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Testing Futures Market Efficiency and Optimal Hedge Ratio Estimation: Evidence from Futures and Options on RTS

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ABSTRACT

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This study investigates futures market efficiency and optimal hedge ratio estimation. First, cointegration between spot and futures prices is studied using Johansen method, with two different model specifications. If prices are found cointegrated, restrictions on cointegrating vector and adjustment coefficients are imposed, to account for unbiasedness, weak exogeneity and prediction hypothesis. Second, optimal hedge ratios are estimated using static OLS, and time-varying DVEC and CCC models. In-sample and out-of-sample results for one, two and five period ahead are reported.

The futures used in thesis are RTS index, EUR/RUB exchange rate and Brent oil, traded in Futures and options on RTS.(FORTS) For in-sample period, data points were acquired from start of trading of each futures contract, RTS index from August 2005, EUR/RUB exchange rate March 2009 and Brent oil October 2008, lasting till end of May 2011. Out-of-sample period covers start of June 2011, till end of December 2011.

Our results indicate that all three asset pairs, spot and futures, are cointegrated. We found RTS index futures to be unbiased predictor of spot price, mixed evidence for exchange rate, and for Brent oil futures unbiasedness was not supported. Weak exogeneity results for all pairs indicated spot price to lead in price discovery process. Prediction hypothesis, unbiasedness and weak exogeneity of futures, was rejected for all asset pairs. Variance reduction results varied between assets, in-sample in range of 40-85 percent and out-of sample in range of 40-96 percent. Differences between models were found small, except for Brent oil in which OLS clearly dominated. Out-of-sample results indicated exceptionally high variance reduction for RTS index, approximately 95 percent.

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Tutkielman tarkoituksena on tutkia futuuri markkinoiden tehokkuutta sekä optimaalista suojauslaskenta kerrointa. Ensiksi, spot ja futuuri hintojen yhteis-integraatio tutkitaan käyttäen Johansenin menetelmää, kahdella eri malli spesifikaatiolla. Löydettäessä yhteisintegraatio, asetetaan rajoitteita yhteis-integratio vektorin sekä muutoskertoimen parametreille, futuurien harhattomuuden sekä heikon eksogeenisuuden toteamiseksi. Toiseksi, optimaaliset suojaus-kertoimet muodostetaan käyttäen staattista OLS, sekä ajassa muuttuvia DVEC sekä CCC malleja.

Tutkittavina futuureina käytetään, Futures and options on RTS (FORTS), markkinalla vaihdettuja RTS indeksi, EUR/RUB valuuttakurssi sekä Brent öljy futuureja. In-sample periodi vaihtelee kaupankäynnin aloituspäivän mukaan, RTS indeksi elokuusta 2005, EUR/RUB valuuttakurssi maaliskuusta 2009 ja Brent öljy lokakuusta 2008 alkaen, loppuen 31. toukokuuta 2011. Out-of-sample periodi kattaa kesäkuun 2011 alusta joulukuun 2011 loppuun.

Tulokset osoittavat että kaikki spot ja futuuri omaisuuserät ovat yhteisintegroituneita. RTS indeksi osoittautui harhattomaksi, molemmilla malli spesifikaatioilla, valuuttakurssi toisella, sekä Brent öljy osoittautui harhaiseksi. Heikon eksogeenisuuden testi tulokset kaikille pareille osoittavat spot hintojen johtavan hinnan muodostus prosessissa. Yhdistetty hypoteesi, harhattomuus sekä futuurien heikko eksogeenisuus, hylättiin kaikille pareille. Malleilla estimoitujen optimaalisten suojaskerrointen erot arvopaperien kesken olivat pienet, lukuun ottamatta Brent öljyä, jossa OLS dominoi selvästi. Out-of-sample tulokset osoittivat poikkeuksellisen suurta varianssin vähennystä RTS indeksille, likimäärin 96 prosenttia.

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1. Introduction

1.1 Background

Development of Russian financial markets has been considerably rapid and eventful. Russian trading system (RTS) was established in 1995 as first regulated stock market. At the same time RTS Index was first calculated to account as benchmark for exchange's 50 most capitalized shares. In 2001 trading in Futures and options on RTS (FORTS) was established, and in shadow of 1998 crisis, trading was started nearly at a scratch. Currently, FORTS provides futures and options on shares and bonds of leading Russian firms, RTS Index, interest rates, exchange rates and various commodities, where total of 47 contracts are offered. Statistics provided by Futures Industry Association (FIA) ranks FORTS to be tenth largest derivative market, by number of contracts traded, in year 2011 with 74 percent growth from last year.[1] RTS Index futures is the most liquid derivative in FORTS and, in reference to statistics of FIA, is ranked the third most actively traded equity index futures contract in the world. At the moment FORTS is leading derivative market of Russia and Eastern Europe, however, little attention has been given to quantitative analysis of derivatives traded in market place. To our knowledge there is no previous research, where methods used in thesis have been applied on futures traded in FORTS.

This thesis should be particularly useful for risk managers, institutional investors and speculators operating in FORTS, alike academic researchers. Short discussion of modern corporate risk management theory may also be beneficial for corporate risk managers adjusting their risk management policy. Main focus is on quantitative analysis and serves especially participants looking for analysis of RTS Index, EUR/RUB exchange rate and Brent oil futures.

[1] See, Acworth, W. (2012).

1.2 Objectives and research methodology

Market participants can use futures to speculate, to arbitrage and most importantly, to manage price risks arising from business and investment operations. To be successful in hedging operations done with futures, one would expect futures market to work efficiently, that being futures prices should work as an optimal price estimates of future spot price. As futures are mainly used to hedge against market risk, estimation of optimal hedge ratio is among others one of the most important aspects for risk managers, investors and researchers. In thesis we shed light to above questions. Research questions are summarized below

Q1 What are main sources of hedging benefits for firms operating in imperfect markets in reference to modern corporate risk management theories and does hedging have effect on firm value?

Q2 Are spot and futures prices bound together in a long run, thus do prices share a common trend and is there a risk premium included in futures prices?

Q3 Which one, if none, spot or futures lead in price discovery process and are futures prices jointly, unbiased and lead in price discovery?

Q4 Do time-varying models perform better in hedging effectiveness compared to static model?

The question number one is purely based on a literature review about the conventional theories used to explain why hedging would lead to appreciation in firm value and in what situation especially firms should consider active risk management policy. Short review on research done on hedging effect on firm value is also presented.

Intuition behind second research question is, that as spot and futures of the same asset react to same information, short-run deviations between prices are possible but in a long run spot and futures prices are expected to share equilibrium in which the two converge. Thus, deviation without a bound would imply futures market inefficiency. To answer latter question cointegration tests are usually employed. In thesis, cointegration between spot and futures is tested using Johansen cointegration method. Cointegration is regarded as simple efficiency. As Lai and Lai (1991) argue, existence of cointegrating vector is not yet sufficient for futures market efficiency. In addition of cointegration, spot and futures prices should be unbiased predictors of the future spot price. Unbiasedness implies that there is no risk premium and futures work as an optimal forecast of future spot price. Unbiasedness is studied by imposing restrictions on cointegrating vector coefficients. Methods used in thesis have also been used by (e.g. Lai and Lai 1991; Crowder and Hamed 1993; Switzer and El-Khoury 2007).

To answer third research question about price discovery, restrictions on adjustment coefficient in vector error correction model (VECM), are employed. Adjustment coefficient values the rate of adjustment from short term variations to long-run equilibrium. Intuitively, if one of the assets shows no adjustment to long-run equilibrium, we conclude that it leads in price discovery. Joint test, unbiasedness and weak exogeneity of futures, also referred as prediction hypothesis are tested. Prediction hypothesis bases on the assumption, that for futures market efficiency futures prices should be unbiased and lead in price discovery, assumption which still requires confirmation. Naturally, prerequisite for unbiasedness, weak exogeneity and prediction hypothesis tests is cointegration between spot and futures prices. Similar procedures have been used by (e.g. Crowder and Phengpis 2005; Floros and Vougas 2008; Carter and Mohapatra 2008).

To derivation of optimal hedge ratios, static and time-varying models are used. Static optimal hedge ratio (OHR) is derived regressing spot on futures prices from where slope coefficient is used as constant OHR for whole sample period. However, if the joint distribution of the spot and futures prices is changing over time, the classical constant hedge ratio might be inappropriate. It is well known in the finance literature, that asset returns typically exhibit time-varying conditional heteroskedasticity. As time-varying models adjust to changes in (co)variance, enhanced results are expected, results though have been mixed. In thesis Diagonal Vec (DVEC) and Constant conditional correlation (CCC) models are employed. The portfolio approach is used in thesis, where aim is minimizing the portfolio variance. Hedge effectiveness is reported as hedged portfolios variance reduction percentage compared to spot variance. Results for in-, and out-of-sample are presented. OHR methods and models used in thesis, have been studied among various assets by (e.g. Baillie and Myers, 1991; Bera et al. 1997; Hsu et al. 2008; Park and Jei 2010; Chang et al. 2011).

1.3 Limitations

EUR/RUB exchange rate and Brent oil futures have been traded for limited time in FORTS. Relatively short period may influence tests, as shorter time period may capture trends created by irrational investors, which in a long-run would be cleared off. In addition, small sample size bears lower test power. Spot and futures values for exchange rate and Brent oil are taken from different markets and are not closed exactly the same time. Due to previous limitations, some consideration is needed while interpreting results of exchange rate and Brent oil. RTS Index sample period is well sufficient and spot and futures are closing date at the same time.

In thesis efficiency results are based on error correction (ECM) framework. Results of test indicate no risk premium between spot and futures prices and if risk premium exists, it is time invariant. In addition of assumption of time-invariant risk premium, ECM model can only account for linear price dynamics in the conditional mean of spot prices, and further as ECM estimation relies on ordinary least squares (OLS) estimation, variance is expected to be constant. Results of time-varying risk premium are mixed, (e.g. McKenzie and Holt 2002) found support for time-varying risk premium assumption.

We expect univariate distributions to follow normal distribution, assumption which due to empirical nature, leverage effects and asymmetric responses to uncertainty, of financial returns may not be supported. While estimating conditional optimal hedge ratios multivariate GARCH (MGARCH) models are employed. We estimate models with assumption that spot and futures returns follow a multivariate normal distribution with linear dependence. Linear dependence between spot and futures is argued to be rational as both assets react to same information. In favor of models, that permit non-linear and asymmetric dependence between spot and futures was argued by (e.g. Hsu et. al. 2008).

1.4 Structure

The rest of this master´s thesis is organized as follows. In chapter 2, theoretical framework, we discuss corporate risk management theories and present research results on hedging effect on firm value. Secondly, in theoretical framework derivation of futures prices using no-arbitrage pricing relation for different assets is presented. Thirdly, futures market efficiency theory is explained and last, optimal hedge ratio methods are introduced. In chapter 3, methodology of all tests and models used in thesis are explained in detail. In chapter 4 we describe used data. In chapter 5 we present results of the futures market efficiency tests and hedging effectiveness results. Chapter 6 finishes in conclusions.

2. Theoretical framework

In a classical Modigliani and Miller (M&M) world with perfect capital markets, risk management should be irrelevant. In a world with no information asymmetries, taxes, or transaction costs hedging financial risk should not add to firm value as shareholders can undo any risk management activities implemented by the firm at the same cost. In practice however, capital markets are not perfect, and these imperfections create a rationale for lowering the volatility of earnings through hedging. Conventional explanations address to the cost of financial distress, tax incentives, the under investment problem, and managerial risk aversion. Risk management may though also add value, if hedging positions in derivatives contracts carry a premium that is not commensurate with risk, or if active trading creates a profit.

The last two decades have witnessed a dramatic increase in the number of research studies seeking to explain why firms hedge, yet there is no well accepted framework which practitioners could use while setting their risk management strategies. Research involving corporate hedging theories has been partly deluded by the lack of decent and large data-bases but the situation is expected to improve as firms are required to present information on risk management policies. In next section we present the most popular methods that have been used to challenge M&M proposition that risk management is irrelevant.

2.1 Corporate risk-management theory

The cost of bearing risk is a crucial concept for any firm. Most financial policy decisions, whether they concern capital structure, dividends, capital allocation, capital budgeting, or investment and hedging policies, revolve around the benefits and costs of a firm holding risk. (Froot, 2007) In their groundbreaking research, Modigliani and Miller (1958), show and deduct that with fixed investment policy and with no contracting costs or taxes, financing policy of the corporate is irrelevant. If firms were to change their financing policy by hedging, investors holding assets issued by the firm could offset hedging policy effect by changing their own holdings of the risky assets accordingly. By being so, hedging would have no effect on the investors overall distribution of wealth, and financing policy would be irrelevant. If this were to be true and hedging policy still would affect corporate value, hedging effects would have to arise from aspects affecting the firm, which could not be offset by investors.

Corporate risk management theory, however, identifies several market imperfections, that can make volatility costly. Conventional market imperfections include taxes, financial distress costs, underinvestment costs and managerial risk aversion. These conventional models are based on theoretical models and are most used in literature. Next we present the conventional theories, used to argument in favor of active risk management and research done on these theories. We complete in hedging activities effect on firm value.

