improve the market wide liquidity and price discovery efficiency and reduce the cash market volatility. Over past nine years, the Indian equity futures and options (F and O) segment (in terms of trading activity) has acquired significant position among the peer markets across the world because it is one of the most liquid derivative markets of the world.

Since the date of launch of equity derivatives in the Indian capital market, various researchers have attempted to examine different empirical issues related to the trading of futures and options contracts. Gupta and Singh (2006b) and Gupta (2008) examined whether price movements in the Indian equity futures market are random and they found that daily returns in the Indian equity futures market are predictable, hence, it does not conform to the Efficient Market Hypothesis (EMH). In addition, Raju and Karande (2003), Gupta and Singh

(2006a and 2006c), Mukherjee and Mishra (2006), Sah and Kumar (2006), Thomas (2006) and Gupta (2008) investigated the relationship between price movements in equity futures and cash markets and they all observed that both markets observe strong and stable co movement over long-run, whereas, during short-run, cash market leads the futures market. However, Bhatia (2007) and Gupta and Singh (2009) by using high frequency data (at five minutes interval) have found that Indian equity futures market leads the cash market.

On the basis of empirical evidence related to the persistence of lead-lag relationship between Indian equity futures and cash markets, Vipul (2005), Misra et al., (2006), Gupta and Singh (2007), Gupta (2008) and Gupta and Singh (2009) attempted to explore whether the price spreads in two markets generate exploitable arbitrage opportunities. They have found that significant amount of price spreads between two markets persist over the period, which offers exploitable arbitrage opportunities in the market. They have observed that arbitrage opportunities are a positive function of time to expiry and illiquidity, however, Gupta and Singh (2009) by using high frequency data found negative relationship between price spreads and time to maturity, which they attribute to heavy rollover pressure during one week before the expiry of futures contracts.

In addition, Gupta (2002), Gupta and Kumar (2002), Thenmozhi (2002), Bandivadekar and Ghosh (2003), Nath (2003), Raju and Karande (2003), Shenbagaraman (2003), Sah and Omkarnath (2005), Karande (2006), Singh and Bhatia (2006), Thomas (2006) and Gupta (2008) investigated the impact of futures and options trading on cash market volatility and they all observed that after introduction of derivatives instruments in the Indian capital market, the unwanted component of cash market volatility has significantly declined. Moreover, Gupta (2008) found that after the introduction of futures trading, the information dissemination efficiency in the Indian cash market has improved and the new information set has gained more importance in the price discovery process than before.

In brief, a vast amount of empirical literature is available, which has widely investigated different empirical issues related to the Indian equity futures market and its impact on the price discovery efficiency, liquidity and volatility in the cash market. However, if we carefully read the analysis and results of these studies, we find that robustness of the findings of all these studies are subject to one common underlying assumption that Cost-of-Carry model (COC) can be used to price the futures contracts. Whereas, Jarrow and Oldfield (1981) and Cox et al., (1981) observed that in real life, interest rates are stochastic in nature rather than being constant, which is contrary to the assumptions of COC, therefore, it can't be used to price the futures contracts. Hemler and Longstaff (1991) further observed that inconsistent with the assumptions of COC, volatility of the underlying asset market plays important role in price formation of the futures contracts. Moreover, Hsu and Wang (2004), Wang and Hsu (2005), Wang and Hsu (2006) and Wang (2007b) have observed that in the presence of market imperfections, COC does not correctly price the futures contracts.

Therefore, in the light of above theoretical and empirical evidence, it is imperative to examine whether COC fits in the Indian market conditions because if the assumptions of COC does not hold true in the Indian market conditions and still academicians and practitioners are following it to estimate the theoretical futures price, the inputs for policy reforms and portfolio management would be misleading. To the best of author's knowledge, this is the first attempt to examine the validity of COC in India, hence, findings of the study aims to fill the literature gap. In order to examine the validity of COC in India, the study has been organized into four sections, where section (1.0) introduces the problem, section (2.0) defines database and research methodology, section (3.0) discusses analysis and results and section (4.0) concludes the study.

