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Relationship between futures and spot prices on Russian index RTS

A dissertation submitted in partial fulfilment of the requirements of the School of Business and Law, University of East London for the degree of **MSc Finance and Risk**

17 May 2016

13,010 words

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Abstract

The dissertation investigates relationship between futures and spot prices on Russian index RTS during the crisis period between September 2013 and March 2016. For purpose of the study, cointegration and causality between prices were tested and the total period was divided into two sample periods, namely the Pre devaluation sample and the Post Devaluation sample. Daily data of futures and spot prices were collected via Moscow Exchange. Cointegration between prices was tested with Augmented Dickey-Fuller (ADF) test and was approved only in the Post Devaluation sample. To test causality relationship between two market VAR Model, VECM, Granger causality test and Sims Methodology were used. The tests gave different results. VAR Model suggested a weak causality running from spot to futures in the Post-Devaluation sample, but no other lead-lag relationships. VECM results suggested that both markets adjust to equilibrium (the past day error), however there are unexpected signs for the error correction terms in spot regressions, less significant t-statistics and lower R² provides a basis for the need of further research to understand better the relationship and dynamics of both markets. Granger causality test suggested that there is no Granger causality in any sample. Sims Methodology results indicated that there is a leadership of the futures markets in the Pre-Devaluation period whilst a bi-directional causality exists in the Post-Devaluation sample. The results of dissertation open the field for further investigations by using intra day data.

Table of Contents

1 Introduction.....	10
2 Theoretical Review.....	13
2.1 Cost-of-Carry Model	13
2.2 Future-Spot price Behaviour	14
3. Literature review	18
3.1 Cointegration between futures and spot prices.	19
3.2 Lead-lag relationship.....	21
3.2.1 `Reason and lead-lag relationship	21
3.2.2 Advantage of future market that makes it leading over spot	23
3.2.3 Bidirectional causality and Spot leading futures	24
4 DATA Review.....	26
4.1 RTS Spot Market.....	26
4.2 RTS Futures Market	27
4.3 Samples	27
5. Data Analysis	31
5.1 Descriptive Statistics	31
5.2 Integration Tests	33
5.3 Cointegration Tests	38
5.4 Concluding Remarks.....	42
6. LEAD-LAG RELATIONSHIP	43
6.1 Vector Autoregressive (VAR) Model.....	43
6.2 Vector Error-Correction Model (VECM) Model.....	45
6.3 Granger Causality Test.....	48
6.4 Sims Methodology.....	51
6.4 Concluding Remarks	53
Conclusion and recommendations	54
Bibliography.....	57

1 Introduction

Since the first index futures contract started trading via the exchange market, many studies and researches that examine relationship between futures and spot prices were published. Futures play the risk-transferring role in the financial market. It allows market participants to leverage market movement and to exploit their market expectations about the future changes. Relationship between prices became subject of interest because both prices derive from the value of underlying asset. In a perfect market where securities backed by the same asset reflect to the same information and no-arbitrage opportunity exists, the prices of futures index and spot index should move together in response to the new information arriving to the market. However, in the real world futures contract could react to new information faster as the result it could lead spot price to change. In spot market this information will be transferred and adjusted into the price. Moreover, sentiments and variety of market participants could move prices into unexpected direction. Depending on the scenario the link between prices could narrow or even be broken.

Relationship between futures and spot markets could be described as a financial process that involved two securities backed by the same asset moving into the markets and reflecting to the information about an underlying asset. The process attracts different market participants driven by sentiments and market expectations. Relationship and theoretical difference between prices could be explained via Cost Of Carry model. However, market imperfection such transaction cost and difference in information adjustment could deviate the real future price from theoretical explained by the model. Market imperfection and existence of arbitrage opportunity are the main reasons for lead-lag relationship between prices. Relationship between two markets could contain lucrative and beneficial information for traders and the whole economy. Price discovery role of one market could be useful for market participants to predict and to leverage market movements. Traders prefer to exploit new information in futures market due to high liquidity, low

transaction cost and leverage. Short selling restriction makes futures market lead spot by greater degree if the new information could negatively reflect market expectations. While futures index is more preferable to exploiting the wide range of information, the spot index reflects severely to information as regards specific firm.

The Financial crisis in 2008 created a huge uncertainty about the financial market and caused mispricing between assets. Developed countries suffer from it as well as emerging countries. There is a lack of studies related to relationship between prices during the financial crisis and volatile conditions in emerging markets. Crisis scenario and high volatility in market could influence relationship between prices. Different market participants will change their trading strategies and cause prices to move into the different pattern. Kawaller, Koch and Koch (1993) argue that relationship between prices may vary over time. However, also they state that during volatile period the link between prices will not be broken. But this could be more suitable for developed countries while relationship in close and emerging economies may vary and, thus, be questioned. Bakaert and Harvery (1997) characterized emerging market by low liquidity, high volatility, low correlated returns with developed markets and uninformed traders. Moreover, market imperfection such as transaction cost more pronounced for emerging markets and, thus, speed of informational adjustment could vary between assets.

Russia is an emerging market with the unique state and the fiscal structure that features with the high level of government involvement in the national economy. In the recent years Russian economy faced global isolation and falling oil prices that made Russian currency one of the most depreciated in the world. High volatility and lack of international investments put Russian economy in the weak conditions. Futures on index RTS was introduced in 2006. Since then trading index futures started, it became an integrant part of the Russian exchange market. Dmitro Kovalchak (2010) investigated relationship between futures and spot markets previously. He discovered bidirectional causality between markets, where futures price had a stronger leading effect. That means Russian financial market followed the

same empirical principals as the developed world. During the recent crisis rapid and correspondent devaluation of national currency, sentiments of market participants have changed as well as forecast for the future economic growth, so the relationship should vary for those periods.

The paper tests relationship between futures and spot prices during the recent crisis from September 2013 until March 2015. The time period divided in two-sample period: the first period is the Pre devaluation sample and the second is Post devaluation sample. Purpose of the study is to investigate and to compare relationship between futures and spot prices on Russian index RTS during the two sample periods, namely the Pre Devaluation and the Post Devaluation. The research question: Does Russian economy follows the same financial principals as in developed world on the example of relationship between future and spot prices on Russian index RTS during volatile conditions and how relationship between two market will improve from the start and after the devaluation in Russia.

In the Chapter two Theoretical review, relevant theories that explained the nature of relationship between prices is discussed as well as the crucial role of market participants for information adjustment and basis movement. The third chapter Literature review critically evaluates the academic literature related to the subject, all major discoveries and assumptions were discussed and reviewed. The forth chapter introduce the data, and briefly reviews spot and futures market in Russian index RTS in Moscow Exchange. The fifth chapter discusses and conducts experiment to test cointegration between price with Augmented Dickey-Fuller (ADF) test. The chapter six tests causality relationship between two prices by using VAR Model, VECM, Granger causality test and Sims Methodology. The results and findings presented in conclusion chapter. The last chapter gives recommendation for future studies.