2.1.1 Taxes

Smith and Stulz (1985) were the first to develop theory of tax argument. With respect to their research, if firm faces a convex tax function and if hedging reduces the variability of the taxable income, by using Jensen's inequality the firm will end up with a lower tax liability. For a firm facing some form of tax progressivity, when taxable income is low, effective marginal tax rate will be low. When income is high, tax rate will be high. If such a firm were to hedge, the tax increase in circumstances where income would have been low is smaller, than the tax reduction in situation where income would have been high, thus lowering expected taxes. As the convexity of the tax schedule increases, reduction in expected taxes increases, leading to the after tax firm value increase and vice versa. As a result of the convex tax function, as long as hedging costs do not exceed benefits, hedging increases after tax corporate value. Tax schedule convexity is directly related to statutory progressivity. While progressivity increases so does convexity. Progressivity is not only one affecting convexity. Tax prefence items do also have an effect. These Items are tax loss carry forwards, foreign tax credits and investment credits. These proposition were found, among others, to be consistent by Nance et al. (1993), as they found that firms with more tax credits use significantly more hedging instruments, as do firms which have more income coming from the region where statutory tax schedule is more progressive.

It is though worth of noticing that three variables mentioned, are measures of the tax function convexity. As they provide information about existence of the tax advantage they do not provide information about the level of the advantage. Graham and Smith (1999) produce a simulation where they calculate a potential savings for selected hedging cases. Assuming that taxable income follows a random walk with drift and that hedging reduces the volatility of taxable income. Their simulation indicates that as firms with convex tax functions are assumed by hedging to reduce taxable income volatility by five percent, induces tax liabilities base savings by on average, 5.4 percent. The distribution is skewed and by being so for the firms in 99^{th} percentile potential tax savings are nearly 50 percent.

2.1.2 Financial distress costs

Financial distress cost appears, when promises to creditors are broken or honored with difficulty. Investors know that levered firms are more prone to fall into financial distress. Costs of financial distress depend on the probability of distress and the magnitude of costs encountered if distress occurs. (Brealey, et al. 2008) Assuming that financial distress is costly, firm is better off with hedging activities as they reduce the probability of it. According to Smith and Stulz (1985), alongside taxes, financial distress costs also give an explanation why firms hedge. Assuming a fixed investment policy, they argue that even though hedging is costly, it can decrease the present value of financial distress costs. While financial distress costs, expected value of direct bankruptcy cost and the loss of debt tax shield, are decreased consequently shareholder wealth increases by hedging.

Financial distress costs affecting hedging decisions have been mainly studied using leverage, (e.g., Graham and Rogers 2002; Haushalter 2002) and interest coverage ratio (e.g., Nance et.al. 1993; Berkman and Bradbury 1996). Different variables mentioned provide decent information on what variables should be used while measuring for financial distress costs and how probable they are, yet they fail to correspond to question how costly these costs are in general. To tackle this problem, Graham and Rogers (2002) have combined leverage with firm’s market to book ratio. By doing so they are able to capture information on probability of financial distress and also the costs of distress. Results indicate that firms hedge to in response of expected financial distress costs.

2.1.3 Underinvestment costs

Underinvestment cost refer to situation where shareholders are not willing to forego positive net present value projects as the main proportion of the gains made by investments go to bondholders. Firms having not sufficient internal funds and most financially constrained suffer most from underinvestment. Problem can be alleviated by hedging. Froot et al. (1993) argue that by hedging firm can add value, as it helps to ensure that a firm has sufficient internal funds available as interesting investment opportunities arise. Further, Morellec and Smith (2002) state that risk incentives balance two opposite effects of hedging on the firm’s investment policy. First, hedging allows better control of the free cash flow problem and thus increases the level of investment in a short run. Second, hedging reduces the firm’s credit risk and increases the level of investment in the long run. Additionally managers who have growth options in their use, are more willing to hedge, even though hedging constrains short term investment, it reduces the probability of default and increases positive NPV investments in a long run.

2.1.4 Managerial risk aversion

Due to managers human capital and compensation value tied to the profitability of the firm value, managers are usually less diversified than regular shareholders. Consequently they will require additional compensation for this greater risk baring. As a result, managerial risk aversion provides an incentive for managers to manage risk through hedging activities as risk management could lead to lower managerial compensation.

According to Smith and Stulz (1985) managers are expected to hedge, as long as their expected utility is a convex function of the firm value, even though their expected utility is a concave function of their personal wealth. By this reasoning it is appropriate to expect that managers holding options are less willing to hedge less, as options create a convex relation between the manager's utility and firm value. This theorem has been supported by Rajgobal and Shevlin (2002) and Rogers (2002) among others. Smith and Stulz (1985) further argue that compensation packages that lead to concave function between manager's wealth and the firm value should enhance managers hedging practices. Accordingly managers holding significant stock proportions of the firm should be more interested and more active in the firms risk management activities.

To be optimal about the compensation through options, Carpenter (2000) has used a dynamic portfolio choice problem where manager is paid with an option he can't hedge. Carpenter shows that option compensation does not necessarily lead to higher risk seeking by the managers as according to her model stock options create two opposing effects to the manager's wealth. Firstly, as options are more valuable as volatility increases, payoffs from options become more important to the managers and hence they are expected to hedge less. Secondly, as if stock price decrease, option value becomes less valuable and though inciting more hedging to prevent stock prices to decrease in value. She shows that managers who are paid in options and when second proposal is advancing, managers become more hedged. For example, results from her research were confirmed by Knopf et al. (2002).

2.1.5 Hedging premium

After getting acquaintance with corporate risk-management theories, reasons why hedging should increase value of firm operating in imperfect markets, next we present research done on hedging activities affect on firm value. Allayanis and Weston (2001) examined usage of foreign currency derivatives of 720 large U.S. nonfinancial firms. They used Tobin's Q as a proxy for firm value and found hedging premium to be 4.87 percent for firms facing currency risk. Hedging premium was found both statistically and economically significant. Contradicting results were found by Jin and Jorion (2006). They studied hedging activities of U.S. oil and gas producers and found hedging activities to reduce sensitivity of firm's stock value to oil and gas prices, but no evidence in favor of market value increase. Carter et al. (2006) investigated firm hedging behavior within U.S. airline industry. Air line industry is regarded to fit especially well to analyzing purposes, as industry is largely homogenous and competitive. Research focuses hedging of jet fuel, which is grucial for profitability of the firms as higher jet fuel prices result in lower cash flow. Results indicated hedging premium to be approximately 12-16 percent, resulting mainly from reduction of underinvestment costs.

2.2 Futures price valuation

Futures and forwards with same price and same delivery date can be considered equal. Forward contract is an agreement to deliver a specified quantity of an asset or commodity at a specified future date, at a price (the forward price) to be paid at the time of the delivery. The asset specifications and point of delivery (as well as quantity, price and date of delivery) are spelled out in the contract. There are two parties to a forward contract: the buyer (long position), who will receive the asset or commodity and pay the forward price, and the seller (or short position), who will deliver the commodity or asset specified in contract. Forward contracts are usually traded directly among producers and industrial consumers of the commodity and in some cases they are traded in organized exchanges.

A futures contract is also an agreement to deliver a specified quantity of a commodity or an asset at a determined future date, at a price (the futures price) to be paid at the time of delivery. As compared to forwards, which are usually traded over-the-counter, futures contracts are often traded on organized exchanges, such as the New York Mercantile exchange (NYMEX), Intercontinental Exchange, (ICE) and Futures and options on RTS (FORTS). Futures and forwards differ slightly in pricing due to the margin used in futures contract, but in general presented pricing methods can be applied to both. For simplicity, now on, in thesis futures are used as a proxy for forwards also.

2.2.1 No income paying asset

Futures contracts can and usually are priced using a no-arbitrage pricing relationship between the futures and spot prices. At first we look at the simplest case of a future contract on underlying asset, which pays no income. In latter situation relationship between the futures contract and the spot price becomes as in equation (1)

$$F = Se^{r(T-t)} \tag{6}$$

Where F is the price of future contract, S the spot price of underlying asset, e the exponential operator, for conditional compounding, r is the risk free rate and, $(T - t)$ the time until maturity of the futures contract.

In written, price of the contract depends on the current price of the underlying financial asset, the risk free rate and the time to the maturity. Noticeable is that the risk free rate is used, instead of required rate of return. The reason behind this is that there would exist arbitrage opportunities if equation (1) did not hold. For example consider situation, where $F > Se^{r(T-t)}$. Arbitrager could make certain profit by first, borrowing cash at risk free interest rate and would use the money to buy underlying asset at spot price S. Second, investor would sell the underlying asset to be delivered at time T at the futures price F. Finally, at the maturity of the contract arbitrager would deliver the underlying asset, pay the interest on borrowed money and receive the futures price. If the opposite $F < Se^{r(T-t)}$ incurred the reversed action would be taken. Usually futures contracts on financial assets are not settled by physical delivery of the underlying asset but in cash. (Anson, 2002)

2.2.2 Currencies

While considering foreign currency as income producing asset, when investor can earn interest on bond nominated in a foreign currency. Interest received is nominated on foreign currency and rate being foreign risk free rate. In this context the relationship between a futures contract on foreign currency and the current spot price can be shown as in equation (2)

$$F = Se^{(r-f)(T-t)} \tag{2}$$

Where terms are defined the same as in equation (1) and f is the foreign risk free rate. Equation (2) simultaneously expresses covered interest rate parity theorem that states exchange rates between currencies will depend upon differences between interest rates in countries. In this case one can say that currency futures are priced using a no-arbitrage pricing relationship between futures and spot prices. Investor would be indifferent between, investing in domestic bonds, and converting domestic funds into foreign denominated funds at a current spot price, investing in foreign bonds and converting these funds back into domestic funds at the previously contracted futures rate. Where, difference in interest rates is regarded as a differential or cost of carry. (Brenner and Kroner, 1995; Moosa, 2003)

2.2.3 Dividend paying assets

Most financial assets pay some form of income specifically independent stocks in form of dividends. Stock index futures trace the movement of an underlying index so that all the changes in stocks comprising the index are taken into account. When value of the underlying stock changes so does the value of the index accordingly. Usually stock indices are not adjusted for dividends, so while owner of the stock receives cash dividend, owner of the indices do not. If that is the case, in response to this one must take into account the lack of dividend payments. In general dividend paying assets are priced as in equation (3)

$$F = Se^{(r-q)(T-t)} \tag{3}$$

Where terms are defined the same as in equation (1) and q is equal to the dividend yield on the stocks that comprise the index. In general, if dividend yield were not taken into account one could borrow at risk free rate and while dividend yield lowers overall interest rate, arbitrage possibility would emerge (Hull, 2002).

2.2.4 Commodities

Commodities are not financial assets but the pricing relation of spot and futures price is similar to financial assets with specific variables augmented for purposes of pricing physical assets. First variable is storage costs. Physical assets must be stored, and costs arising from this factor should be included in the pricing equation. Storage costs are seen as cash outflow when holding a commodity, increments costs and these costs should be included while pricing commodity futures. Futures pricing equation with storage costs included is presented in equation (4)

$$F = Se^{(r+c)(T-t)} \tag{4}$$

Where terms are defined the same as in equation (1) and c is equal to storage cost associated with ownership of the commodity.

Second variable differing from financial assets is convenience yield. Owners of the physical assets may feel they have some benefit arising from owning the physical asset, rather than obtaining futures contract. These benefits may be, for example, ability to profit from temporary or local supply and demand imbalances, the ability to keep production line running, or for certain metals pay lease rates. As convenience yield is taken into account pricing is conducted as in equation (5)

$$F = Se^{(r+c-y)(T-t)} \tag{5}$$

Where terms are defined the same as in equation (1) and y is the convenience yield. As convenience yield is reducing the cost of holding the asset, it is subtracted from the risk-free rate and the storage costs. For commodities arbitrage possibilities differ slightly from financial assets as commodities are difficult to borrow. Consequently, they can´t be shorted same way as financial assets. So if we assume $F > Se^{(r+c-y)(T-t)}$ investor should borrow S to purchase the underlying commodity and sell the futures contract F for receiving arbitrage profit. Reverse though does not work, if investor does not already own the commodity. (Moosa, 2003) As we have presented how different futures are priced, we next turn to section where we review in detail how futures market efficiency has been studied and how it is executed in thesis.

2.3 Futures market efficiency

Great amount of research has focused on analyzing the relationship between spot and futures prices, and their returns. The efficient market hypothesis is essential in understanding and decision making in both speculation and hedging. In financial decision making efficient market hypothesis is also important while deciding optimal allocation of assets and associated risks, as futures are expected to work as an optimal forecast of the future spot price.

As Fama (1970) pointed out, weak form efficiency, or speculative efficiency hypothesis, of financial market is considered when prices fully reflect all available information and no profit opportunities are left unexploited. While joint assumptions of risk neutrality and rationality hold, in efficient markets the expected returns of speculative decisions should be zero. Further, forward and futures markets current price of asset delivered in specific date should work as an unbiased and efficient predictor of the future spot rate (Kellard, 2002). Hypothesis has been studied extensively across different financial assets and commodities. However, due to author´s knowledge, futures market efficiency has not been studied on futures traded on FORTS, therefore thesis provides valuable new information about dynamics of assets traded in market place.