2.0 Data Base and Research Methodology

As mentioned, derivatives trading in the Indian equity futures market started in 2000 and both index and individual stock futures contracts are available for trading with three trading cycles i.e. one month (near month), two months (mid month) and three months (far month). Both index and individual stock futures contracts are contributing to approximately 30% each to the aggregate traded value in the F&O segment. Since, near month Nifty futures contracts contributes to approximately 40% or more to the total traded value in the Indian equity futures market, therefore, present study investigates the fitness of COC on near month Nifty futures contracts with a sample period of nearly five and half years i.e. January 2004 to May 2009. Initial three and half years (i.e. June 2000 - December 2003) of trading in the segment have been left in order to allow the market to adjust with the introduction of other derivative instruments and investors to become comfortable with the trading in the F&O segment, which is reflected through huge volume in the market from 2004 onwards. The daily closing prices of near month Nifty futures contracts have been downloaded from the website of National Stock Exchange of India.

In addition, in order to estimate the theoretical futures price ($S_{t,T}$) by following COC (equation (1)), we need closing price of the underlying asset (S_t), risk free rate (r), daily dividend yield (d) and time to maturity (T-t). The daily closing prices and dividend yield of S&P CNXNifty (Nifty henceforth) have been secured from historical statistics for indices available on the website

of National Stock Exchange of India. Following Vipul (2005), 91 days T-Bill rate has been considered as a proxy for risk free rate and the required data is downloaded from historical data on debt market available on the website of National Stock Exchange of India. However, time to maturity is the difference between maturity date and transaction date of the futures contract. Since, the COC assumes that dividend yield is continuous and risk free rate is constant over the contract cycle, therefore, equation (1) will be followed to estimate the theoretical futures price.

$$S_{t,T} = S_t e^{(r-d)(T-t)} \quad \ldots\ldots(1)$$

In order to investigate the fitness of COC in the Indian market conditions, the overall sample period (i.e. January 2004 to May 2009) is subdivided into two sub periods i.e. January 2004 to December 2007 and January 2008 to May 2009. The first sub period had observed consistent Bull Run in the Indian equity market and in the later sub period, the Indian capital market underwent sharp fall due to global financial turbulence. Since, Karpoff (1987) observed that speculative asset markets experience asymmetrical relationship between returns and volatility, which implies that due to panic factor, volatility in the falling market will be higher than that in the rising market. Therefore, present study attempts to examine the fitness of COC in the overall Indian market conditions and during the sub periods, i.e. low volatility and high volatility periods respectively.

Nevertheless, a vast amount of empirical literature is available, which has investigated the relationship between theoretical and actual futures prices and they followed COC to estimate the theoretical futures price but as already mentioned, in real life it has been observed that the assumptions of COC does not hold true. For instance; in case of index futures contracts the dividend yield are assumed to be constant and continuous, whereas, in markets like Japan, Korea and Taiwan dividend payments have been found to be irregular and relatively lumpy (for detail, see Wang (2007b)). Moreover, COC assumes that risk free rate will remain constant over the contract cycle, however, Jarrow and Oldfield (1981) and Cox et al., (1981) provide strong evidence that in real life, risk free rate is stochastic in nature. Besides, COC assumes that volatility in the underlying asset does not play significant role in the price formation of the futures contracts; however, Hemler and Longstaff (1991) found that volatility of the underlying asset plays significant role in the price discovery process of the futures contract.

Therefore, given these empirical observations, present study aims to investigate the fitness of COC in the Indian equity futures market. In order to test the validity of COC in the Indian equity futures market, we follow the methodology used by Wang (2007a). As per COC, equation (1) can be rewritten as equation (2), where, $\ln F_t$ is the natural log of actual futures prices, $\ln S_t$ is the natural log of cash market prices, r is the risk free rate, d is the dividend yield and T-t is the time to maturity with T as maturity date and t as transaction date.

$$\ln F_t = \ln S_t + (r-d)(T-t) \quad \ldots\ldots(2)$$

Furthermore, by following Hemler and Longstaff (1991), the fitness of COC model will be tested by estimating equation (3), which tests whether volatility of the underlying asset has any explanatory power in the price formation of the futures contract. In equation (3), $L_t = \ln(F_t e^{d(T-t)} / S_t)$ where, $F_t e^{d(T-t)}$ is the dividend adjusted futures price and V_t is the volatility of underlying index (i.e. Nifty in present study). According to the general equilibrium model for pricing of stock index futures contracts, if COC holds true in the Indian market conditions, the estimated coefficient of â = T-t and ë = 0.