2 Theoretical Review

2.1 Cost-of-Carry Model

In order to examine whether the futures market serves its informational role one has to understand the essence of the pricing relationship between the spot and futures prices.

Theoretically, the total cost of carrying a good forward in time determines a pricing relationship between spot and futures prices. The theoretical fair value of the stock index futures prices is fairly approximated by the net cost-of-carry model, which states that the futures price of an asset equals the continuously compounded spot price:

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

where F_t is the futures price at time t , S_t is the spot index price at time t , r is the continuously compounded cost of carrying the spot index basket from the present time t to time T which is the expiration date of the stock index futures contract, d is the dividend yield on the stock index and e denotes an exponential function. Historically market interest rates have exceeded the dividend rate on common stocks and, thus, the stock index futures price normally exceeds the stock index value.

This cost-of-carry relationship is maintained by arbitrageurs who are trying to capitalize on deviations of stock index futures prices from

perceived fair value, or in other words, whenever violations of the above parity relation arise. However, market imperfections such as transaction costs and regulatory constraints will create a band around the theoretical price within which arbitrage is impossible. Only when the futures-spot price differential, called basis, moves outside the no-arbitrage boundaries arbitrageurs will initiate purchase or sale in order to lock-in a risk-less profit.

2.2 Future-Spot price Behaviour

In order to understand nature of relation between the movements of index spot value and futures price it is necessary to distinguish between market participants who use the stock index futures contracts. Generally, there are three groups of market participants who influence the future-spot price relation: speculators, hedgers and arbitrageurs. Speculators actively use futures contracts in order to take advantage of anticipated market price movements. Hedgers purchase or sell index futures in anticipation of intended spot market trade, so that the hedge provides compensation for adverse price moves prior to the spot transaction. And finally, arbitrageurs simultaneously purchase or sell stocks and futures in order to capture realignment of relative prices following a perceived mispricing opportunity. Thus, only arbitrageurs use both stocks and futures simultaneously, hedgers and speculators normally take position only in one type of instrument at any point in time.

During a typical trading day when new information arrives, speculators bid values up and down in equity and index futures markets. Since stock index and stock index futures represent the claim against the same asset, new information should affect the stock index value and index futures price similarly. As hedgers process new information they will change the composition of their portfolios affecting the prices in both markets in the same way. Therefore, on a typical trading day both prices should move together. In a perfect and frictionless market the rates of change in the prices of spot and futures indices should be perfectly and positively

correlated. However, real markets are not perfect one market may have advantages over the other.

The academic literature makes several theoretical predictions of why one market adjusts to new information more quickly than the other. When new information is received, traders have a choice of exploiting this information either in the spot markets or in the futures ones. The decision made by the trader depends on the type of new information. In case of unsystematic information about a particular company he might exploit it in the spot market because the index will not move as much as the price of a particular company. However, if the trader possesses systematic information about the whole economy he will most probably use index futures since futures market has a number of advantages.

The costs of trading the market through index futures are substantially lower than those of executing basket trades in the index stocks. It is also quicker to execute the trade through the futures market. What is required from an investor in order to take position in the futures market is only to invest a margin. The futures markets are also more liquid than the underlying spot markets. Green (1986) pointed out that due to difficulties in short selling of shares, traders without initial long position in shares cannot reveal any bad expectation about returns. In the world with futures trading such traders will reveal their information by selling futures. There is another technical factor, which may cause the index futures to reflect information faster even if futures market advantages are absent. On receipt of new information to be reflected in actual spot value of the index trade must be made in every share of the index .

A number of researchers have also predicted that some investors with systematic information may exploit it through the spot market. Cornell and French (1983) argued that a stock portfolio provides an investor with a tax-related timing option. Some traders, such as pension funds, may be unable to trade futures due to their own regulations. Therefore, to exploit opportunity they will trade in the stock market. Besides the value of spot represents part of information set by futures traders and, therefore, spot index changes may be reflected in the subsequent futures price changes.

Thus, depending on whether the investor finds it more appropriate to trade in futures contracts or stock, either the futures or the equity market will react faster to the new information. The strength of the futures-spot price relationship should vary from day to day as market conditions change. On arrival of new information in the market the speculators and hedgers may respond to it to a different extent. In such an environment the spot and futures prices may temporary diverge and arbitrage opportunities occur. At that time the strength of the price relationship is influenced by arbitrage activities.

If the futures price exceeds the upper boundary of no-arbitrage band, in which case futures contract is overpriced, arbitrageurs can initiate investments at time t in order to achieve risk-less profits at time T using the following scenario which is called cash-and-carry arbitrage. At time t arbitrageurs will borrow an amount equal to S_t , purchase the stock index portfolio in the spot market and sell the futures contract. Thus, at time t the total cash flow is zero. As time goes by towards T , the arbitrageurs receive payments of dividends, which are reinvested. At time T the arbitrageurs deliver the underlying asset to the investor holding the long position in the futures contract and receive the payment of F_t for it. At the same time the loan is repaid at a cost of $S_t e^{(r-d)(T-t)}$ for it. Assuming certain dividends, a constant riskless rate and no marking to the market, the riskless profit of $(F_t - S_t e^{(r-d)(T-t)})$, is achieved. Therefore, the arbitrageurs will attempt to trade as many futures contracts as possible. The arbitrage activity should lead to fall in the futures price and rise in the spot price until the prices return to equilibrium. Similarly, if futures contract is underpriced, arbitrage seekers will engage in opposite investment strategy called reverse cash-and-carry arbitrage. In this case the arbitrageurs will buy the underpriced asset, i.e. futures contracts, and sell the overpriced asset, i.e. shares of the index. Again, this should force prices back to equilibrium. Therefore, in the long run the two prices will not depart from one another, at least for a long time, and there will be a long run equilibrium relationship between the two markets.

Thus, as long as the basis lies within no-arbitrage band, new information will affect both prices in the same direction. Since an investor will actually prefer the use of one market to the other, the price in one market will lead the price in another one, i.e. the information will be quickly reflected in one market and then, with some lag, will be transmitted to another market. Therefore, one of the markets will serve as a price discovery vehicle. If the basis varies outside the no-arbitrage band, an investor, in order to earn risk-less profit, has to take the opposite positions in two markets simultaneously. The price relationship at the time when arbitrage opportunities exist is reasonably expected to differ from the relationship in case of no arbitrage activity.