Following Delcoure (2003), as unbiasedness hypothesis states, under risk neutrality and rational expectations futures rate is expected to be an unbiased predictor of the spot rate. As we expect no risk premium in markets, expected futures rate can be presented as in equation (6)

$$E_t(S_{t+k}) = f_t \tag{6}$$

Where f_t is the futures rate at time t to be delivered k periods later, S_{t+k} is corresponding spot rate at time $t+k$ and E_t is expectations operator conditional on the information set available at time t. Because $E_t(S_{t+k})$ is yet unobservable, under rational expectations futures rate can be presented as in equation (7)

$$S_{t+k} = E_t(S_{t+k}) + \mu_{t+k} \tag{7}$$

Where μ_{t+k} is the rational expectations realized forecast error, which must have conditional expected value of zero and be uncorrelated with any information available at time t. When we substitute two above equations, unbiased futures prices are expected to follow equation (8)

$$S_{t+k} = f_t + u_{t+k} \tag{8}$$

Unbiasedness hypothesis stated in equation (8), has traditionally been studied by using regression model presented in equation (9)

$$S_t = \alpha + \beta F_{t-1} + \epsilon_t \tag{9}$$

Where S_t is the spot price at time t, F_{t-1} is futures price at time $t-1$ and ϵ_t is error term with mean zero and finite variance, and α and β are constant coefficients. As stated above no such strategy should exist where traders can profit consistently speculating in futures markets for future spot price. By being so, efficiency is tested by restrictions, $\alpha = 0$, and $\beta = 1$, in equation (9) to hold. However, as price series are usually found to be non-stationary and contain unit root, results from the regression model and parameter restrictions are no longer appropriate. (Elam and Dixon, 1988)

Lai and Lai (1991) were the first ones to provide alternative solution for traditional efficiency tests based on constant coefficient restrictions in regression model. Usage of cointegration analysis basis on idea, that as spot and futures prices of same asset or commodity are influenced by same fundamentals and news, prices should not deviate far apart without bound. Further the hypothesis suggests that futures price is on average unbiased predictor of the spot price and futures prices should not consistently over or under predict the spot prices. Futures prices should not also include risk premium. Lai and Lai (1991) argued cointegration to be one of the necessary conditions for futures market efficiency. In addition restrictions for the cointegrating vector parameters are tested to provide evidence on the joint hypothesis of market efficiency and no risk premium.

If cointegrating vector is found between spot and futures time series, unbiasedness of futures market is tested by imposing restrictions on the cointegrating vector. For futures prices to be unbiased forecasts of the spot price, cointegrating vector should equal $\beta' = (\beta_1 \beta_2) = (1, -1)$. Test of the unbiasedness hypothesis can be convoyed by Likelihood ratio (LR) test, where test statistic follows χ^2 distribution, with one degree of freedom. (Johansen, 1991) If, $h_0: \beta' = (\beta_1 \beta_2) = (1, -1)$, is not rejected, we conclude that equation (8) holds, and futures work as an unbiased predictor of the spot price.

We test weak exogeneity of spot and futures prices to test, which of the variables lead in price discovery. To test for weak exogeneity, we impose restrictions on adjustment coefficient in error correction equation. Intuitively testing for adjustment coefficients a implies, which of the variables are the main source of the common trends. Retracing Johansen (1991), interpreting a as the common trend and β as the factor loadings. Interpretation is, if aXt is found weakly exogenous to the long-run parameters, adjustment coefficient a does not respond to disequilibrium in the system. As spot and futures prices are studied, weakly exogenous variables are causally prior to other. Thus, weak exogeneity can be used to test which series adjusts to new information first and leads in price discovery. Weak exogeneity is studied using LR test statistic distributed χ^2 with one degree of freedom. Hypothesis tested are $\alpha_s = 0$ and $\alpha_f = 0$. If null hypothesis is not rejected, we conclude that variable has no effect on the adjustment to the long-run equilibrium. Moreover, work as attractor for endogenous variables, ones that adjust to disequilibria. (Crowder and Phengpis, 2005)

Finally we perform joint test, combining the two hypotheses presented above. We test the joint hypothesis that futures are unbiased and futures adjustment coefficient is zero, also referred as prediction hypothesis. $h_0: \beta' = (\beta_1 \beta_2) = (1, -1), \alpha_f = 0$. (Carter and Mohapatra, 2008; Yang et al. 2001) While testing the prediction hypothesis, we assume that futures price lead in price discovery process or both adjust to disequilibrium simultaneously.

To our knowledge FORTS has not been used to test for futures market efficiency by methods developed above. In other markets futures market efficiency, has been studied extensively for oil spot and futures prices, few to mention Crowder and Hamed (1993) and Switzer and El-Khoury (2007). In their research, spot and futures prices were found to be cointegrated. In addition they found oil futures to be unbiased predictors of the future spot price. For exchange rates Lai and Lai (1991) found cointegration vector between spot and futures prices and rejected the hypothesis for futures unbiasedness. Carter and Mohapatra (2008) used hog futures. In their research, cointegration was found, in addition of weak exogeneity of futures and also support for prediction hypothesis. Floros and Vougas (2008) studied Greek stock index futures, FTSE/ASE-20 and FTSE/ASE MID40, and found cointegration between spot and futures prices and futures prices to lead in price discovery. Stock index futures efficiency has also been studied by Crowder and Phengpis (2005). They studied S&P 500 spot and futures prices and also found cointegrating vector between spot and futures stock index prices. Unbiasedness hypothesis was not supported by their results. They found spot prices to be weakly exogeneous, thus futures prices were adjusting to spot price and spot price was leading in price discovery.

In general, cointegration between spot and futures prices is found. Results from unbiasedness, weak exogeneity and prediction hypothesis differ more between assets and time periods used in research.

2.4 Optimal hedge ratio estimation

Optimal hedge ratio estimation has been in the interest of risk managers and researchers alike. Futures have been extensively used to manage price risks, and in such situation estimation of optimal hedge ratio is grucial. In respond, methods to derive optimal hedge ratio estimates are extensive. Differences are in objective function to be minimized and models used in optimal hedge ratio estimation. The most used objective function is based on the minimization of the variance of the hedged portfolio. Minimum variance (MV) method ignores the expected return of the hedged portfolio and MV method has been argued to be inconsistent with mean-variance framework. However it can be shown, that if futures prices follow pure martingale process, MV and mean–variance methods provide same optimal hedge ratio estimates. Mean-variance based strategies are developed to maximize expected utility. Problem with maximization of expected utility is that if utility function is not quadratic or the returns are not jointly normal, hedge ratio estimated is not optimal. To tackle these problems minimization of the mean extended-Gini (MEG) and generalized semivariance (GSV) method are proposed. Without going into detail of derivation, Shalit (1995) shows, that if prices are normally distributed MEG and MV hedge ratios will be the same. For GSV model, Lien and Tse (1998) show that if the spot and returns are jointly normally distributed and if the futures price is pure martingale process, GSV is equal to MV hedge ratio. For more detailed discussion between methods we refer to Chen et al. (2003). As presented, under different assumptions alternative methods converge to MV method. As we are not familiar with return distributions, for the ease of computation and overall popularity, MV hedge ratio is used in thesis.

As differences among objective function exists, even more diverse are models used to estimate optimal hedge ratio. Conventional optimal hedge ratio estimate is derived from ordinary least square (OLS) regression model. Optimal hedge ratio is derived regressing spot returns against futures returns. OLS method derived by OLS is static model as the same optimal hedge ratio is used for estimated sample period and variance and covariance are expected to be constant. Other more complex models allow optimal hedge ratio to change over time. Time-varying, also referred as conditional, models expect variance and covariance to change over time and in response, optimal hedge ratio changes also. Time-varying models are usually based on univariate ARCH and GARCH models, where parameterization differs between models. The most popular models include BEKK, Diagonal BEKK, Diagonal vec (DVEC), constant conditional Correlation (CCC) and dynamic conditional correlation (DCC). In thesis OLS, DVEC and CCC models are employed in optimal hedge ratio estimation.

Baillie and Myers (1991) were one of the first ones to compare and estimate optimal hedge ratios using time-varying models. They used six commodities and found time-varying DVEC model to outperform static OLS. Variance reduction between assets varied between 56.8 percent for soybeans, compared to 1.6 percent in beef prices. Yang and Allen (2005) studied Australian stock index futures and found time-varying models outperform OLS model in terms of minimizing variance. Bera et al. (1997) studied hedging effectiveness for corn and soybeans and found DVEC model to provide largest reduction in the hedged portfolio variance. Hsu et. Al. (2008) studied FTSE100 and S&P500 futures. In-sample results for FTSE100 indicated CCC model to outperform static OLS and reverse for S&P500. Out-of-sample results indicated higher variance reduction for both FTSE100 and S&P500 when CCC model was applied. Results for optimal hedge ratio research are mixed as results differ between used assets and sample periods. In general, differences in variance reduction between models are usually found small. As there is no clear evidence in favor of one time-varying model to be superior over another, or even time-varying models to clearly outperform OLS model, due to shortcomings and expectations that may be too restrictive in all time-varying models. We have chosen to use static OLS and time-varying DVEC and CCC models, whose benefits, shortcomings and derivation are presented in next section.

3. Methodology

In this section we present methodology of different tests used in thesis. We start with unit-root test, which is important in detecting order of integration of time series. We then continue to present methodology of Johansen cointegration method, used to model futures market efficiency, in terms of cointegration, unbiasedness, weak exogeneity and prediction hypothesis. After cointegration methodology, we present optimal hedge ratios derivation models. As time-varying models are based on univariate general autoregressive conditional heteroskedasticity (GARCH), GARCH estimation methodology is also provided. We finish in how out-of-sample estimates are forecasted.

3.1 Unit root test

Unit root testing is performed to test for detecting the presence of stationarity in time series. A unit root test is statistical test, for proposition that in an autoregressive statistical model, the autoregressive parameter is one. Stationarity in time series regards to situation where mean and variances of stochastic series are constant and time invariant. Non-stationary time series, however, exhibit time varying mean and variance which change over time. Applications used for testing for unit roots have shown that an economic time series usually are non-stationary and means and variances change over time. Non-stationarity in time series can also be interpreted as an efficiency test as stationary variable can be interpreted as variable, which is random and determination of values can't be derived from the previous data points.

Augmented Dickey-Fuller test, (ADF), is employed in thesis to test for unit roots. In Thesis ADF test of unit root is done using three models of processes, model without constant and trend, with constant but no trend, and with constant and linear trend. This result is tested in levels form. If levels form is found to be stationary, original data is differenced and tested again. If time series becomes non-stationary in its first difference it is said to be integrated of order one or,$I(1)$ In general series will be integrated of order d that is $I(d)$, when series becomes stationary after differencing d times, so series contains d unit roots. (Dickey and Fuller, 1981)

3.2 Johansen cointegration method

Prerequisite for Johansen cointegration test is that time series used are integrated of the same order. If time series are integrated of the same order and linear combination of these time series exist that is stationary, these series are stated as being cointegrated. Cointegration implies, that both time series move together in a long run and are bound to each other and cannot drift apart, in a long run.

Johansen approach is based on the vector autoregressive model (VAR) The vector Xt in equation (12) inhibits variables thought as endogenous and has the dimension, $n \times 1$, where n is number of endogenous variables. Each variable is estimated dependent on its own lagged variables and the lagged variables of other endogenous variables.

$$X = \Pi_1 X_{t-1} + \cdots + \Pi_k X t_{t-k} + \varepsilon_t \text{ with } t = 1, \dots, T \qquad (12)$$

The matrix of coefficients Π_k has dimension of $n \times n$. Referring to equation (12), VAR can be transformed to first difference form by subtracting the lagged variables of the endogenous variables from both sides. VAR model is presented as in equation (13)

$$\Delta X_t = + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-1} + \varepsilon_t \qquad (13)$$

where $\Gamma_i = I + \Pi_1 + \cdots + \Pi_i \; with \; i = 1, \dots, k-1$ and $\Pi = -(I - \Pi_1 - \cdots - \Pi_k)$ Information contained in matrices Γ_i are short-term adjustment coefficients for the lagged differenced variables. Long run relationship between time series is indicated by the error correction term in ΠX_{t-1}.

Conclusions about the number of cointegrating vectors are then made on basis of rank of the Π matrix. (Johansen and Juselius, 1990)

Johansen method is based on the rank of the matrix Π. Rank of the matrix shows number of linearly independent processes and as expected differences of the endogenous variables and their lagged differences are stationary. Being so, test for cointegration is based on the rank of matrix Π. If rank is found to be larger than 0 and less than endogenous variables, matrix Π can be decomposed matrices α and β so that $\Pi = \alpha\beta'$. In non-stationary vector process X_t can then be made stationary by creating linear combinations $\beta' X_t$. (Johansen, 1988) When process in equation (13) is made vector error correction model, matrix α is the speed of adjustment from long-run equilibrium, and matrix β contain coefficient of cointegrating, relation that is weight of the linear combination. (Johansen, 1998; 1991) Our restriction based efficiency tests are imposed on values of matrix α and matrix β.

The cointegration rank is tested by tests based on statistical significance of the matrix Π. Two tests are developed, Trace and Maximum eigenvalue tests. Hypothesis of Trace test is developed as, at most, r cointegrating vector against alternative rank $(\Pi) > r$.Trace test is based on likelihood ratio test presented in equation (14) (Johansen, 1988; 1991)

$$\lambda_{trace} = -T \sum_{i=r+1}^{p} \ln(1 - \hat{\lambda}) \tag{14}$$

Maximum eigenvalue test is second test proposed to test for cointegrating relation in a system. As trace test bases on idea that rank of the matrix is greater than, maximum eigenvalue test restricts more, as test is based on hypothesis, rank is r in addition to alternative hypothesis rank is, $r+1$. Maximum eigenvalue test is expressed in equation (15)

$$\lambda_{max} = -Tln \ln(1 - \hat{\lambda}_{r+1}) \tag{15}$$

Both of the tests are asymptotically distributed as χ^2 with $p - r$ degrees of freedom. Parameters, cointegrating vector, adjustment coefficients and eigenvalues are estimated using Maximum likelihood procedure. (Johansen and Juselius, 1990)

3.3 Static and time-varying models

After exploring dynamics of the futures markets using Johansen cointegration method, which gives valuable information about dynamics between spot and futures prices. Next, we move to present models used to derive optimal hedge ratios. Hedging efficiency has been mainly studied by using minimum variance methods, where variance of the hedged portfolio is to be minimized. Various models have been developed from static models to more complex time-varying models. Yet there doesn't exist indisputable consensus about which of the models outperform other and yet is the most efficient in estimation of optimal hedge ratio. As both static and time-varying models were chosen to be used in hedge ratio estimation, thesis will give modest stake to current dilemma, and for market participants trading ideas in FORTS.