$$L_t = á + âr_t + ëVt + å_t \quad \ldots\ldots(3)$$

Finally, in order to conclude whether COC fits in the Indian market conditions, similar to Wang (2007a), we calculate mean percentage error (MPE) and mean absolute percentage errors (MAPE) through equations (4) and (5) respectively. In equations (4) and (5), Ft is the actual futures price and Ft, $t^{\rightarrow}$ is the theoretical futures price estimated by following COC and Hemler and Longstaff (1991) model when risk free rate is non stochastic and volatility of the underlying asset significantly explains the price formation process of the futures contracts. Lower MPE and MAPE will indicate the fitness of futures pricing model.

MPE = 1/n  ……(4)

MAPE = 1/n  ……(5)

3.0 Analysis and Results

COC assumes presence of frictionless markets and efficient arbitrage mechanism, which implies that no transaction cost is involved in arbitrage activity, there is no restriction on short sales, securities are perfectly divisible, arbitrageurs can borrow and lend at the same rate, information is simultaneously available to all market participants and arbitrageurs are able to invest in the securities in the same proportion in which these comprise the stock index. Table I shows the descriptive statistics of Nifty and near month Nifty futures contracts during full period and two sub periods. Descriptive statistics supports the observations of Karpoff (1987) that volatility in the falling market is significantly higher than that during the rising market because the estimated coefficient of standard deviation of returns during second sub period is approximately 1.75 time than that during the first sub period.

Table I Descriptive Statistics of Futures and Cash Markets

Market	Count	Mean		Minimum		Maximum		Standard Deviation	
		Prices	Returns	Prices	Returns	Prices	Returns	Prices	Returns
				Full Period (January 2004 - May 2009)					
Futures	1339	3240.07	6.27E-04	1337.35	-0.16	6288.25	0.16	1208.30	2.11E-02
Spot		3244.74	6.31E-04	1388.75	-0.13	6287.85	0.16	1206.08	1.96E-02
				First Period (January 2004 - December 2007)					
Futures	997	2977.72	1.17E-03	1337.35	-0.16	6189.05	0.10	1167.32	1.71E-02
Spot		2983.21	1.17E-03	1388.75	-0.13	6159.30	0.08	1165.41	1.56E-02
				Second Period (January 2008 – May 2009)					
Futures	342	4004.89	-9.50E-04	2517.50	-0.14	6288.25	0.16	980.17	2.97E-02
Spot		4007.01	-9.41E-04	2524.20	-0.13	6287.85	0.16	978.69	2.82E-02

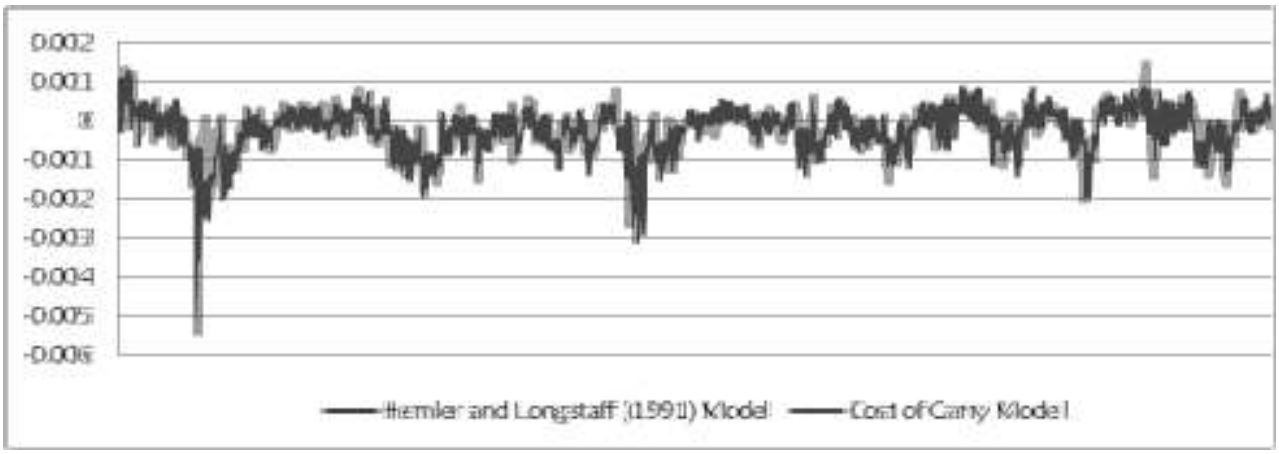
In addition, the descriptive statistics in table II suggests that Nifty futures contracts in India are trading at discount, however, the amount of discount and premium does not seem to be different over two sub periods. Moreover, the estimated t statistics (in panel A) suggests that theoretical futures price estimated by using COC is significantly different from the actual futures price, hence, in the Indian market conditions, COC may not hold true. Nonetheless, t statistics in panel B also suggests that theoretical futures price estimated through Hemler and Longstaff (1991) is significantly different but the amount of mean percentage errors during second sub period are significantly lower. This evidence can also be read through figure 1 where mean percentage errors estimated through COC overshadows the mean percentage errors estimated through Hemler and Longstaff (1991) model. These evidences suggest that Hemler and Longstaff (1991) model fits better than COC in the Indian market conditions.