3. Literature review

There are numerous studies that investigate relationship between futures index and spot index. Most of them are related to developed countries and markets. Moreover, they examine relationship between prices in different markets with vary indices for different periods of time. Since creation of the first index futures contract until the recent days, literature has developed significantly. More complex methods of analysis started to be used. Pizzie (1998) states that use of erro correction model and cointegration analysis let one to distinguish short-run and long-run relationship form indicating the price discovery and the long-run deviations that accounts for market efficiency and market stability. In the majority of scenarios relation between prices were approved. However, depending on a market and sentiments of market participants some data gave different outcomes. The outcome also depends on a type of analysis conducted. There is a debate over the appropriate statistical procedure to use for estimating cotemporaneous and lead-lag relationships:e.g. vector autoregression (VAR), simultaneous equations models(SEM), ECM, etc. (Koch (1993)). Different tests have individual limitation, and depending on the research method and initial data results may vary.

Lead-lag relationship between variables was tested as well as correlation over time. There is no denying of existents of relation between two prices, but depending on a market, correlation between prices could not exist in a long run. Researchers are arguing about the nature and the role of one market for price adjustment into another and how relationship will react to different conditions. Most investigations are consistent with the two steps

procedure constructed by Quan (1992), which required prices to be nonstationary. It allows the researches to test relationship between the prices over time and to determine the price discovery role of futures for spot or vice versa. Majority of researchers follow the same steps, but applying different methods and models of analysis. The first step is the most important in order to study lead-lag relationship, it is the necessary to approve cointegration during the desired period. If cointegration was not discovered, it would mean that relationship between prices didn't exist and further investigation was pointless. As Cuthbertson, Hall and Taylor stated(1992), If cointegration between future and spot prices exists there must be lead-lag relationship between them. So if cointegration is approved, one can assume the existence of the relation between prices where one price causes another to change. The second step is to determine the direction of the lead-lag relation between prices, which will reveal the price discovery role of one market for another. So eventually researchers were able to approve not only the existence of relationship between prices but also to determine a direction at which one prices causes another to change and to define the price discovery role.

3.1 Cointegration between futures and spot prices.

Since prices of futures and spot contracts rely on a value of an underlying asset, both contracts should reflect to the same information so their prices will correlate over time. Charles Sutcliffe 1997 describes relationship between prices due to all securities moving into a market and their prices are constantly adjusting for new information that randomly penetrate the market. All prices of securities adjusted for inflation over time and new information that could cause value of securities to change revealed randomly. Lie and Tse (2000) assume that futures are important to determine for price discovery in the spot market and

In the literature, cointegration was approved by many studies with vary indices (see Ghosh (1993); Martens, Kofman and Vorst (1995); Yong Ge

and Delei Ye (2008)). They plotted regression analysis to discover the correlation over the certain period of time. Long-run relation between futures index and spot index let them to analyze market for the level of efficiency and stability. Market efficiency assumes that all assets reflect to the same information simultaneously and eventually limiting arbitrage opportunity. Therefore, if market is efficient both prices should reflect to the same information and their movements should be correlated in the long run. By studying the long run relationship between prices we can also determine whether the market is stable or not. Huge shift in prices and abnormal relation between them could confirm that market is not stable.

Long-run relationship between prices was not always approved. For instance, Booth Martikainen and Puttoinen (1993) rejected cointegration between S&P 100 index spot and S&P 100 index futures. As stated by Kowaller, Koch and Koch 1992, relationship between prices may change over time. Market participants could change their strategies or new market players could enter the markets, so relationship may change. In the real world, contracts features and speed of information adjustment could vary price movement over time. As was demonstrated by the financial crisis sentiments of market participants could change rapidly. Moreover, Chowdhury (1991), Crowder and Hamed (1993), Krehbiel and Adkins (1993), MacDonald and Taylor (1988a) reject cointegration between spot and futures price. This immediately calls into question the use of futures price to forecast cash price, an important question for both practitioners and for researchers. Brenner and Kroner (1995) argue that this result may not indicate inefficiency because carrying costs could explain the difference between futures price and subsequent spot price. Futures and spot prices essentially differ from each other, but that could be explained via cost-of-carry model or with assumption that future price is the spot price at the future time T . In a perfect market where no arbitrage opportunity exists, two derived securities from the value of underlying asset should reflect to the same information simultaneously. In the reality one market could reflect to new information faster and market participants could move prices into different direction. They could change their strategies over certain scenarios

or new players will enter the market. For example, hedgers and speculators trade are usually in the stable market, while arbitrage traders could enter the market during volatile periods where securities move far from fundamentals and could be mispriced.

However, Kowaller, Koch and Koch (1992), also states that during stress period correlation between prices even could become stronger. Indeed, many studies that investigate relation between prices during stress conditions determine that correlation prolonged even during the crisis. Christos Floros and Dimitrios V. Vougas (2007), examine relation between prices in Greece during the crisis between 1999-2001. Cointegration between prices was approved and the direction of the lead-lag relation was consistent with the previous discoveries during the stable period. Moreover, Haofei (2015) examined lead lag relation between future and spot markets on the S&P 100 during the financial crisis between 2008 and 2009. The purpose of the research was to investigate lead-lag relationship in stress conditions. The relationship between both markets remained during the period with futures price leading spot. Indeed, numerous studies approve that crisis do not effect the relation between prices. It could be explained by the fact that arbitrage traders will enter the market to execute mispricing between assets quickly and the relation between the prices will be strong.

3.2 Lead-lag relationship

3.2.1 Reason and lead-lag relationship

If the both prices are moving in the same direction there must be relationship when one price causes another to change. Especially in a market where transaction cost exists. While it is hard to study the nature of relationship between prices in depth, it is possible to examine degree of lead-lag relationship between markets. Based on lead-lag relationship researchers discover which market is leading another and could be used as the price discovery vehicle. Rajhans and Jain (2015) state that lead-lag relationship between futures and spot market indices can be explained

based on the reasoning that if some information arrives in futures market, price in spot market will be adjusted and hence, futures market will lead spot market and vice-versa. However, many studies put significance of lead-lag relationship under consideration (see Cheung and NG (1990); Ihara, Kato and Tokunaga (1996) ;Fleming, Ostdiek and Whaley (1996)). Arguing that often both prices react to information simultaneously. They discovered cases where contemporaneous relationship between prices are more significant than lead-lag.

Brooks, Rew, and Ritson (2001) underline two phenomena that linked future and spot price on index. The first is sentiments of market participants and the second is an arbitrage trading. By sentiments they mean advantage of future market over spot that attract traders to exploit their expectations. Indeed, the numbers of characteristics of futures contract make it one of the most liquid financial instrument in exchange market. Arbitrage opportunity between prices could rise in the certain scenario where it is possible to exploit the gap between prices for two securities on the same underlying asset. Kawaller, Koch and Koch (1987), wrote that by calculating the basis, traders could track the arbitrage opportunity but such conditions will be executed quickly. Moreover, the reason for lead-lag relationship between prices could be explained also because of market imperfections that allow one price to reflect to new information faster and eventually cause one market lead and another lag for some time.