3.3.1 Conventional model

As one period model is considered. At the beginning of the period economic agent has some untradeable long (short) spot position on a specific security that one wishes to hedge. To reduce the risk one goes short (long) in the futures market. The futures position is chosen to minimize the variance of the hedged portfolio. The optimal hedge ratio is defined as the amount of futures position per unit of spot position such that the hedged portfolio variance is minimized. (Lien et al. 2002)

Denoting, r_s as the return on spot, r_f as return on futures and F_{t-1}as the information set, the optimal hedge ratio denoted by h, can be calculated as in equation (16)

$$h = \frac{Cov(r_s, r_f / F_{t-1})}{Var(r_f, / F_{t-1})} \tag{16}$$

To estimate the hedge ratio, a conventional method involves estimating the following linear regression model in equation (17)

$$r_{st} = \alpha + \beta r_{ft} + \varepsilon_t. \tag{17}$$

where r_{st} and r_{ft} are the spot and futures returns, respectively, for period t and ε_t is the disturbance term. From the linear regression model (OLS) estimator β provides an estimate for the optimal hedge ratio h. Coefficient is used for whole in-sample and out-of sample period as an estimate of optimal hedge ratio.

Linear estimator properties have been extensively researched and well understood. Many models can also made linear by taking logarithms or some other suitable transformation but it is less likely and even expected that relationships within field of finance would actually be linear but intrinsically non-linear. Linear model also fail to tackle the problems faced with many financial data including leptokurtosis, volatility clustering and leverage effects. Leptokurtosis is financial asset returns tendency to have distributions that have fat tails and excess "peakedness" around the mean. Volatility clustering refers to situation where volatility in asset returns does not appear evenly but high (low) volatility, large (small) return changes, is expected to follow large (low) return changes of the same sign. Volatility also has a tendency to rise more due to fall in asset prices as for rise in asset prices of the same magnitude, which is called leverage effect. (Brooks, 2002)

The conventional method assumes that the second moments remain unchanged over time. However, it is well known in the finance literature that asset returns typically exhibit time-varying conditional heteroscedasticy. Thus, in attempt to enhance the estimation results, it is important to take account the possible time-varying nature of the second moments.

To take account for the possible time-varying moments, the hedge ratio may be estimated directly from the conditional moments. (Tse and Tsui, 2002)

3.3.2 Multivariate GARCH models

Conventional optimal hedge ratio is based on idea that the model is linear in the parameters so that there is one parameter multiplied by each variable in the model. While applying conditional time varying hedge ratios, it is considered similar to the conventional hedge ratio, except that the conditional variances and covariances replace the unconditional variances and covariances. By doing so, one can model time series, on accordance to changing joint distribution of the spot and futures prices. As it is well known in finance literature, that time series usually exhibit time-varying conditional heteroskedasticity, it is appropriate to take account for the possible time-varying in the second moments. Autoregressive conditional heteroskedasticity (ARCH) model developed by Engle (1982) and generalized ARCH (GARCH) model of Bollerslev (1986) has been extensively used as basis in modeling conditional optimal hedge ratios in futures markets as is done in thesis also.

As optimal hedge ratio estimation boils down on estimation of variance and covariance, accurate estimates are in pin point of our interest. Before Engle (1982) presented ARCH model, usually models to predict variance was based on weighted average of past events. Models biggest shortcoming was the fact that it weighted past values the same. One would argue that more recent values should have greater weight on the predicted value. ARCH models let these weights to be determined by the data and to determine best weights.

Bollerslev (1986) developed GARCH model that is also based on the idea of weighted average of past squared error. The idea in GARCH model is that best estimate of next periods variance is predicted by long–run average variance, the variance predicted for this period, and the new information in this period which is captured by the most recent squared residual. Weight parameters for these values are estimates that give the data best fit. This adaptive updating process is also regarded as bayesian updating. (Engle, 2001)

To model weak dependence of successive price changes following univariate GARCH specification is used to describe each series (Baillie and Myers, 1991)

$$\Delta y_t = \mu + \varepsilon_t \tag{18}$$

$$\varepsilon_t | \Omega_{t-1} \sim Nd(0, \sigma_t^2, v) \tag{19}$$

$$\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2 \tag{20}$$

where y_t is the logarithm of price; and $Nd(0, \sigma_t^2, v)$ represents the normal density distribution with zero mean, variance σ_t^2, and degrees of freedom v. Time-dependent conditional heteroskedasticity is accounted by the GARCH(1,1) model of Bollerslev (1986), in which ω is weight parameter for long-run average, α is weight parameter for most recent squared residual and β is weight parameter for variance predicted for this period.

A. Diagonal VEC (DVEC)

Motivation behind usage of multivariate GARCH (MGARCH) models in hedge ratio estimation is that spot and futures prices react to same information and in relation to this, have non-zero (co)variances conditional on the available information set. According to Bera et al. (1997), one can specify a general model

$$R_t^s = \mu_s + \epsilon_{st} \tag{21}$$

$$R_t^f = \mu_f + \epsilon_{ft}$$

$$\epsilon_t | \Omega_{t-1} \sim MN(0, H_t) \tag{22}$$

Where R_t^s and R_t^f are defined above, $\epsilon_t = (\epsilon_{st}, \epsilon_{ft})'$, MN denotes multivariate normal distribution and H_t is time-varying 2×2 positive definite conditional covariance matrix. General form of H_t for MGARCH (p,q) comes as in equation (23)

$$vech(H_t) = vech(C) + \sum_{i-1}^{q} \Gamma_i vech\,(\epsilon_{t-1}\epsilon'_{t-1}) + \sum_{i-1}^{p} D_i\, vech(H_{t-1}) \qquad (23)$$

Where C is 2×2 positive definite symmetric matrix and Γ_i and D_i are 3×3 matrices. The vech operation stacks the lower triangular elements of symmetric matrix in column. Parametrization given above is hard to estimate since positive definites of H_t is not assured without imposing non-linear parametric restrictions. Moreover the model contains too many parameters, e.g. for p=q=1, H_t has 21 parameters. To tackle this problem one can specify model by making assumption that a conditional variance depends only on its own lagged squared residuals and lagged values. By making this assumption Γ and D matrices become diagonal and by being so MGARCH (1,1) model is given by equation (24)

$$vech(H_t) = \begin{bmatrix} h^2_{ss,t} \\ h^2_{sf,t} \\ h^2_{ff,t} \end{bmatrix} = \begin{bmatrix} c_s \\ c_{sf} \\ c_f \end{bmatrix} + \begin{bmatrix} \gamma_{ss} & 0 & 0 \\ 0 & \gamma_{sf} & 0 \\ 0 & 0 & \gamma_{ff} \end{bmatrix} \begin{bmatrix} \epsilon^2_{ss,t-1} \\ \epsilon_{s,t-1}\epsilon_{f,t-1} \\ \epsilon^2_{ff,t-1} \end{bmatrix} - \begin{bmatrix} \delta_{ss} & 0 & 0 \\ 0 & \delta_{sf} & 0 \\ 0 & 0 & \delta_{ff} \end{bmatrix} \begin{bmatrix} h^2_{ss,t-1} \\ h^2_{sf,t-1} \\ h^2_{ff,t-1} \end{bmatrix} \qquad (24)$$

this form is called the diagonal vec, DVEC. Variance and covariance estimates are then estimated as expressed in equations 25-27

$$h^t_{ss} = c_t + \gamma_{ss}\epsilon^2_{ss,t-1} + \delta_{ss}h^2_{ss,t-1} \qquad (25)$$

$$h^2_{ff,t} = c_f + \gamma_{ff}\epsilon^2_{ff,t-1} + \delta_{ff}h^2_{ff,t-1} \qquad (26)$$

$$h^2_{sf,t} = c_{sf} + \gamma_{sf}\epsilon_{ss,t-1}\epsilon_{ff,t-1} + \delta_{sf}h^2_{sf,t-1} \qquad (27)$$

Where, c is weight parameter for long-run average, γ is weight parameter for most recent squared residual, and δ is weight parameter for variance predicted for this period. A disadvantage of the VECH model, however, is that it does not ensure the conditional variance-covariance matrix of the spot and futures returns to be positive definite.

B. Constant conditional correlation (CCC)

Bollerslev (1990) has developed an intruiqing model, constant conditional correlation (CCC) model which has extensively been used to optimal hedge ratio estimation. CCC is a simple conditional heteroskedastic time-series model where model has time varying conditional variances and covariance but constant conditional correlation. He argues that model greatly simplifies the estimation and inference procedures and yet furthermore assumption of constant correlations allows for obvious between period comparisons and tackles with well documented hetero-skedastic nature of dynamics of short run changes in asset prices. As we let y_t denote the $N \times 1$ time-series vector of interest with time-varying conditional covariance matrix H_t, i.e.

$$y_t = E(y_t|\varphi_{t-1}) + \epsilon_t \tag{28}$$

$$Var(\epsilon_t\ |\varphi_{t-1}) = H_t \tag{29}$$

An appealing feature is embedded in with constant conditional correlation, which relates to simplified estimation and inference procedures. By being so we can, according to Bollerslev (1990), rewrite each of the conditional variances as

$$h_{ijt} = \omega_i \sigma_{it}^2, i = 1, \dots, N \tag{30}$$

where ω_i is a positive time invariant scalar and $\sigma_{it}^2 > 0$ for all t. The full conditional covariance matrix H_t, is partioned as in equation (31)

$$H_t = D_t\,\Gamma D_t \tag{31}$$

where D_t denotes the $N \times N$ stochastic diagonal matrix with elements $\sigma_{1t}, \dots, \sigma_{Nt}$ and Γ is an $N \times N$ time invariant matrix with typical element $\rho_{ij}\sqrt{\omega_i \omega_j}$. It follows from now that H_t will be positive definite for all t if and only if each of the N conditional variances are well defined and Γ is positive definite. Comparing to other alternative parametrizations for the time varying covariance matrix, these are easy to impose and verify. CCC model in a matrix form is presented in equation (32)

$$H_t = \begin{bmatrix} h_{11.t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix} = \begin{bmatrix} \sqrt{h}_{11,t} & 0 \\ 0 & \sqrt{h_{22,t}} \end{bmatrix} \begin{bmatrix} 1 & \rho_{12} \\ \rho_{12} & 1 \end{bmatrix} \begin{bmatrix} \sqrt{h_{11,t}} & 0 \\ 0 & \sqrt{h_{22,t}} \end{bmatrix} \quad (32)$$

where ρ_{12} is the constant conditional correlation coefficient. Individual variances are $h_{11,t}$ and $h_{22,t}$ which are assumed to follow a standard GARCH process. (Park and Jei, 2010) Variance and covariance estimates are then estimated as expressed in equations (33-35)

$$h_{ss,t}^2 = C_{ss} + \gamma_{ss}\epsilon_{ss,t-1}^2 + \delta_{ss}h_{ss,t-1}^2 \quad (33)$$

$$h_{ff,t}^2 = c_{ff} + \gamma_{ff}\epsilon_{ff,t-1}^2 + \delta_{ff}h_{ff,t-1}^2 \quad (34)$$

$$h_{sf,t}^2 = \rho_{sf}\sqrt{\left(h_{ss}^2 * h_{ff,t}^2\right)} \quad (35)$$

Where c is weight parameter for long-run average, γ is weight parameter for most recent squared residual, δ is weight parameter for variance predicted for this period, and ρ_{sf} is the constant correlation parameter.

CCC is one of the most popular MGARCH models even though it's shortcomings, which are mainly the assumption of the constant conditional correlation and models incapability of capturing interactions among assets in the model. However, models advantages are that is easier to interpret due to less parameters, compared to other MGARCH models, and its simplicity to estimate, which has made it widely used in optimal hedge ratio estimation.

3.4 Hedge ratio estimation and hedge effectiveness

Estimation of conventional and time-varying models differ in estimation of (co)variances of variables. For conditional model optimal hedge ratio estimation required running regression. From multivariate conditional models, DVEC and CCC, conditional covariance matrix, H_t is obtained from where estimates are used to calculate optimal hedge ratio. Time-varying optimal hedge ratio at time $t-1$ can be obtained as presented in equation (36)

$$b_{t-1}^{*} = \frac{h_{sf,t}^{2}}{h_{ff,t}^{2}} = HR_t \tag{36}$$

where $h_{sf,t}^{2}$ is covariance of spot and futures, and $h_{ff,t}^{2}$ is the variance of futures. Presented optimal hedge ratio estimation aims at minimizing conditional variance of the hedged portfolio.

After calculating optimal hedge ratios in order to compare usefulness of the model we look how well model manages to reduce variance. In optimal hedge ratio research variance reduction is the most used efficiency measure, which is used in thesis also. To compare variance reduction, first we need to calculate return on the hedged portfolio. If we assume an investor with long cash position in an asset at time $t-1$ who trades on the futures market to manage risk. The return on portfolio of holding one unit of the spot asset and proportional units of the futures contract at time $t-1$ can be written as in equation (38)

$$R_t = (S_t - S_{t-1}) + hr_{t-1}(F_t - F_{t-1}) = R_t^{s} - hr_{t-1}R_t^{f} \tag{37}$$

Where R_t is the difference return on hedged portfolio, $S_t - S_{t-1}$ and $F_t - F_{t-1}$ cash and futures price at time t and $t-1$ respectively, R_t^{s} and R_t^{f} are the difference return from holding the spot and futures positions from $t-1$ to t and β_{t-1} is the hedge ratio with respect to holding one unit of cash position.