Table II Descriptive Statistics of Percentage Errors

Sample Period	Count	Mean		Minimum		Maximum		Standard Deviation		t Statistics	
		MPE	MAPE	MPE	MAPE	MPE	MAPE	MPE	MAPE	MPE	MAPE
						Panel A: Cost of Carry Model					
Full Period	**1339**	-2.53E-04	4.45E-04	-0.005	3.61E-07	0.001	0.005	5.85E-04	4.558E-04	-15.84*	35.74*
First Period	**997**	-3.05E-04	4.61E-04	-0.005	3.61E-07	0.001	0.005	5.94E-04	4.822E-04	-16.22*	30.21*
Second Period	**342**	-1.02E-04	3.98E-04	-0.002	2.41E-07	0.001	0.002	5.31E-04	3.646E-04	-3.56*	20.19*
						Panel B: Hemler and Longstaff (1991) Model					
Full Period	**1339**	-2.20E-04	4.37E-04	-0.005	2.90E-07	0.001	0.005	5.887E-04	4.518E-04	-13.68*	35.37*
First Period	**997**	-2.52E-04	4.44E-04	-0.005	3.07E-07	0.001	0.005	6.023E-04	4.437E-04	-13.22*	29.25*
Second Period	**342**	-1.27E-04	4.17E-04	-0.002	2.90E-07	0.001	0.002	5.371E-04	3.613E-04	-4.37*	21.33*

* Significant at 1% significance level.

Figure I Mean Percentage Errors



Source: Equation (5) has been used to calculate the Mean Percentage Errors through Hemler and Longstaff (1991) and Cost of Carry Models.

Furthermore, in order to test the fitness of COC in the Indian market conditions through Hemler and Longstaff (1991) model, we need daily volatility of Nifty. In the present case, daily volatility of Nifty has been estimated by using GJR procedure (equation (6)), because volatility of Nifty has been found to be asymmetrically responding to good and bad news. In equation (6), $R_{s,t}$ = daily natural log return of Nifty [$\ln(R_{s,t}/R_{s,t-1})$], $R_{s,t-j}$ are the autoregressive terms, h_t = conditional heteroscedastic volatility of daily Nifty returns, ε^2_{t-i} = ARCH term, ξ_{t-i} = dummy with 1 if change in prices is positive and 0 otherwise and h_{t-i} = GARCH term.

$$R_{s,t} = \acute{a} + \sum_{j=1}^{k} \beta_j R_{s,t-j} + \mathring{a}_t \quad \sim N(0, \acute{o}^2)$$

$$h_t = \grave{u} + \sum_{i=1}^{p} \alpha_i \varepsilon^2_{t-i} + \sum_{i=1}^{p} \alpha_i \varepsilon^2_{t-i} \xi_{t-i} + \sum_{i=1}^{q} \beta_i h_{t-i} + \grave{i}_t \quad \text{.....(6)}$$

Table III reports the results of estimated equation (3), where the natural log ratio of dividend adjusted futures prices to spot prices has been found to be significantly predictable by its lagged terms, therefore, equation (3) has been estimated by including the autoregressive terms and the number of autoregressive terms included in the equation have been decided on the basis of AIC and SIC. In addition, the variance of error term in equation (3) has been found to be heteroscedastic, hence, equation (3) has been estimated through GARCH (p,q) procedure by assuming t distribution.