Asche and Guttormsen (2002) argue the majority of studies that investigates lead-lag relationship do not consider relationship between futures with different maturity and spot. Several futures could be traded at the same time and the relation could vary if one will conduct research with futures under different maturities. However, for futures and spot prices on indices, some studies that compare futures with different maturities and spot found the same relationship (see Pizzi, Economopoulos, and O'Neill, 1998).

3.2.2 Advantage of future market that makes it leading over spot

As were stated by Cox (1976), futures contract will attracts traders who never trade spot before and as the result it will increase the amount information adjusted into spot market. Indeed, creation of futures market increased the information adjustment in spot market. New traders will exploit the information in future market and that information related the same asset could be transferred into the spot market. Future index contract is more attractive than spot market. As the result, majority of experiments determine importance of future contract for price discovery in the spot market. If prices reflect to the same information over period of time it means that market is efficient and both prices deriving from the value of underlying asset reflect to the same information.

Empirically, vast majority of tests outcome leading futures price over spot(see Ghosh (1993); Tse (1995); Raj (1995)). The reason that makes futures market reacts to new information faster than spot, create lead-lag relationship between the prices where futures is leading and spot is lagging sides. Majority of studies approved relationship between two prices where spot price was lagging over the future price movement. Black (1975) gives an assumption that traders could prefer to trade futures rather than to buy individual stocks in the spot market due to the leverage granted with futures. Indeed, futures market gives enormous leverage for investors to speculate on future market movements. However, the higher leverage means a bigger risk and not all investors, especially big ones, are interested in highly volatile investments.

Futures index contract even more important for price discovery in the index spot price. As were stated before, trading futures index is more pronounce for investors who want to exploit the systematic information, so traders will exploit their market expectations in index futures market rather than in spot stock market. Chan (1992), states if investors have a long position in the spot he still could short sell in the future market and the degree at which futures market will lead spot will be less. Indeed, leading effect of future market will be less significant but futures market will be the

first were bad news will be exploited especially if that news related to the whole economy. He also underlines two factors that make index futures contract leading over spot (i) futures index faster react to new information, especially to information that related to the whole market, (ii) contract features that allows complex trading operation such as short selling. Indeed, those are main factors that explain why futures index price are often leading spot index price.

3.2.3 Bidirectional causality and Spot leading futures

There could also be bidirectional causalities between prices, where spot as well as future could lead each other to change. Indeed, it was discovered that not only futures lead the spot price, but spot price lead the future for some time. However, leading side of spot price over futures price was not significant in most cases. Pizzi, Economoulos and O'Neil (1997) analyzed relation between futures three months and futures six months prices with the spot prices. They discovered evidence that both future contracts prices lead the spot price. However, they also discovered that spot prices lead futures prices too. They concluded that while futures market has stronger lead effect, unidirectional causalities between markets is refuted.

There are also studies that discovered the lead-lag relation between futures index and spot index where spot price leading the future and spot price reacted to the new information faster. Therefore, traders use information about spot market for price discovery in the futures market. According to Charles Sutcliffe (1996), It could be explained when new information about specific firms received, traders will prefer to trade a single share in the spot market and, as the result it could put pressure on the index spot price. They will buy individual shares rather than index, but with such activities the price index could change and eventually the index spot price may lead the futures price on that index. Moosa 1996 states that spot could lead the futures and such action could be triggered by all kinds of market participants. Indeed, arbitrages could make spot price lead the future as well

speculator by exploiting firm's specific information will prefer to trade single share rather than futures index. Moreover, If new information related to firms that substantially contribute to index, spot index would be adjusted first and as the result will lead futures.

However, the scenario of severe leading effect of futures price over spot price was not discovered. The studies that discovered spot leading futures mostly investigate financial markets where volumes of future contracts traded were much smaller than spot. Those markets are emerging and traders prefer to trade spot rather than index futures due to immature futures market. For instance, Pradhan and Bhat (2009) and Moonis (2009) studied relationship between NIFT futures index and NIFT spot index and discovered lead-lag relationship where spot price was leading futures. The rationale for this was provided as immature derivative market and lack of proper information among market participants of derivative market. Zakaria and Shamsuddin (2012) discovered the same relationship. They applied cointegration and Granger causality regression on daily data in Malaysia. The long run relationship between future and spot prices were discovered, while direction of this relation was unexpected. They found that spot price lead future, so spot market reacts to new information faster and play an important role for price discovery in case of Malaysia. The spot market contains information that could be used to forecast futures market fluctuations. Those results could be the cause of non-developed futures market in Malaysia and low volume of futures trading via exchange. Investors prefer to trade in spot market, therefore new information will reflect the spot prices faster and information adjustment in the spot market will lead the spot. As we see abnormal relationship between futures and spot prices on major indices in Malaysia and India revealed a trend where spot prices lead futures price. Therefore, how those relationships will perform long under severe economic crisis and high volatile conditions in financial markets could be questioned. Indeed, there is a gap in the academic literature in revealing lead-lag relationship during stress conditions in emerging market.

4 DATA Review

4.1 RTS Spot Market

Russian Stock market is one of the largest Eastern European equity markets. The RTS is the major index traded in Russia, which reflects changes in the market value of joint stock companies included in the index basket. The value of the index represents the average share price weighted by market capitalization of 50 largest companies in Russia. At different points in time the companies included in the RTS index represented about 85% of market capitalization. In comparison to other major indices the RTS reflects all the stock distributions in its calculation such as dividends, subscription rights, stock splits, etc. The RTS is cap-weighted composite index and assumes that dividends are reinvested in the shares of the same company. When the share goes ex-dividend the share price falls. If the shares of a number of large companies go ex-dividend on the same day this may cause a discernable decline in the stock index. Even if this situation does not happen the ex-dividends cause small drops in the index. The omission of dividends would understate the long term reward by holding shares by the amount of dividends. Thus in comparison to other price indices which are price indices the RTS is a pre-tax performance index.

Since 2006 trading of stocks comprising the RTS index is executed through the electronic trading MOEX (Moscow Exchange). Cash transactions are executed by an automatic computerized system. A trading session on the exchange lasts from 9:30 to 19:00 for securities and from 10:00 to 23:50 for derivatives (Moscow Time). Exchange members participate in trading through workstations connected to a mainframe computer. Authorized traders of the exchange members can continuously, even before or during the trading session, enter orders to buy or sell securities into the automatic trading system. The computer matches the order with the one quoted in the system and immediately executes the trade, if it is allowed by the price

terms of an entered order. The traders may get information about new orders, trades and particular events through their individual workstations.

4.2 RTS Futures Market

RTS Futures are also traded at the MOEX which is operating the electronic trading platform and provides an automated and integrated joint clearing house for products and participants, thereby achieving centralized, cross-border risk management. Through its structure, MOEX offers participants a high-quality, cost-efficient and comprehensive range of services covering the entire spectrum from trading to final settlement via a single electronic system. Synergy effects are created for all participating exchanges through the operation and maintenance of only one trading and clearing platform.