After calculating return for the hedged portfolio we calculate variance of the hedged portfolio and compare it to the situation where there is no hedging, thus spot price of underlying asset. Hedge effectiveness in portfolio of spot and futures prices is expressed as in equation (38)

$$HE = 1 - \frac{Var(R^p)}{Var(R^s)} \quad (38)$$

Where, $Var(R^p)$ represents variance of the hedged portfolio and $Var(R^s)$ variance of the spot, thus unhedged portfolio. Hedge effectiveness is reported as percentage of variance reduced.

3.5 Forecasting method

To further study the efficiency of how well the estimated models perform, we estimate variance and covariance values for out of sample results also. Time series is divided into two parts, in-sample period which begins from start of trading of each futures contract and lasting till end of May, 2011. Out-of-sample period goes on from start of June 2011, till end of December 2011.

As presented before, optimal hedge ratio estimates depend on the variances and covariance of spot and futures prices. Forecasted hedge ratios are naturally derived from forecasts of variance and covariance. For conventional method, forecasted value is same slope parameter, as is used in in-sample optimal hedge ratio estimation. For time-varying models, future estimates for variance and covariance are forecasted using sample estimates. Forecasts from the MGARCH models can be made accordingly as in univariate GARCH models. For DVEC and CCC models forecasts are based on univariate GARCH model and then scaled using parameters from MGARCH models. For multivariate models we can generate predictions, by using in-sample period for estimation of parameters and parameters are then used to forecast values for future time period. (Zivot, 2006)

Conditional covariance matrix is forecasted for variance of spot and futures and covariance between assets in for DVEC and CCC. Forecasts of conditional covariance matrix, variance and covariance, values for time period $t+1$ is obtained at time $t$for DVEC as presented in equations (39-41)

$$h_{ss,t+1}^2 = c_f + \gamma_{ff}\epsilon_{ff,t}^2 + \delta_{ff}h_{ff,t}^2 \quad (39)$$

$$h_{ff,t+1}^2 = c_f + \gamma_{ff}\epsilon_{ff,t}^2 + \delta_{ff}h_{ff,t}^2 \quad (40)$$

$$h_{sf,t+1}^2 = c_{sf} + \gamma_{sf}\epsilon_{s,t}\epsilon_{f,t} + \delta_{sf}h_{sf,t}^2 \quad (41)$$

and for CCC model $t+1$ forecast values of conditional covariance matrix are derived as in equations (42-44)

$$h_{ss,t+1}^2 = C_{ss} + \gamma_{ss}\epsilon_{ss,t}^2 + \delta_{ss}h_{ss,t}^2 \quad (42)$$

$$h_{ff,t+1}^2 = c_{ff} + \gamma_{ff}\epsilon_{ff,t}^2 + \delta_{ff}h_{ff,t}^2 \quad (43)$$

$$h_{sf,t+1}^2 = \rho_{sf}\sqrt{\left(h_{ss,t+1}^t * h_{ff,t+1}^2\right)} \quad (44)$$

For forecast period k>1, forecasted values from $t+1$ are then used to forecast values for longer period. When $k=2$ it can be shown that same as in univariate model, forecasts are done based on forecasted value of $t+1$ and parameter estimates at time t. Forecast in period k for DVEC model, variance and covariance are presented in equations (45-47)

$$h_{ss,t+k}^2 = c_f + \left(\gamma_{ff} + \delta_{ff}\right)^{k-1} * h_{ff,t+1}^2 \quad (45)$$

$$h_{ff,t+k}^2 = c_f + \left(\gamma_{ff} + \delta_{ff}\right)^{k-1} * h_{ff,t+1}^2 \quad (46)$$

$$h_{sf,t+k}^2 = c_{sf} + (\gamma_{sf} + \delta_{sf})^{k-1} * h_{sf,t+1}^2 \quad (47)$$

for CCC predicted values are also derived from forecast value of $t+1$ and parameter estimates at time t, presented in equations (48-50)

$$h_{ss,t+k}^2 = C_{ss} + (\gamma_{ss} + \delta_{ss})^{k-1} * h_{ss,t+1}^2 \quad (48)$$

$$h_{ff,t+k}^2 = C_{ff} + (\gamma_{ff} + \delta_{ff})^{k-1} * h_{ff,t+1}^2 \quad (49)$$

$$h_{sf,t+k}^2 = \rho_{sf}\sqrt{\left(h_{ss,t+k}^t * h_{ff,t+k}^2\right)} \quad (50)$$

After finding forecasted values of variance and covariance, hedge ratios for time $t+k$ are then derived using equation (51)

$$hr_{t+k} = \frac{h_{sf,t+k}^2}{h_{ff,t+k}^2}. \tag{51}$$

Forecasted optimal hedge ratios at time $t+k$ are used directly to calculate hedged portfolio return by, $R_{t+k} = R_{t+k}^s - hr_{t+k}R_{t+k}^f$, referred as point estimates. We are also interested in variance reduction of hedged portfolio for time period $t+k$ when forecasted optimal hedge ratio value is used for whole forecast period. Return series for forecasted time period is created by summing one day return values for spot and hedged portfolio for time period of a $t+k$. As expected, summing of one day returns increases variances of the time series and if variance reduction is compared to original return series, variance reduction estimates become misleading. For point estimates and after scaling for new return series, hedge effectiveness is reported as percentage reduction of hedged portfolio variance compared to spot position, derived from equation (38)

4. Data Description

To study efficiency of futures market and optimal hedge ratio estimation Futures and options on Russian trading system, (FORTS) was chosen. FORTS is relatively new market and research done on assets traded in market place is yet relatively scarce and suits well for research purposes to gain knowledge of dynamics of assets traded in market. In thesis we wish to use assets from the different classes, stock, currency and commodity. Futures that are included in research are RTS Index (RIZ1), EUR/RUB exchange rate (EuZ1) and Brent oil (BRX1) futures. RTS index futures are to be settled in relation to RTS Index, EUR/RUB futures are settled as EUR/RUR exchange rate published by the European Central Bank. Corresponding assets are to be used as the spot price. Europe Brent FOB spot price is used as corresponding spot price for Brent oil futures. All data was acquired from Thomson Datastream, in which closing prices are to be used for weekdays only, as trading on weekends is not conducted. Data points were transformed to return series by taking natural logarithm of time series as in equation (52)

$$R_t = \ln\left(\frac{S_t}{S_{t-1}}\right) \quad (52)$$

Time period to be covered was chosen from the start of trading of each futures contract. Due to former, in-sample period for RTS Index starts from August 2005, for EUR/RUB march 2009, and for Brent oil October 2008, and lasts till end of May 2011. Out-of-sample period covers start of June 2011 till end of year 2011. Futures contracts for RTS and EUR/RUB, are to be settled on quarterly basis, March, June, September and December and for Brent oil monthly. Price to be used for futures is closing price of the day, which also is settlement price for the nearby contract. By nearby contract is meant contract, which settlement date is closest.

4.1 Data statistics

Summary statistics for the in-sample return data is presented in table (1). Mean values of returns varies from -0.0002 for EUR/RUB exchange rate to 0.0006 for RTS index. Mean for spot and futures prices are same for RTS index and exchange rate. For Brent oil, mean of futures is clearly higher for futures, as mean of spot is 0,0003 and for futures 0,0005. Standard deviation for RTS index and exchange rate asset pairs is greater for futures values, as for Brent oil, spot has larger standard deviation. Standard deviations on yearly basis on average are 42 percent for RTS Index, 9 percent for exchange rate and 40 percent for Brent oil, as estimated by the annualized standard deviation of daily returns. RTS Index has encountered most volatile movements as maximum and minimum daily price change is in the range of -0.2120 and 0.2020. Most volatile movements are from the time of 2008 credit crunch and declining oil prices that hit Russian stock markets relatively hard. Largest price movements for Brent oil are between -0,1139 and 0,1719 from same crisis period. Not surprisingly daily price changes are smallest for exchange rate between -0,0257 and 0,0319 which is due to dynamics of exchange rate, that usually are less volatile, compared to stock or commodity prices. Further, time period used for exchange rate is taken after crisis.

Skewness of RTS index is negative, which means that most of the values lie on the right side of the mean and for exchange rate the opposite. Skewness between assets pairs is relatively same for spot and futures prices. Kurtosis values are notably higher for futures in exchange rate and for spot in Brent oil, and close each other in RTS index. From Jarque-bera test- statistic we conclude that none of the assets are normally distributed. Calculation of Jarque-Bera statistic is prone to react excessively on few major variations from “normal” values, which is clearly seen in RTS Index Jarque-Bera value. Jarque-Bera value is smallest for spot exchange rate as we conclude that, distribution is closest to normal distribution.

Table 1. Summary statistics of the daily returns

Summary statistics for daily logarithmic returns for spot and futures assets used in thesis. Statistics for RTS index are from 3. August 2005, for EUR/RUR exchange rate from 30. March 2009, and for Brent oil from 8. October 2008, till 31. May 2011.

	RTS index		EUR/RUB		Brent oil	
	R_t^s	R_t^f	R_t^s	R_t^f	R_t^s	R_t^f
Mean	0.0006	0.0006	-0.0002	-0.0002	0.0003	0.0005
Median	0.0011	0.0000	-0.0002	-0.0001	0.0004	0.0000
Maximum	0.2020	0.2472	0.0209	0.0319	0.2165	0.1719
Minimum	-0.2120	-0.2087	-0.0185	-0.0257	-0.1685	-0.1139
Std.dev.	0.0245	0.0286	0.0050	0.0058	0.0264	0.0242
SK	-0.4606	-0.4281	0.3503	0.3292	0.2575	0.2426
KUR	14.9026	14.0433	4.8972	6.7848	11.8932	8.4155
JB	9020.39	7765.22	96.463	348.05	2784.019	848.71
Correlation	0.9128		0.7421		0.6710	

Correlation between spot and futures is highest for RTS index, 0.9128, and relatively high for exchange rate 0.7421 and for Brent oil 0.6710. In figures (1-3) we see that for sample period Brent oil is trending upwards whole time. Values of spot and futures follow closely each others in RTS Index and Brent oil. For exchange rate there is deviation between assets in the beginning of sample period. Return series for assets are presented in appendix 1.

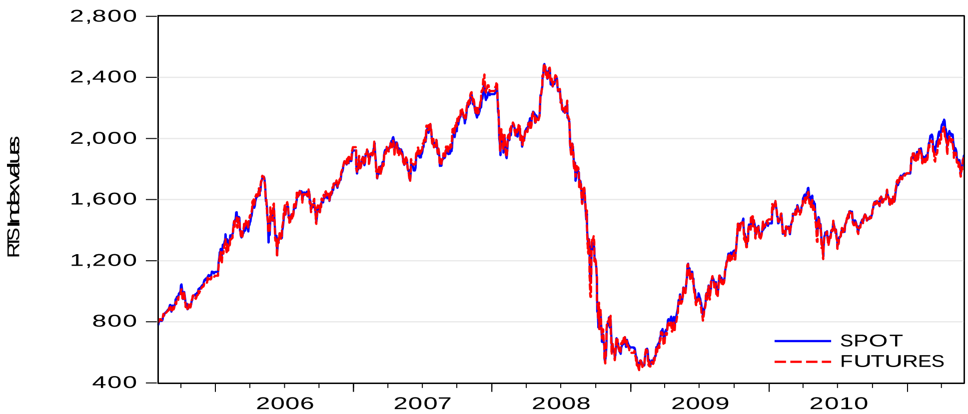

Figure 1. RTS Index, spot and futures values

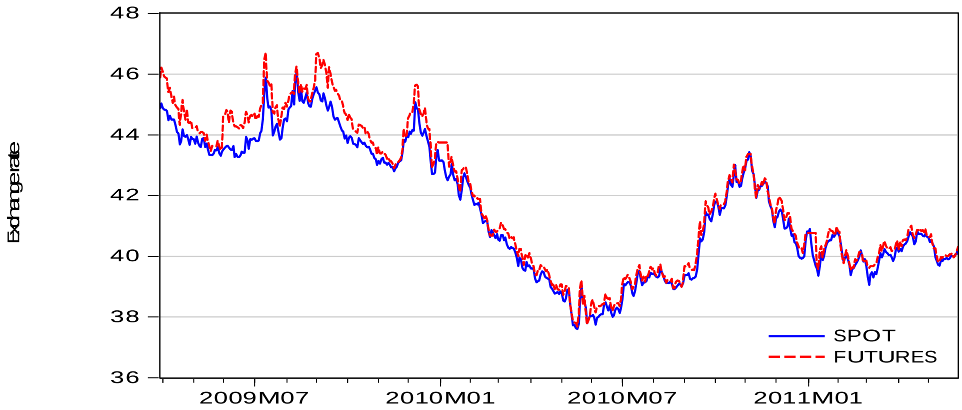

Figure 2. Euro/Ruble Exchange rate, spot and futures values

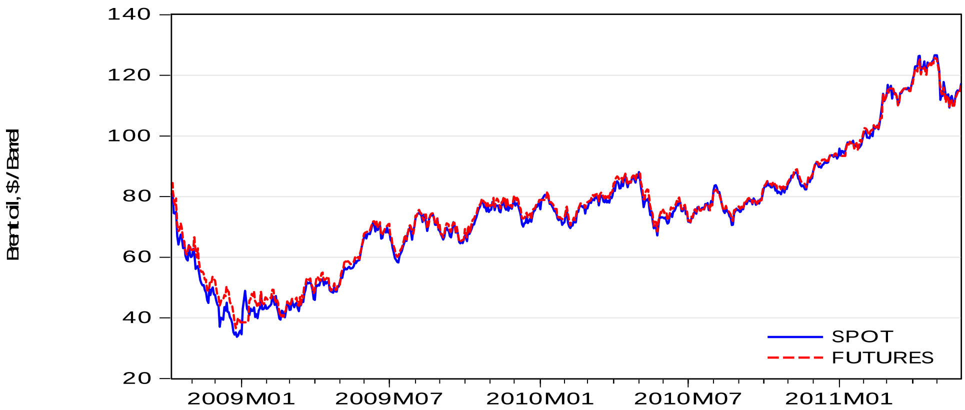

Figure 3. Brent oil spot and futures prices

5. Empirical results

5.1 Unit root results

Hypothesis of unit root has an important implication in economics as unit root often has theoretical implication for rational use of new information which agents can use in decision making. Referring to efficient market hypothesis, which concludes that as information arrives to market, it is randomly good or bad and so should be the market reaction. Asset prices should therefore be random and follow random walk process and prices should not be able to be forecasted from the previous price changes. We conduct Augmented Dickey-Fuller test for spot and futures price series to illustrate the randomness and stationarity of the time-series. Stationarity refers to situation where the mean value and standard deviation remain constant in the series over time. We expect time series to be integrated of order one,$I(1)$.