Results in table III provides important inputs to comment on the fitness of COC in the Indian market conditions because inconsistent with the assumptions of COC, â coefficient in equation (3) is significantly different from time to expiry (T-t). In addition, the estimated coefficient of volatility (i.e. ë) of Nifty is statistically significant, which implies that volatility of the underlying index plays important role in the price discovery process of the index futures contracts and these findings are consistent with empirical findings of volatility spillover between two markets. These empirical findings strongly suggest that COC does not hold true in the Indian market conditions.

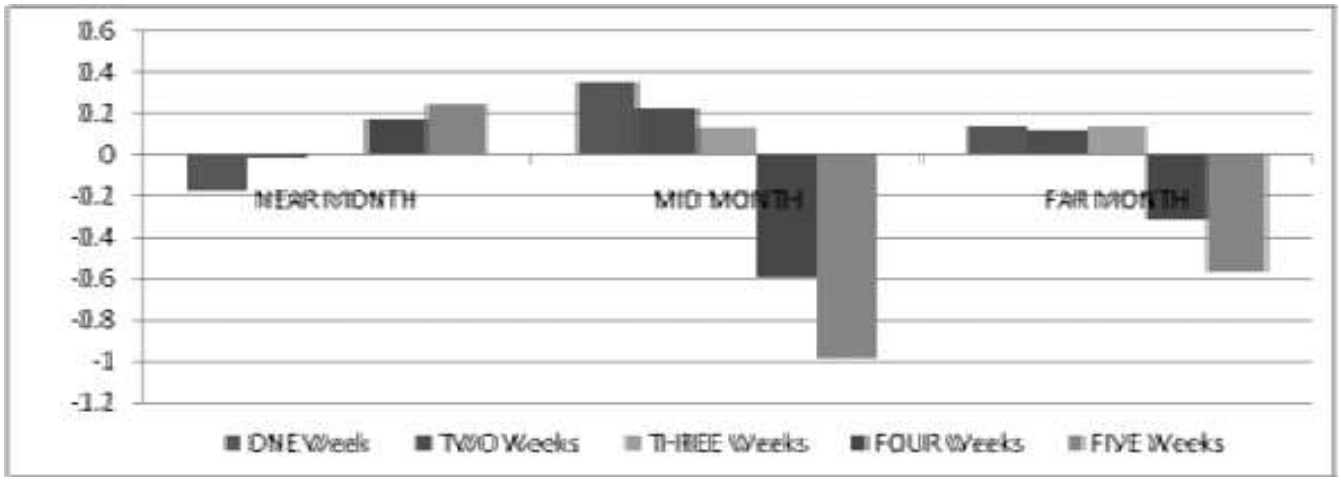
There may be several reasons for rejecting the fitness of COC in the Indian market conditions. In addition to the factors identified in the literature for non suitability of COC for pricing index futures contracts (like, stochastic interest rate, significant explanatory power of the volatility of underlying index and inability of arbitrageurs to open positions in all component stocks of the underlying index in same proportion), the market microstructure design in India may be a prominent cause for this. COC assumes the presence of strong arbitrage base in the market, however, in India institutional traders are not set free to participate in the futures market[1].

Table III Testing the Efficiency of Cost-of-Carry Model Through Hemler and Longstaff (1991) Model

Sample	Mean Equation					Variance Equation		
Period	C	AR(1)	AR(2)	R	V	C	ARCH(1)	GARCH(1)
Full Period	-0.0006***	0.5295*	0.2745*	-0.0005 (57.14*)	1.1420*	3.76E-07*	0.0985*	0.8545*
First Period	2.71E-05	0.4843*	0.2957*	0.0003 (49.39*)	-3.8896*	2.76E-07*	0.1081*	0.8635*
Second Period	-0.0001	0.5141*	0.2687*	-0.0019 (28.68*)	0.9560**	5.50E-07	0.1140	0.8255*

*Significant at 1% significance level, **Significant at 5% significance level and *** Significant at 10% significance level. Figures in parenthesis are the t statistics comparing the mean of time to expiry and estimated â coefficient of R in equation (3).