Trading on the fully computerized MOEX platform is distinctively different from trading on traditional open-outcry markets - it transcends borders and offers members technical access from any location, thereby creating a unique global liquidity network. During the period of investigation there were a trading volume encompassing 7,040,208 million contracts.

The trading hours for the DAX index contracts are between 10:00 and 18:45, and evening between 19:00 and 23:50 (Moscow Time) in accordance with the underlying stocks trading session. The contract is cash-settled on the basis of the quarterly delivery cycle with deliveries in March, June, September and December of each year, the last trading day being the third Thursday of the Contract's settlement month of the settlement year.

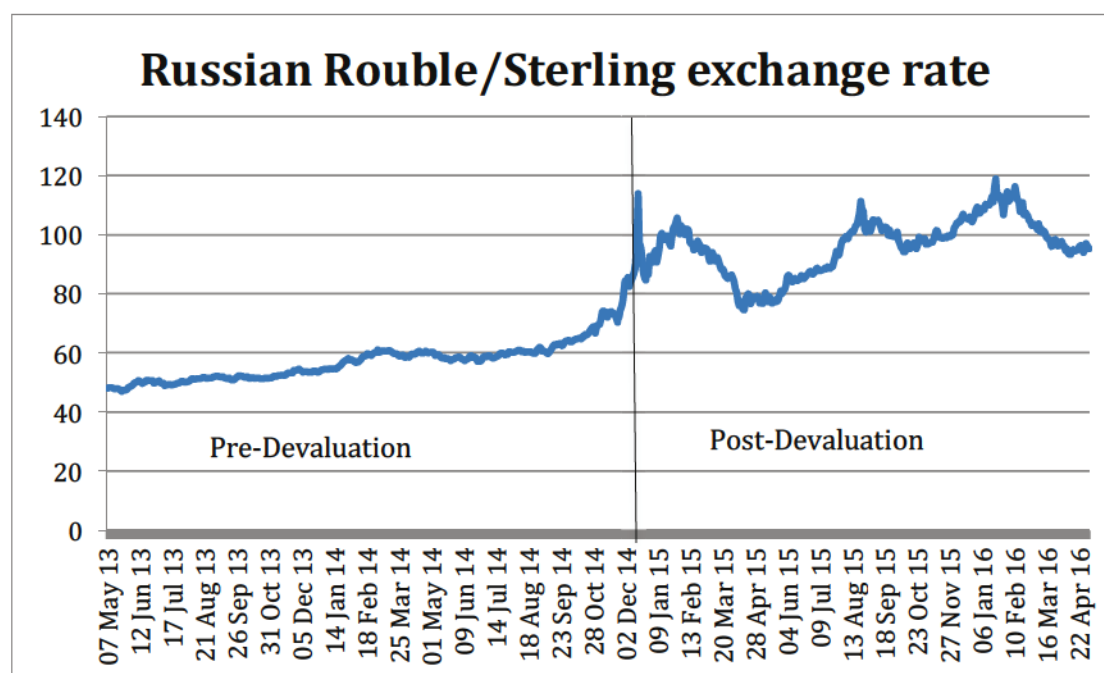
4.3 Samples

The primary data used in this study consists of daily price histories recorded during the period from 16 September 2013 to 15 March 2016 for the RTS Stock Index. For RTS Index Futures the data is available for contracts expiring in September, December and March, June each year. The index

futures price series from the nearest contract, which has the highest volume, is used in each sample. The rationale behind this is that the more actively traded asset has the more information in its prices. Therefore, futures prices are selected from contracts December 2013 until March 2015. The switching to a new futures contract is done one day prior to the expiration date as there could be possible problems associated with expiration day effects. The returns are calculated as the difference of the natural logs of the prices.

Overall the sample consists of 624 observations for both RTS index and index futures. This allows investigating not only the total sample, but more importantly the two equally divided sub-samples which are split at the moment of significant market stress associated with devaluation of Russian currency. In December 2014 Russian Rouble experienced a significant devaluation which may affect the relationship between the spot and futures markets. Therefore, it is of interest to investigate how results change for the two sub-samples, namely: Pre-Devaluation sample from 16 September 2013 to 12 December 2014 containing 313 observations; and Post-Devaluation sample from 15 December 2014 to 15 March 2016 and containing 311 observations. The below graph visualises the exchange rate of Russian Rouble to the British Pound which shows the magnitude of the local currency devaluation:

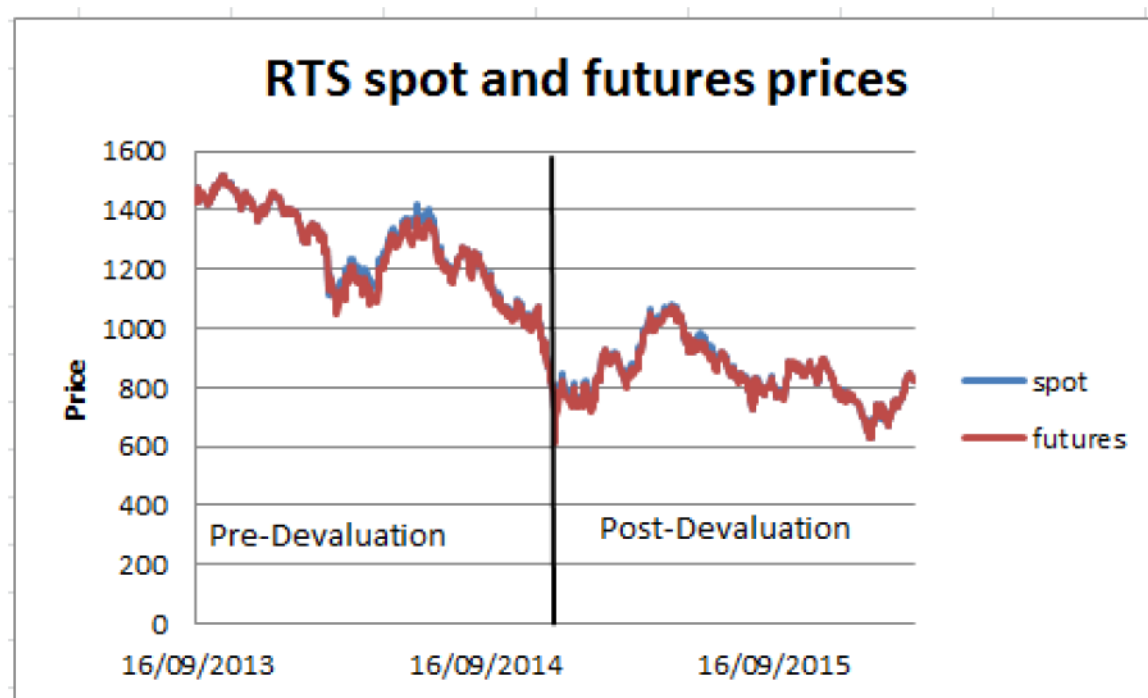
Figure 4.3.1 Russian Rouble to Sterling exchange rate (Source: Bank of England, <http://www.bankofengland.co.uk/Pages/home.aspx>).