As presented in the table (2), asset prices, while none and constant term is included for all time series, we fail to reject the null-hypothesis of the ADF-test, which designates that price series are non-stationary. However, for return series we fail to reject the null hypothesis of the ADF-test, and further conclude that return time series are stationary, and yet random. Interestingly while constant and linear term is included, time series for both Crude oil spot and futures price series are stationary in their price level, and integrated of order zero, $I(0)$. This process is trend stationary, which can be rationalzed when seeing picture 3, where Brent oil price is clearly trending upwards whole sample period. Prerequisite for Johansen cointegration tests is that series used are integrated of the same order. If we were to use constant and linear trend in cointegration analysis test results for Brent oil would be futile, as test is based on finding stationary linear combination between two variables integrated of the same order,$I(d)$, where linear combination of the two series is integrated of order $I(b)$ where, $b < d$. While excluding constant and linear trend for Brent oil spot and futures prices, time series are supposed to fit well for cointegration methods used in thesis and Johansen cointegration tests are expected to give unbiased results.

Table 2. Unit-Root test

ADF stands for augmented Dickey-Fuller, which is used for testing the hypothesis that series has a unit root. Test is run with, no intercept or trend in data, intercept in data, and with intercept and trend in data.

	None		Intercept		Intercept and Trend	
	p_s	p_f	p_s	p_f	p_s	p_f
RTS	0.2971	0.2590	-1.7259	-1.7304	-1.7189	-1.7279
Eur/Rub	-0.9509	-1.1193	-1.6238	-1.7596	-1.6179	-1.7234
Crude	0.2891	0.7188	-0.8088	-0.1151	-4.2768**	-4.1927**
	r_s	r_f	r_s	r_f	r_s	r_f
RTS	-34.977**	-37.411**	-34.984**	-37.414**	-34.979**	-37.408**
Eur/Rub	-17.194**	-18.271**	-17.212**	-18.300**	-17.216**	-18.311**
Crude	-29.432**	-26.065**	-29.424**	-26.068**	-29.434**	-26.202**

Notes: p_s is price series of spot and p_f is price series of futures respectively. r_s is return series of spot and r_f is return series of the futures. Lag length was chosen by using Scwarz information criteria with 20 maximum lags. Critical values for ADF test are 5% -2.86 and 1% -3.44. *denotes significance at 5% level and ** significance at 1% level.

5.2 ARCH specification test

By following Engle (1982) ARCH specification test is conducted to see whether disturbances follow an ARCH process and yet are eligible to be used in GARCH estimation procedure. In the linear model of Engle (1982), the time-varying conditional variance is postulated to be a linear function of the past lagged squared innovations. ARCH effect is tested by simply regressing series using constant as an explanatory variable. Next error terms of the regression are then squared and regressed on wanted number of lagged residuals to be used. ARCH LM test statistic is computed as the number of observations times the R-squared from the test regression. LM test statistic is asymptotically distributed $\chi^2(q)$ under quite general conditions. LM stands for Lagrange multiplier (LM) test for autoregressive conditional heteroskedasticity in the residuals. If LM test statistic is larger than critical value, we reject the null hypothesis of no ARCH effects.

Table 3. Test for ARCH effects

In this table results from ARCH effect test statistic are reported.

	RTS index		EUR/RUB		Brent oil	
Lags	R_t^s	R_t^f	R_t^s	R_t^f	R_t^s	R_t^f
1	59.1681**	173.9788**	21.2653**	0.0692	14.1252**	1.611
2	101.0828**	207.6454**	28.6961**	15.4278**	17.8789**	4.2409
3	166.3703**	254.4780**	28.6150**	15.7570**	24.4058**	10.1703*
4	175.0956**	267.7095**	31.6345**	16.3462**	37.8781**	11.1420*
5	183.0315**	270.3253**	33.9950**	16.3212**	38.1934**	17.4982**

Critical values for $\chi^2(q)$ 1% 6.635, 9.210, 11.345, 13.277, 15.086 and for 5% 3.841, 5.991, 7.815, 9.488, 11.070. ** denotes significance for 1 percent, and * significance for 5 percent level

As we see from table (3), all lagged squared error terms for spot and futures price of RTS index, for spot exchange rate and for spot Brent oil are higher than designated critical values. As null hypothesis is rejected, we conclude that series exhibit ARCH effect and yet models are suitable to be used for GARCH methods. Presence of ARCH effects indicates that return series shows strong conditional heteroscedasticity, which is normal feature of financial data. In written there are quiet periods with small price changes and turbulent periods with large oscillations. Interestingly however, for futures exchange rate in first lag and Brent oil futures in first and second lag seem not to inhibit ARCH effects, but error of disturbances, seem to have same variance in overall sample observation points. As in testing GARCH(1,1) is used, insignificance might put some doubt on estimation of parameters and results may be illusive, while using models that are based on GARCH(1,1).

5.3 Univariate GARCH parameters

In table (4), are presented results of the univariate GARCH parameter estimates. Coefficients are statistically significant in conditional variance equation. Brent oil futures seem not to fit GARCH model well, as weight parameter α is negative and β is over one. We would expect α to be non-negative and β less than one, for stable process. However, sum of the two weight parameters are less than one. If this was not the case, process would be mean fleeing as mean reversion is expected. From sums $\alpha + \beta$ we conclude the rate of variance mean revertion process to be slow for Brent oil and RTS index spot and futures returns. Variance mean reversion is faster for exchange rate, especially in futures.

Table 4. The univariate GARCH(1,1) parameter estimates for return series

In table 4 are reported weight parameter estimates for, univariate GARCH(1,1) model. Results are based on return data of in-sample data period.

	RTS index		EUR/RUB		Brent oil	
	R_t^s	R_t^f	R_t^s	R_t^f	R_t^s	R_t^f
C	0.0018**	0.0017**	-0.0003	-0.0003	0.0015*	0.0011
	(0.0004)	0.0005	(0.0002)	(0.0003)	(0.0008)	(0.0007)
ω	0.0000**	0.0000**	0.0000	0.0000*	0.0000	0.0000**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
α	0.0954**	0.1005**	0.1206**	0.0605*	0.0314**	-0.0124**
	(0.0083)	(0.0107)	(0.0288)	(0.0242)	(0.0103)	(0.0032)
β	0.8775**	0.8743**	0.7923**	0.7621**	0.9583**	1.0050**
	(0.0100)	(0.0124)	(0,0497)	(0.1052)	(0.0103)	(0.0032)
$\alpha + \beta$	0,9730	0,9748	0.9129	0,8225	0,9897	0,9927
LL	3875.179	3734.569	2215.145	2163.859	1615.862	1696.596

Number in parentheses are asymptotic standard errors, and LL stands for Log-Likelihood test statistic. *denotes significance at 5% level and ** significance at 1% level.

5.4 Futures market efficiency

Futures market efficiency is studied by Johansen cointegration method. If cointegration is found, restrictions are imposed on cointegrating vector and adjustment coefficients. Prequisite for Johansen cointegration method is that used time series are integrated of the same order. Assumption holds for time series, except for Brent spot and futures, while intercept and trend, were included. For other series order of integration was confirmed by ADF test as series were non-stationary in their price level but became stationary in their first difference, hence $I(1)$. Johansen cointegration test provides two different test statistics, Trace and Maximum eigenvalue. When testing for cointegration, different assumptions about linear trend in data, and intercepts included in cointegrating equation and VAR can be made. Intuitively, test is first run by expecting no linear trend in data and with no intercepts. Secondly, we run tests and allow for linear trend in data, intercept and trend in cointegrating equation and intercept in VAR. While assuming linear trend in data, Brent oil is not included as stationary vectors can't be found cointegrated, as series are both stationary, $I(0)$ already at their price level. Trace statistic tests the null hypothesis that there is at most r cointegrating relations, against alternative of m cointegrating relations where $r = 0{,}1, m - 1$. Maximum eigenvalue statistic tests the null hypothesis as there are r cointegrating relations against alternative of, $r + 1$ cointegrating relations. As only two variables, spot and futures, are included in the test, there naturally can be zero or one cointegrating vector. Lag interval for Johansen cointegration test was chosen to be one. Results for Johansen cointegration test and corresponding cointergating vector and adjustment coefficients are reported in table (5)

Table 5. Cointegration test results

In table 5 are reported Johansen cointegration test results and corresponding coefficient estimates for cointegrating vector β, and adjustment coefficient α, with no intercept in cointegrating equation, nor linear trend is assumed in data. Johansen cointegration hypotheses for Trace statistic $\boldsymbol{h_0}$: $\boldsymbol{r} = \mathbf{0}$ against alternative $\boldsymbol{r} > 0$, and for Maximum eigenvalue $\boldsymbol{h_0}$: $\boldsymbol{r} = \mathbf{0}$ against alternative $\boldsymbol{r} = \mathbf{1}$, where $\boldsymbol{r}$ denotes cointegrating vector.

	RTS index		EUR/RUB		Brent crude	
r	Trace	Max	Trace	Max	Trace	Max
0	84.8225*	84.7287*	32.0272*	31.3469*	60.7038*	60.1374*
1	0.1138	0.1138	0.6803	0.6803	0.5663	0.5663

	RTS index		EUR/RUB		Brent oil	
	Spot	Fut	Spot	Fut	Spot	Fut
β	1	-1.0009**	1	-0.9924**	1	-0.9887**
		(0.0013)		(0.0012)		(0.0026)
ECM						
α	0.0828*	0.2273**	-0.0005	0.1323**	0.0038	0.1808**
	(0.0396)	(0.0451)	(0.0306)	(0.0369)	(0.0411)	(0.0357)

Critical values for Trace test in 5% level for zero cointegrating vectors 15.495 and more than zero, 3.841. For Maximum eigenvalue zero, 14.265, and one 3.841. *denotes significance at 5%. For β and α coefficients number in parentheses are asymptotic standard errors, Critical values for t-test for 5% level is 1.96 and for 1% 2.68. *denotes signifigance at 5% level, ** denotes signifigance at 1% level.

For all asset pairs, null hypothesis of zero cointegrating vectors is clearly rejected. Alternative hypothesis of more than zero cointegrating vectors for trace statistic, and one cointegrating vectors for maximum eigenvalue statistics is not rejected. As Cointegrating vector is found in spot and futures we conclude that spot and futures prices do not drift too far a part in a long-run. There exists a long run relationship between the spot and futures. Johansen cointegration test results give strong support for the existence of cointegration between all asset pairs.

Normalized cointegrating vector estimates and adjustment coefficients are also presented in table (5). Note, that Johansen method uses normalization, which is done on spot price. Vector parameters β are relatively close to one, and adjustment coefficients α values are significant and higher for futures compared to spot in all asset pairs. From adjustment coefficients we infer, that short-term shocks are mainly corrected to long-term equilibrium by changes in futures prices. When cointegrating vector was found between spot and futures prices, next we impose restrictions on cointegrating vector β and adjustment coefficients α to test unbiasedness, weak exogeneity and joint hypothesis. We use Likelihood ratio (LR) test to test hypotheses. LR test statistic is distributed as χ^2 , with degrees of freedom equal to number of restrictions. Results are presented in table (6)

Table 6. Hypotheses tests for efficiency of futures market

Hypotheses	LR Test Statistic (P-value)		
	RTS index	EUR/RUB	Brent oil
Unbiasedness			
$h_0: \beta' = (1, -1)$	0.4356**	15.8721	14.3062
	(0.5092)	(0.0000)	(0.0002)
Weak exogeneity			
$H_0: \alpha_{spot} = 0$	4.3797*	0.0003**	0.0087**
	(0.0364)	(0.9874)	(0.9258)
$H_0: \alpha_{futures} = 0$	35.1824	12.5254	25.1265
	(0.0000)	(0.0004)	(0.0000)
Prediction hypothesis			
$h_0: \beta' = (1, -1), \alpha_{futures} = 0$	25.7264	24.5758	31.3140
	(0.0000)	(0.0000)	(0.0000)

Number in parentheses are p-values, *denotes signifigance at 5% level, ** denotes signifigance at 1% level.