Figure II Change in Open Interest Over Different Weeks to Expiry



[1] Unlike the developed markets (like U.S.A. and U.K.) of the world (where institutional traders are major volume drivers), in India, pension funds are banned from participating in equity market, insurance companies are handicapped by Insurance Regulatory and Development Authority (IRDA) restrictions and the internal risk management mechanisms prevent banks and mutual funds from extensively participating in the derivatives markets.

FII and MF position limit in all index futures contracts on a particular underlying index shall be Rs.500 crores or 15 % of the total open interest of the market in index futures, whichever is higher. This limit would be applicable on open positions in all futures contracts on a particular underlying index.

In addition to the above, FIIs & MF's shall take exposure in equity index derivatives subject to the following limits:

a) Short positions in index derivatives (short futures, short calls and long puts) not exceeding (in notional value) the FII's / MF's holding of stocks.

b) Long positions in index derivatives (long futures, long calls and short puts) not exceeding (in notional value) the FII's / MF's holding of cash, government securities, T-Bills and similar instruments.

In this regard, if the open positions of an FII/MF exceeds the limits as stated in item no. (a) or (b), such surplus would be deemed to comprise of short and long positions in the same proportion of the total open positions individually. Such short and long positions in excess of the said limits shall be compared with the FII's / MF's holding in stocks, cash etc as stated above. (Circular No. NSCC/F&O/C&S/348).

Source: Daily open interest has been downloaded from the website of National Stock Exchange of India and change in open interest has been calculated as log ratio of daily open interest positions in the market. In figure II, seven trading session comprise of one week to expiry.

Therefore, restriction on their exposure in the F&O segment enforce them to unwind their current positions in the market, which seem to create rollover pressure during one week prior to the expiry date as shown in figure II. From figure II it is clearly visible that change in the open interest position during one and two weeks prior to the expiry date of near month futures contract are negative, while it is positive in case of mid and far month futures contracts, which supports the argument of early liquidity option (as suggested by Brennan and Schwartz (1990)) exercised by institutional traders.

4.0 Conclusion

Practitioners, academicians and regulatory bodies have shown equal interest in the pricing efficiency of speculative asset markets because if the markets are inefficient, practitioners will get opportunities to book abnormal profits, academicians will be interested to find out the factors responsible for such inefficiency and regulatory bodies would like to initiate changes in the market design so as to improve the price discovery efficiency. Since these stakeholders have vested interest in the mispricing of the asset, therefore, they test the actual price series against the theoretical price series estimated by following a theoretical model suitable in such market conditions.

Cost of Carry model is one of the most popular models followed in the futures markets to estimate the theoretical price of the futures contracts. Practitioners, academicians and regulatory bodies are supposed to be determining the presence of price spreads by using this model and if they find mismatch between actual and theoretical futures price series, practitioners will raid the market to book risk free profits and regulatory bodies will initiate policy reforms to improve the price discovery efficiency. Effectiveness of trade executed by practitioners, policy reforms suggested by academicians and executed by regulatory bodies in this case will depend on the fact whether the theoretical properties of COC holds true in the present market conditions and if the answer is no, robustness of the activities of practitioners, academicians and regulatory bodies will be questionable.

Therefore, present study investigates the fitness of COC in the Indian market conditions. Using daily data of Nifty and near month Nifty futures contracts, it has been found that futures contracts trade at discount and actual futures price is significantly different from theoretical futures price estimated through COC. In addition, by using Hemler and Longstaff (1991) model, it has been found that two assumptions of COC (i.e. non stochastic interest rates and volatility of the underlying asset does not explain the price discovery process of index futures contracts) does not hold true in the Indian market conditions. In addition to these two assumption of COC, another assumption of the model is not valid in Indian market i.e. strong arbitrage base is present to exploit the persistent price spreads.

As already discussed, in India, institutional traders have limited access to the F&O segment; therefore, persistent price spreads may not be fully exploited because in the presence of restrictions on trading by institutional traders, retail traders (who base their investment decision on firm-specific information, which may be little stale or late (Thomas (2006))) are dominating the total trading activity in the segment. Nonetheless, short sales per se are allowed in India but if portfolio managers can participate in Indian derivatives markets with the objective of rebalancing their portfolio not to take speculative positions and that too up to limited amount, it means indirectly short sales restrictions are levied upon them, which might constrain them to plug the price gap. Therefore, the present study concludes that COC does not fit into the Indian market conditions.

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