Graph below the total sample under investigation, which providing visual evidence in favor of the existence of trending behavior of the time series under consideration. A stochastic trend will be more formally detected using unit root tests in the next chapter. It is also noticed that at certain intervals each of the series have upward and downward sloping deterministic trends.

I am grateful to the Moscow Exchange (www.moex.com) for providing the data for this research.

Figure 4.3.2 RTS spot and futures price.



5. Data Analysis

5.1 Descriptive Statistics

Before conducting any analysis we firstly provide several descriptive statistics to analyse the data. In further analysis the natural logarithms of the stock index spot and futures prices are used due to multiplicative effect. Table 5.1.1 provides summary statistics for the level series used in the empirical analysis, namely s_t and f_t . Let us firstly consider the first moment of the series, which is the mean. It is the average value of the series, obtained by adding up the series and dividing by the number of observations. It is an unexpected feature that the first moment of the futures price is smaller than the first moment of spot price in all samples, which means that the futures price is smaller on average as opposite to the Cost-of-Carry model prediction. The second moment of the series is the standard deviation which is a measure of dispersion or spread in the series. There is no clear pattern in the second moments and they are rather similar for spot and futures in each sample. The second moment of the total sample is larger than those of each sub-samples since the spread between prices is wider for the total sample. Since both RTS index and index futures are priced in Russian Roubles, a possible explanation is that market participants had an expectation of the Russian Rouble devaluation and therefore investors (especially foreign ones) priced this into a future value of the index during the sample period. Another possible reason is inability to exploit arbitrage opportunities due to difficulty to short sell index constituent stocks when the spot index is overpriced, specifically for illiquid stocks for which ETFs are not available. In such instances the basis defined as difference between futures and spot prices may stay negative for prolonged time since arbitrageurs simply cannot do anything about it in order to exploit such opportunities.

The third and fourth moments of the distribution are skewness and kurtosis. Skewness is a measure of an extent to which a distribution is not symmetric around its mean. The skewness of the normal distribution is zero. The normal distribution is symmetric around its mean while skewed

distribution will have one tail longer than the other. Positive skewness means that the distribution has a long right tail while the negative skewness implies that the distribution has a long left tail. There is a clear pattern in skewness for sub-samples, exhibiting negative skewness for the Pre-Devaluation sample and switching to positive skewness in the Post-Devaluation sample series.

Kurtosis measures the peakedness or flatness of the distribution of the series. The kurtosis of the normal distribution is 3. If the kurtosis exceeds 3, the distribution is peaked at the mean (leptokurtic) relative to the normally distributed random variable. However, if the kurtosis is less than 3, the distribution is flat (platykurtic) in the mean relative to the normal distribution. Similar to the situation with skewness the kurtosis is changing from being leptokurtic for the Pre-Devaluation sample to platykurtic for the Post-Devaluation sample. This indicates that after the currency devaluation the distribution became flat with more of the distribution in the shoulders.

Table 5.1.1: Descriptive Statistics for s_t and f_t .

Sample	Size	s_t					f_t				
		μ	σ	S	K	$J-B$	μ	σ	S	K	$J-B$
<i>Total</i>	625	6.9363	0.2338	0.0094	1.6971	0.00	6.9279	0.2333	0.0346	1.7263	0.00
<i>Pre</i>	313	7.1359	0.1265	-0.7850	3.3607	0.00	7.1265	0.1286	-0.6490	3.0461	0.00
<i>Post</i>	311	6.7354	0.1142	0.0997	2.7596	0.51	6.7281	0.1132	0.0959	2.7854	0.56

Notes :

1. s_t and f_t denote the log levels of the spot and the futures price, respectively,
2. μ – mean, σ – Standard Deviations, S - Skewness and K – Kurtosis,
3. $J-B$ is Jarque-Bera p -values,
4. *Pre* denotes “Pre-Devaluation” sample and *Post* denotes “Post-Devaluation” sample.

Jarque and Bera (1987) suggested the procedure for testing whether the series is normally distributed. The test statistic measures the difference of the skewness and kurtosis of the series with those from the normal distribution. The statistic is computed as:

$$Jaque - Bera = \frac{N - k}{6} \left(S^2 + \frac{(K - 3)^2}{4} \right)$$

where S is the skewness, K is the kurtosis, and k represents the number of estimated coefficients used to create the series. Since for the normal distribution the value of the kurtosis is 3 it is possible to define the coefficient of excess kurtosis as $(K - 3)$. The normal distribution will have the coefficient of the excess kurtosis of zero. Under the null hypothesis of a normal distribution, the Jarque-Bera statistic is distributed as with 2 degrees of freedom. The reported probability is the probability that a Jarque-Bera statistic exceeds (in absolute value) the observed value under the null hypothesis. The probability values for the total and Pre-Devaluation series are zero leading us to reject the null hypothesis of a normal distribution. However, for the Post-Devaluation series we cannot reject the hypothesis of normality.

The descriptive statistics suggests that the two sub-samples, namely Pre-Devaluation and Post-Devaluation, are very distinct in terms of distributions, the third and fourth moments are changing to their inverses after the Rouble devaluation. Another interesting feature is that spot prices are higher on average than futures prices in both sub-samples.

5.2 Integration Tests

Most of security prices follow a random walk with a drift (Samuelson (1965)). This corresponds with the concept of an efficient market hypothesis, which states that the current price (Y_t) reflects all the relevant information. The price changes each period due to certain economic factors (i.e. inflation). When new random information (ε_t) arrives the price immediately adjusts. Thus the price follows a random walk with a drift, $Y_t = Y_{t-1} + \theta + \varepsilon_t$. The random walk is a nonstationary process, but the first differences of a random walk are stationary, $Y_t - Y_{t-1} = \theta + \varepsilon_t$. The random walk process can also be called difference stationary series. Generally speaking, a difference

stationary series is said to be integrated and is denoted as $I(d)$ where d is the order of integration. The order of integration is the number of unit roots contained in the series, or the number of differencing operations it takes to make the series stationary. For the random walk above, there is one unit root, so it is an $I(1)$ series. Similarly, a stationary series is $I(0)$.

Standard inference procedures do not apply to regressions which contain an integrated dependent variable or integrated regressors. Therefore, it is necessary to verify, before conducting further analysis, that two price series under consideration are nonstationary. For this purpose the series are checked for the presence of unit root using the broadly used the augmented Dickey-Fuller (1981) test. Let us firstly provide some theoretical background for these two tests.