Unbiasedness hypothesis, for RTS index is not rejected in which we conclude that RTS futures work as an unbiased estimates of future spot price. Unbiasedness hypothesis is rejected for exchange rate and Brent oil. By studying weak exogeneity hypothesis of spot and futures prices we see that hypothesis, for all futures prices, are rejected. Correspondingly hypotheses hold for all spot coefficients. Test results indicate that futures prices are adjusting to spot prices, what is more, spot prices are leading component in price discovery. In all asset pairs, test results give no confirmation for prediction hypothesis.

To get confirmation and detailed information about efficiency of futures market, we also present results when linear trend is assumed in data and intercept and trend are included in cointegrating equation and intercept in VAR. Intercept and trend coefficient are not presented. As Brent oil spot and futures prices were found trend stationary $I(0)$ test is not performed on Brent oil. In table (7) are presented cointegration test results and coefficient estimates, with alternative model assumptions.

Table 7. Cointegration test results

In table 7 are reported Johansen cointegration test results and corresponding parameter estimates for cointegrating vector β, and adjustment coefficient α. In test, linear trend in data was assumed and intercept and trend were included in cointegrating equation and intercept in VAR. Trend and intercept values are not reported. h_0:hypothesis for trace statistic is $r = 0$ against alternative, $r > 0$, and for Maximum eigenvalue, h_0: $r = 0$ against alternative, $r = 1$. Where r denotes cointegrating vector.

	RTS index		EUR/RUB		Brent oil	
r	Trace	Max	Trace	Max	Trace	Max
0	101.8702*	98.6460*	51.9356*	48.0184*	n.a	n.a
1	3.2243	3.2243	3.9172	3.9172	n.a	n.a

	RTS index		EUR/RUB		Brent oil	
	Spot	Fut	Spot	Fut	Spot	Fut
β	1	-0.9902**	1	-0.9639	n.a	n.a
		(0.0037)		(0.0184)		
ECM						
α	0.0802	0.2508**	-0.0375	0.1795**	n.a	n.a
	(0.0434)	(0.0495)	(0.0410)	(0.0489)		

Numbers in parentheses are asymptotic standard errors. Critical values for Trace test in 5% level are for, zero cointegrating vectors 15.495 and more than zero, 3.841. For maximum eigenvalue zero, 14.265, and one 3.841. *denotes signifigance at 5% level. For **β** and α, number in parentheses are asymptotic standard errors, Critical values for t-test for 5% level is 1.96 and for 1% 2.68. *denotes signifigance at 5% level, ** denotes signifigance at 1% level.

Results for Johansen cointegration test are alike from previous test results, where intercepts and linear trend, were not included. Null of zero cointegrating vectors is rejected, and alternative hypotheses are accepted, with high significance values. Results indicate yet stronger support for the cointegration between spot and futures prices. Cointegrating vector and adjustment coefficients are also similar with previous results. Cointegrating equation coefficient values are close to -1 and adjustment coefficients values are significant and greater for futures. Futures market efficiency hypotheses results are illustrated in table (8)

Table 8. Hypotheses test for efficiency of futures market

Hypotheses	LR Test Statistic (P-value)		
	RTS index	EUR/RUB	Brent oil
Unbiasedness			
$h_0: \beta' = (1, -1)$	6.2267*	3.0740**	n.a
	(0.0126)	(0.0796)	
Weak exogeneity			
$H_0: \alpha_{spot} = 0$	3.3164**	0.7949**	n.a
	(0.0686)	(0.3726)	
$H_0: \alpha_{futures} = 0$	24.7512	12.3345	n.a
	(0.0000)	(0.0004)	
Prediction hypothesis			
$h_0: \beta' = (1, -1), \alpha_{futures} = 0$	33.8996	18.5664	n.a
	(0.0000)	(0.0001)	

Number in parentheses are p-values, *denotes signifigance at 5% level, ** denotes signifigance at 1% level.

As similar with previous test results, RTS Index futures are confirmed to be unbiased estimate of future spot price. Interestingly as linear trend is assumed in data and intercepts and trend coefficients are included, unbiasedness hypothesis for exchange rate futures is also accepted. Weak exogeneity test results are similar with previous test results. Weak exogeneity hypotheses are rejected for futures, and accepted for spot prices. Results confirm that spot prices lead price discovery and futures prices adjust to spot prices. Prediction hypothesis is similarly rejected for all asset pairs.

In reference, to Crowder and Hamed (1993) and Switzer and El-Khoury (2007), results where unbiasedness of oil futures were confirmed, we would have expect, evidence in favor of Brent oil futures unbiasedness. For exchange rate results were similar with Lai and Lai (1991) when no intercept or trend, were assumed in data. As for RTS Index, weak exogeneity results are similar with Crowder and Phengpis (2005), where stock index, S&P500, spot price was found to lead in price discovery. In addition, our results indicate unbiasedness of stock index futures. As expected all asset pairs were found cointegrated, as was also the case in all previous research presented.

5.5 In-sample results

First, we estimate variable parameters to be used in estimation of optimal hedge ratios for different models and evaluate how well the estimated coefficients fit the data to be used. In table (9) are the results of the conventional hedging model where regression slope coefficient is used as optimal hedge ratio.

Table 9. Coefficients from ordinary least squares (OLS) model

In table 9 are presented ordinary least squares (OLS) regression model estimates. Results are based on return data of in-sample data period.

	RTS	EUR/RUB	Brent oil
Constant	0.0001	0.0000	0.0002
	(0.0003)	(0.0001)	(0.0008)
Slope	0.7823**	0.6388**	0.7612**
	(0.0090)	(0.0243)	(0.0335)
R-Squared	0.8332	0.5502	0.4303
Loglikelihood	4836.974	2416.585	1674.474
Durbin-watson	2.5804	2.4031	2.4140

Number in parentheses are asymptotic standard errors. Critical values for t-test for 5% level is 1.96 and for 1% 2.68. *denotes signifigance at 5% level, ** denotes signifigance at 1% level.

As we see from table (9), all constants in regression model are close to zero and values are not statistically significant for any of assets used. Slope coefficient varies between 0.6388-0.7823 and is highest for the RTS index and smallest for exchange rate. Slope coefficient, which is to be used as an optimal hedge ratio in conventional model, is significant for all assets and one may conclude that slope coefficient is reliable estimate of the conventional model hedge ratio. While regarding r-squared, fraction of the total squared error that is explained by the model, futures can relatively well inhibit changes in the spot values. R-squared is highest for RTS index and smaller and quite the same for exchange rate and Brent oil. While regressing futures prices for spot relatively high r-squared values are expected as prices should reflect each other quite extensively. Lower values for exchange rate and Brent oil may partly be explained by time lag between closing time of spot and futures. While for RTS spot and futures closing value is contracted exactly same time, which is not the case for exchange rate and Brent oil, and relatively small r-squared value may originate from this phenomenom.

Parameter estimates for the DVEC and CCC models are presented in table (10). Notable is that for RTS index and exchange rate estimates of the model fit in used data well. For RTS index all estimates are statistically significant in all parameter estimates. All parameter estimates are all also significant while using CCC. Correlation coefficient is highest, 0.9402, for RTS Index. All parameter estimates are also statistically significant for exchange rate for both models and correlation coefficient in CCC is 0.7319. Brent oil parameter estimates are also statistically significant and correlation coefficient is 0.7311 in CCC. Weight parameter, γ for most recent squared residual, is minus signed and weight parameter, δ for variance predicted for this period is over one. In general we expect these values to be γ>0 and δ<1, and $\gamma + \delta < 1$. As MGARCH models are based on univariate GARCH model, not surprisingly same estimation problems are carried on to MGARCH parameter estimates for Brent oil.

Table 10. Parameter estimates for CCC and DVEC models

In table 10 are presented parameter estimates for multivariate GARCH, Diagonal VEC (DVEC) and Constant conditional correlation (CCC), models. Results are based on return data of in-sample data period.

	RTS		EUR/RUB		Brent oil	
	DVEC	CCC	DVEC	CCC	DVEC	CCC
C_{ss}	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
C_{fs}	0.0000**		0.0000**		0.0000**	
	(0.0000)		(0.0000)		(0.0000)	
C_{ff}	0.0000**	0.0000**	0.0000**	0.0000*	0.0000**	0.0000**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
γ_{ss}	0.0818**	0.1074**	0.0516**	0.0496**	0.0657**	-0.0130**
	(0.0059)	(0.0061)	(0.0131)	(0.0167)	(0.0127)	(0.0016)
γ_{sf}	0.0799**		0.0510**		0.0406**	
	(0.0063)		(0.0154)		(0.0077)	
γ_{ff}	0.0893**	0.1283**	0.0644*	0.0269*	0.0217**	-0.0147**
	(0.0074)	(0.0093)	(0.0258)	(0.0106)	(0.0052)	(0.0022)
δ_{ss}	0.8897**	0.8685**	0.8772**	0.8813**	0.9182**	1.0073**
	(0.0072)	(0.0065)	(0.0274)	(0.0384)	(0.0127)	(0.0021)
δ_{sf}	0.8913**		0.7817**		0.9380**	
	(0.0074)		(0.0581)		(0.0085)	
δ_{ff}	0.8837**	0.8476**	0.6899**	0.8552**	0.9645**	1.0070**
	(0.0080)	(0.0099)	(0.1119)	(0.0646)	(0.0059)	(0.0022)
ρ_{sf}		0.9402**		0.7319**		0.7311**
		(0.0023)		(0.0152)		(0.0112)
LL	9285.899	9210.155	4558.063	4548.273	3599.949	3163.398
AIC	-12.21185	-12.11475	-16.06736	-16.03983	-10.4179	-10.4627

Number in parentheses are asymptotic standard errors. Critical values for t-test for 5% level is 1.96 and for 1% 2.68. *denotes signifigance at 5% level, ** denotes signifigance at 1% level.

In sample results of hedging effectiveness are presented in table (11). Variance of hedged portfolio is compared to position where there is no hedge, thus variance of spot.

Table 11. In-Sample comparisons of hedging effectiveness

In table 11 are reported variances for return series of hedged portfolio, and variances for return series of spot. Hedge effectiveness is presented, by comparing variance of hedged portfolio and variance of spot, from where variance reduction percentage is reported.

	Variance of portfolios			Hedge effectiveness		
Model	RTS	EURRUB	Brent oil	RTS	EURRUB	Brent oil
OLS	9.9708e-04	1.1294e-05	4.5042e-04	83.32%	55.07%	43.03%
DVEC	1.1933e-04	1.1434e-05	4.6234e-04	80.09%	54.51%	41.53%
CCC	1.1191e-04	1.1458e-05	4.4407e-04	80.22%	54.41%	44.26%
Spot	5,999e-04	2.5133e-05	7.9061e-04			

In table (11) we see that variance reduction using different models is highest for RTS index, approximately 80 percent, 55 percent for exchange rate and 43 percent for Brent oil. Greatest variance reduction is achieved with RTS index which can be regarded as good as expected. For exchange rate and especially Brent oil variance reduction is modest. For RTS index variance is minimized with OLS model. Time-varying models inhibit approximately 3 percent lower values in variance reduction. OLS model is the most efficient for exchange rate also, yet differences between models are even smaller. For Brent oil CCC model reduces variance the most. Interestingly CCC model performs best in Brent oil, even though alternation in expected parameter estimates was reported.

Alternation can be also seen in figures (4-6). For RTS Index time-varying models provide clearly stochastic estimates for optimal hedge ratio as expected. For Brent oil, especially in CCC optimal hedge ratios seem to oscillate more, thus being not stochastic. DVEC model is more prone to large spikes compared to CCC model.