To illustrate the methodology let us consider an first-order autoregressive $AR(1)$ process:

$$Y_t = \rho Y_{t-1} + \varepsilon_t \quad (5.2.1)$$

where ρ is a coefficient and ε_t is assumed to be white noise error term. If, $-1 < \rho < 1$, then Y_t is a stationary series if. If, $\rho = 1$, then the series under consideration is a nonstationary series, the series is said to have a unit root. If the absolute value of ρ is greater than one, the series is explosive. In order to evaluate the hypothesis of a stationary series we have to test whether the absolute value of ρ is strictly less than one. The Dickey-Fuller tests take the unit root as the null hypothesis $H_0 : \rho = 1$. Since explosive series do not make much economic sense, this null hypothesis is tested against the one-sided alternative $H_1 : \rho < 1$.

The equation 5.2.1 can be expressed in an alternative form. This is achieved by subtracting Y_{t-1} from both sides of the equation:

$$\Delta Y_t = \gamma Y_{t-1} + \varepsilon_t \quad (5.2.2)$$

where $\gamma = \rho - 1$, and Δ is the first-difference operator. Now the null hypothesis is that $\gamma = 0$, that is, there is a unit root. The alternative hypothesis is that $\gamma < 0$. It may appear that we can find that the estimated γ equals 0 on the basis of the t-statistics. However, the t-statistic under the null hypothesis of a unit root does not have the conventional t-distribution. Dickey and Fuller (1979) showed that the distribution under the null hypothesis is nonstandard, and tabulated the critical values for selected sample sizes. However, these tables are not totally adequate and were extended by MacKinnon (1991) who has implemented a much larger set of simulations. In addition, MacKinnon estimates the response surface using the simulation results, permitting the calculation of Dickey-Fuller critical values for any sample size and for any number of right-hand variables.

The simple unit root test described above is valid only if the series is an AR(1) process. If the series is correlated at higher order lags, the assumption that the error term is white noise is violated. Thus, if the error term is autocorrelated the test has to be modified for this contingency. The Augmented Dickey-Fuller (ADF) test makes a parametric correction for higher-order correlation by assuming that the Y_t series follows an AR(p) process.

The ADF approach controls for higher-order correlation by adding lagged values of the dependent variable to the right-hand side of the regression:

$$\Delta Y_t = \gamma Y_{t-1} + \sum_{j=1}^p \delta_j \Delta Y_{t-j} + \varepsilon_t \quad (5.2.3)$$

This augmented specification is then used to test $H_0 : \gamma = 0$ against $H_1 : \gamma < 0$ in this regression. An important result obtained by Fuller is that the

asymptotic distribution of the t-statistic on γ is independent of the number of lagged first differences included in the ADF regression. The optimal number of lags of the dependent variable is determined using the Akaike Information Criterion (AIC).

If $H_0 : \gamma = 0$ is rejected it would mean that the series does not contain a unit root. If the null hypothesis is not rejected, that means that the series is integrated at least of order one, possibly, of higher order. For further analysis it is necessary to establish that each series has the same order of integration. If a level series possesses two unit-roots, the differenced series must possess one unit-root, therefore, we need to apply the ADF tests to the differenced series. The rejection of the hypothesis of two unit roots means that the level series are integrated of order one and, therefore, their differences are stationary.

Another important question is whether to include other exogenous variables in the test regression. There is the choice of including a constant, a linear time trend, both of them or neither of them. The choice is important since the asymptotic distribution of the t-statistic under the null hypothesis depends on the assumptions regarding these deterministic terms. The asymptotic distribution changes when these assumptions are not satisfied. Both level series under consideration exhibit a nonzero mean, therefore, the constant has to be included in the test regression. Both level series also seem to contain a trend. Thus, the second test regression specification is also used containing both constant and a linear time trend. The first differences or the return series should be fluctuating around a zero mean with no trending behaviour. With the same logic, the two specifications of the test regression are used, one containing just a constant and another containing neither a constant nor a trend.

Thus, the ADF tests are applied to the level and differenced series of index spot and futures prices. The results of the tests are reported in Table 5.2.1. The results indicate that the null hypothesis of a single unit root cannot be rejected even at 10% significance for the level series in all samples. On the other hand, the results of ADF test for the first differences

of the price series indicate that the hypothesis of two unit roots is clearly rejected in all periods at 1% level. The combined results declare that both index spot and futures price series are integrated of order one – $I(1)$. Therefore, stationarity of the series is achieved by taking the first differences of each price series.

Several statistics describing the return series are presented in Table 5.2.2. Both spot and futures series are quite similar for each particular sample, however distribution properties changes in the Pre-Devaluation sample as compared against Post-Devaluation sample. The first moments of spot and futures returns prior to the devaluation of Russian Rouble in December 2014 are negative whilst after the devaluation they are positive. There is also a notable increase the volatility of the both spot and futures returns in the Post-Devaluation sample. The most notable feature is a positive skewness of the both returns in the Post-Devaluation sample which is in contrast to the usually reported stylised feature of a negative skewness in financial returns. Both return series across all the samples are notably peaked at the mean (leptokurtic) relative to the normally distributed random variable as can be seen from kurtosis values. Also according to Jarque-Bera test statistic, all the return series are non-normal.

It is therefore of main interest to investigate whether relationship between spot and futures returns changes across the different samples. This will be investigated in the next Chapter 6.

Table 5.2.1: ADF t -statistics for the level and differenced series.

Sample	s_t	$s_t^{(\tau)}$	f_t	$f_t^{(\tau)}$	Δs_t	$\Delta s_t^{(n)}$	Δf_t	$\Delta f_t^{(n)}$
Total	-1.3826	-2.6693	-1.6023	-2.7093	-18.8780 a	-18.8488 a	-14.1709 a	-14.1364 a
Pre	1.1788	-0.4481	0.8989	-0.7455	-17.2887 a	-17.1213 a	-17.4170 a	-17.2644 a
Post	-2.0283	-2.5698	-2.2303	-2.7646	-9.7539 a	-9.7707 a	-9.6159 a	-9.6265 a

Notes :

1. s_t and f_t denote the log levels of the spot and the futures price, respectively. And Δ is the first difference operator
2. The critical values are obtained from MacKinnon (1991).
3. a, b and c corresponds to significance levels of 1%, 5% and 10%, respectively.
4. The ADF test for level series is based on the OLS regression (5.2.3) where $Y_t = f_t$ or s_t .
5. The ADF test for differenced series based on the OLS regression (5.2.3) where $Y_t = \Delta f_t$ or Δs_t .
6. Superscript (τ) indicates that a linear trend is included in ADF regression. Superscript (n) indicates that neither a linear trend nor a constant is included in ADF regression
7. **Pre** denotes "Pre-Devaluation" sample and **Post** denotes "Post-Devaluation" sample.