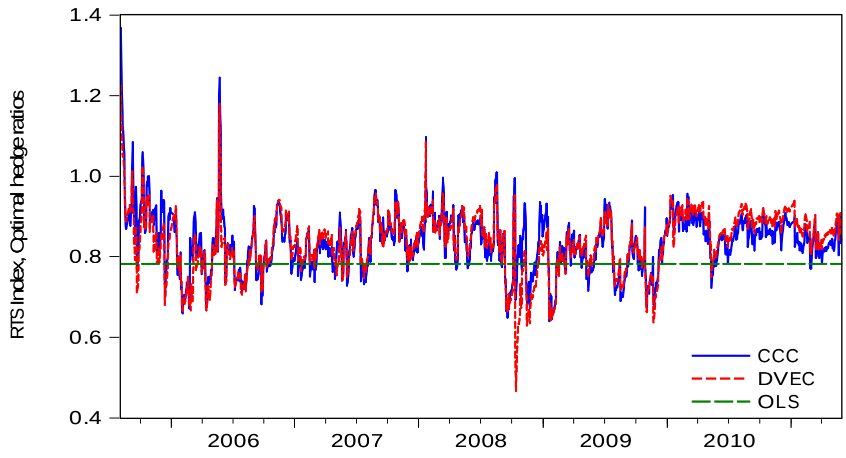

Figure 4. Optimal hedge ratio estimates for RTS Index

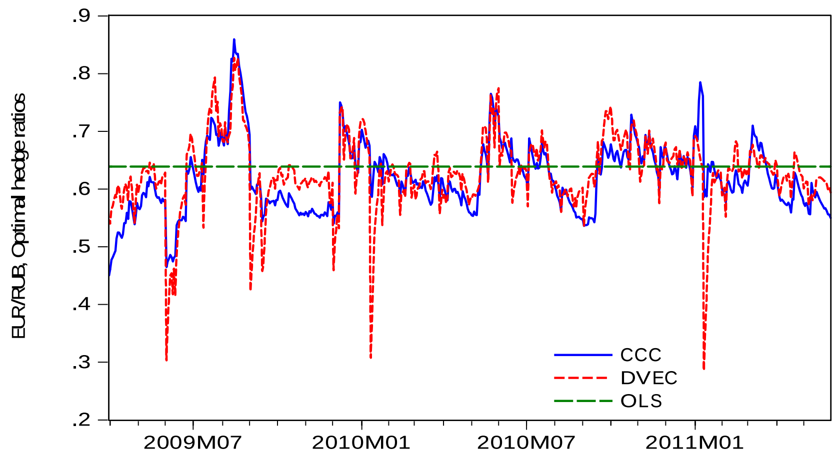

Figure 5. Optimal hedge ratio estimates for EUR/RUB exchange rate

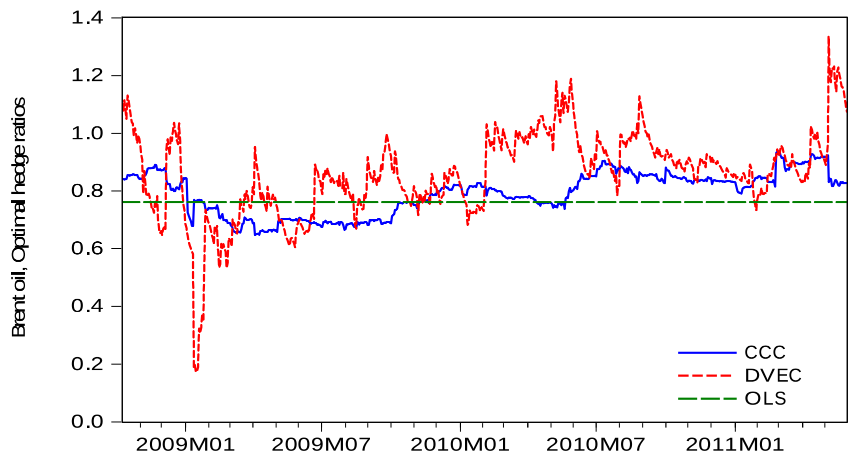

Figure 6. Optimal hedge ratio estimates for Brent oil

Results of the in-sample hedge effectiveness are puzzling. We found time-varying CCC model perform best in Brent oil. Even though, in accordance to ARCH effect, univariate GARCH and MGARCH parameter estimates implied otherwise. As time-varying models are anticipated to perform better as variance and covariance estimates are corrected continually, there however is no clear evidence for time-varying models being superior against conventional model, as was reported by (e.g Baillie and Myers 1991; Bera et.al. 1997; Hsu et.al. 2008), and taken into account validity of CCC results, static conventional model seems to work overall the best compared with time-varying models. As presented in latter research, in general, differences in hedging effectiveness between models are found small, as is also with our data.

5.6 Out-of-sample results

To compare how well models perform, in addition of in-sample hedge effectiveness, estimates of out-of-sample estimates are also required. Point estimates are forecasted for one, two and five period ahead. When comparing hedge effectiveness of summed series, naturally only forecasts for two and five period are included.

5.6.1 Point estimates

In table (12) results for forecasted point estimates are presented. Hedge ratio forecasted for time period ahead is directly used to calculate return for forecasted day.

Table 12. Comparisons of point estimate hedge effectiveness

In table 12 are reported variances for return series of hedged portfolio, and for return series of spot. Hedge effectiveness is reported as variance reduction percentage of hedged portfolio compared to variance of spot.

	Variance of portfolios			Hedge effectiveness		
Model	RTS index	EUR/RUB	Brent oil	RTS	EURRUB	Brent oil
OLS						
1 Day	2.9431e-05	1.6937e-05	7.9632e-05	94.67 %	53.93%	70.86 %
2 Day	2.9619e-05	1.6775e-05	8.0146e-05	94.67%	54.66%	70.82%
5 day	3.0067e-05	1.6838e-05	7.9188e-05	94.68%	54.97%	71.53%
DVEC						
1 Day	2.4302e-05	1.7632e-05	1.7214e-04	95.60 %	52.03 %	37.01 %
2 Day	2.4549e-05	1.7331e-05	1.6267e-04	95.58%	53.15%	40.77%
5 day	2.3556e-05	1.7506e-05	1.4340e-04	95.83%	53.19%	48.44%
CCC						
1 Day	2.5413e-05	1.7036e-05	1.6223e-04	95.40%	53.66 %	40.64 %
2 Day	2.5730e-05	1.6884e-05	1.5595e-04	95.38%	54.36%	43.22%
5Day	2.4570e-05	1.6950e-05	1.4189e-04	95.65%	54.68%	48.99%
Spot						
1 Day	5.5197e-04	3.6761E-05	2.7331e-04			
2 Day	5.5551e-04	3.6994e-05	2.7466e-04			
5 Day	5.6545e-04	3.7400e-05	2.7815e-04			

By comparing unhedged spot variances from table (11), and 1 day spot variance in table (12), we see that period used in out-of-sample estimation is less volatile for RTS index and Brent oil. Variance of exchange rate is slightly higher in out-of-sample period. Hedge effectiveness for forecasted period, compared with in-sample results, is clearly higher for RTS Index. For forecasted period variance is nearly eliminated as approximately 95 percent of variance is reduced. DVEC model performs best for all forecasted periods for RTS Index. For exchange rate there is no notable difference between in-, and out-of-sample results, and using of OLS model narrowly provides most efficient hedging results in all forecast periods. Results, for Brent oil clearly indicate superiority of OLS model, as hedge effectiveness in favor of OLS model is in range of 22-33 percent point. As ARCH effect were not found in Brent futures return series, univariate GARCH parameter estimates for Brent oil futures were conficting, and implied unstability, as also did parameter estimates for CCC model, one should consider whether time varying MGARCH models should be used in optimal hedge ratio estimation for Brent oil.

As compared with results of Baillie and Myers (1991) and Bera et.al (1997), where no deviations between models was found between in-, and out-of-sample hedging effectiveness results. OLS model reduces the variance the most for exchange rate as did also for in-sample period. Our results indicate clear deviation in Brent oil, resulting from the facts earlier described. Out-of-sample hedging effectiveness results for Brent oil using OLS model are clearly better, than for in-sample period. Interestingly, for RTS Index both time-varying models produce better out-of-sample hedging effectiveness results compared to OLS model, opposite of in-sample results. In all out-of-sample periods, optimal hedge ratios estimated by DVEC model, provide the highest variance reduction. Hsu et.al (2008) also presented similar results for S&P500 stock index, as in-sample results indicated OLS to dominate over CCC model, but for out-of-sample results changed in favor of time-varying CCC model.

5.6.2 Summed returns

Table (13) presents results, where forecasted optimal hedge ratio is used for the whole forecasted period. Hedged portfolio and spot returns are summed and variances of new return series are calculated. Hedge effectiveness is reported likewise as for point estimates.

Table 13. Out-of-sample comparisons of hedging effectiveness

In table 13 are reported variances for return series of hedged portfolio, and for return series of spot. For 2 and 5 period forecasts new return series is created for hedged portfolio and spot returns by summing returns of the hedge horizon. Hedge effectiveness is reported as variance reduction percentage of hedged portfolio compared to variance of spot.

	Variance of portfolios			Hedge effectiveness		
Model	RTS	EURRUB	Crude	RTS	EURRUB	Brent
OLS						
2 Day	6.6430e-05	2.2929e-05	1.3873e-04	95.08 %	72.89 %	77.63 %
5Day	2.0403e-04	4.4017e-05	2.7237e-04	94.65 %	80.04 %	83.35 %
DVEC						
2 Day	4.4142e-05	2.3374e-05	3.8202e-04	96.73 %	72.36 %	38.41 %
5Day	1.1725e-04	3.8633e-05	9.180e-04	96.92 %	82.48 %	44.89 %
CCC						
2 Day	4.9300e-05	2.2488e-05	3.5707e-04	96.35 %	73.41 %	42.43 %
5Day	1.3328e-04	2.2053e-04	8.0101e-04	96.50 %	80.81 %	51.01 %
Spot						
2 Day	1.3515e-03	8.4578E-05	6.2022e-04			
5Day	3.8130e-03	2.2053e-04	1.6362e-03			

As expected, summing of returns increases variances of spot and hedged portfolio, and it is appropriate to compare variances between corresponding new return series. Results are similar with point estimate forecast results. For RTS index, DVEC model performs the best as another time-varying model CCC results the second and for OLS variance reduction is smallest. Exchange rate results are yet diverse. CCC model based optimal hedge ratios provide largest variance reduction for two day period and DVEC model for five periods ahead. Hedge effectiveness differences between models for RTS index and exchange rate remain small. For Brent oil time-varying models fail to model time series well and hedging effectiveness between static and time-varying model depart.

6. Conclusions

Purpose of this thesis was to study futures market efficiency and hedge effectiveness of optimal hedge ratios estimated by static and time-varying models. Futures and Options on RTS (FORTS) from where, RTS Index, EUR/RUB exchange rate and Brent oil futures were chosen for closer examination. Prerequisite for futures market efficiency is cointegration between spot and futures prices, which was tested by Johansen cointegration method. When cointegration was found, we imposed restrictions on the cointegrating vector and adjustment coefficients. After futures market efficiency tests, optimal hedge ratios were esimated. Optimal hedge ratios were estimated using static OLS and time-varying DVEC and CCC models. Hedge effectiveness was reported as variance reduction percentage, comparing variance of hedged portfolio to variance of spot.

At first, in discussional part, we presented conventional corporate risk management theories to argue in favor of active risk management. These imperfections include taxes, financial distress costs, underinvestment and managerial risk aversion. We construed that if firms are facing convex tax function, smoothing of taxable income increases after tax value of the firm. As financial distress is expected costly and by hedging probability of distress can be lowered, hedging can be beneficial for a firm. Underinvestment problem, where owners of the companies do not want to fore go positive NPV investments as most of the benefit go to bond holders of the firm, can also be alleviated by better cash management if hedging is used. Managers may not be willing to take risks due to their bigger than normal stake in a firm, referred as managerial risk aversion. By hedging, managers are able to manage inbuilt risk, which is expected to increase firm value. We presented research done on hedging effect on firm value, and research result where hedge premium for firms that use active risk management was found.

Futures market efficiency was studied using Johansen cointegration method. Intuitively, as spot and futures price of the same asset respond in events accordingly, assets should not deviate far apart in a long-run, as deviations in short term are possible. Johansen method bases on finding stationary vector binding non-stationary time series integrated of the same order together. Johansen method was modeled with two model specifications. Firstly, assuming no linear trend in data, and with no intercept in either cointegrating equation or VAR. Secondly, test was run assuming linear trend in data and implementing intercept and trend in cointegrating equation and intercept in VAR. Results from Johansen method, with both model specifications, confirmed that, spot and futures prices were cointegrated among all assets studied. With both model specifications, unbiasedness of RTS Index futures was confirmed. Results for exchange rate were mixed and we found no evidence in favor of Brent oil futures unbiasedness. Unbiasedness results for RTS Index were reassuring for participants operating in FORTS. Futures work, according to our test results, as an optimal estimate of future spot price and do not inhibit risk premium or other deviations. As with more economically justified model specifications results for exchange rate were also assuring. Brent oil results indicated futures not to be unbiased. Weak exogeneity results indicated, for all asset pair, clear evidence that spot prices were leading in price discovery. Due to previous, not surprisingly, we found no support for prediction hypothesis, in which futures are expected to lead in price discovery. Clear indication of futures adjusting to spot prices also raises a question whether phenomenom could be used beneficially, while creating trading and hedging strategies.

In the optimal hedge ratio estimation we used static OLS, and time-varying DVEC and CCC models. Optimal hedge ratio estimation is based on estimates of covariance between spot and futures, and variance of futures. For OLS, estimation boils down to estimating ordinary least squares regression model. From where, slope coefficient is used as optimal hedge ratio estimate for the whole in-sample period. For time-varying models variance and covariance is changing through time, as is optimal hedge ratio accordingly.

In-sample results indicated OLS model to dominate in hedging effectiveness for RTS Index and exchange rate. Surprisingly, regardless of estimation problems, CCC model reduced variance the most for Brent oil. For out-of-sample period estimation problems with Brent oil became evident as OLS model clearly dominated over time-varying models. Out-of-sample results for Brent oil clearly indicate favoring the use of OLS model when determining optimal hedge ratio. However, some consideration is needed. As, for our sample period Brent oil was trending whole period, spot and futures were found trend stationary, no ARCH effect were found in futures and parameter coefficients implied unstable process. Specification test results are not converging with previous research done on oil futures with longer sample periods. Results also give clear indication that as ARCH specification tests are conflicting, static model should be preferred. Consideration is needed as prolonging the sample period is expected to affect hedging effectiveness results of Brent oil futures. For exchange rate use of OLS model is recommended, while estimating optimal hedge ratios. For RTS Index in-sample result indicated in favor of using OLS model but for all out-of-sample periods, time-varying models dominated. DVEC model was found to be appropriate for all forecast periods.

Overall hedging effectiveness for in-sample results for exchange rate and Brent oil are relatively modest, as for RTS Index decent. Results for exchange rate remain same for in-, and out-of-sample period, about 55 percent. For Brent oil OLS out-of-sample results are more assuring approximately 71 percent compared with about 43 percent of in-sample. Hedge effectiveness results for RTS Index, in-sample about 80 percent and out-of-sample 95 percent, indicate that with optimal hedge ratios derived by models, investors can avoid systematic risk in the spot market almost completely.

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Appendix 1. Return series of assets