Table 5.2.2: Descriptive Statistics for Δs_t and Δf_t

Sample	Size	Δs_t					Δf_t				
		$\mu (10^3)$	$\sigma(10^3)$	S	K	$J-B$	$\mu (10^3)$	$\sigma(10^3)$	S	K	$J-B$
<i>Total</i>	623	-0.90	22.44	-0.08	9.31	0.00	-0.89	0.94	-0.10	9.33	0.00
<i>Pre</i>	312	-1.88	17.61	-0.85	11.41	0.00	-1.87	1.03	-0.54	7.66	0.00
<i>Post</i>	310	0.43	25.73	0.29	7.33	0.00	0.53	1.51	0.33	7.57	0.00

Notes :

1. s_t and f_t denote the log levels of the spot and the futures price, respectively and Δ is the first difference operator;
2. μ – mean, σ – Standard Deviations, S - Skewness and K – Kurtosis;
3. $J-B$ is Jarque-Bera p-values.

5.3 Cointegration Tests

In most cases, if nonstationary variables are combined together their linear combination will also be nonstationary. As a further illustration, let us consider two I(1) time series X_t and Y_t and their regression model¹:

$$X_t = aY_t + u_t \quad (5.3.1)$$

where u_t is the residuals. Taking everything except the residuals to the left hand side gives us the following model:

$$X_t - aY_t = u_t \quad (5.3.2)$$

where the residuals can be considered as a linear combination of the variables. As it was mentioned before most of linear combinations of nonstationary variables are also nonstationary. However, there may exist

¹ It is of course possible to include an intercept or a trend in the model. Whether a constant or a trend are included or not could be determined considering the arguments on their theoretical importance in the model.

such coefficient α (known in this case as cointegrating coefficient) at which linear combination (5.3.2) is a stationary process even though the constituents are $I(1)$. The Granger representation theorem states that if there exists a dynamic linear model with stationary disturbances and the data are $I(1)$, then the variables are said to be cointegrated of order $(1,1)$. It implies that the two variables have a long-run equilibrium relationship. As it was covered in Chapter 2, the long-time relationships between spot and futures prices are given by the cost of carry model, so that the series could wander apart without bound. It is of course possible that spot and futures prices may deviate in the short-run but their association would return in the long-run due to market forces arising from no-arbitrage conditions.

In the academic literature several testing procedures were proposed to determine whether a group of non-stationary series are cointegrated or not. Although all the proposed estimators were super-consistent, the quality of the estimators for a finite number of observations differs. Gonzalo (1994) conducted research on comparisons of the finite sample performance of proposed estimators and found that the best performance has Johansen's (1988) maximum likelihood estimator. It was also advocated by many researchers that this method produces the estimator which is more robust in the presence of market shocks. Therefore, the Johansen (1988) methodology is employed to test the cointegration of the variables.

By recent asymptotic results in cointegration theory, the vector autoregressive model (VAR) is given by,

$$y_t = \Pi_1 y_{t-1} + \dots + \Pi_p y_{t-p} + Bx_t + \varepsilon_t \quad (5.3.3)$$

where Bx_t is a d -vector of deterministic variables, ε_t is a vector residuals and y_t is a k -vector of nonstationary $I(1)$ variables (in our case $y'_t = [f'_t, s'_t]$). This can be reparametrized in error correction model as follows (Johansen (1988), Johansen and Juselius (1990)),

$$\Delta y_t = \Gamma_1 \Delta y_{t-1} + \dots + \Gamma_{p-1} \Delta y_{t-p+1} + \Pi y_{t-p} + Bx_t + \varepsilon_t \quad (5.3.4)$$

where $\Gamma_i = -(I_K - \Pi_1 - \dots - \Pi_p)$ with $i = 1, 2, \dots, p-1$ and $\Pi = -I + \Pi_1 + \dots + \Pi_p$. Π represents the long-run response matrix. The test for cointegration is carried out by looking at the rank of the Π matrix via its eigenvalues. If the rank of long-run response matrix is zero ($r = 0$), the variables are nonstationary and there are no cointegrating vectors. If the rank of the Π matrix equals the number of variables in the system ($r = k$), all the variables are stationary and the number of cointegrating vectors is the same as the number of variables in the system since the linear combination of stationary variables is also stationary. The rank of the Π matrix may lie somewhere between the above mentioned cases and there will be a particular number of linear combinations of nonstationary variables. If there is a co-integration the matrix Π will be of reduced rank ($r < k$), then there exist $r \times k$ matrices α and β with rank r such that $\Pi = \alpha\beta'$ and the linear combinations $\beta'y_{t-p}$ is stationary. The complete method of testing for cointegration is explained in Johansen and Juselius (1990). They present statistics (λ_{trace} and λ_{max}) significance of which would indicate that a cointegrating vector does exist.

Thus the Johansen's method is to estimate the Π matrix from an unrestricted VAR and to test whether the restrictions implied by the reduced rank of Π can be rejected. The first step of testing would be to determine the appropriate order of the VAR. The Akaike's Information Criterion is employed to decide on the number of the lags in each particular sample. Also the series have nonzero means and deterministic trends as well as stochastic trends. Similarly, the cointegrating equations may have intercepts and deterministic trends. Therefore, need to make an assumption regarding the trend underlying the data. Johansen (1995) considers five deterministic trend cases from which according to AIC for both sub-samples is selected the one which assumes that the level data and the cointegrating equations have intercepts and no linear trends. For the total sample AIC suggested to

use specification with neither intercept nor trend in the cointegrating equation.

The results of the tests are reported in Table 5.3.1. The Johansen test statistics indicate the rejection of the null hypothesis of no cointegrating vectors under both trace and maximum eigenvalues for only the total and the Post-Devaluation samples. However, for the Pre-Devaluation sample Trace test and Max-eigenvalues tests indicate no cointegration at both 5% and 1% levels. For all the samples the null hypothesis of at most 1 cointegrating vector is not rejected stating that no more than one cointegrating vector exists for each sample (n.b. for the Pre-Devaluation sample there is no cointegrating vector at all). This is an interesting result suggesting that the cointegration did not exist prior to the stress period associated with the significant currency devaluation happened after December 2014. Presence of cointegration between two prices in the Post-Devaluation sample suggests that during the stress period there appeared an arbitrage elasticity and that the RTS stock index futures were serving an important social role during the stress period, which is risk transfer.

Table 5.3.1: Johansen Maximum-Likelihood Cointegration Procedure.

Total Sample										
H0	λ_{trace}	5%	1%	λ_{max}	5%	1%	VAR(p)	f_t	s_t	
$r = 0$	23.04	12.53	16.31	22.09	11.44	15.69	1	1.0000	-0.9987	
$r \leq 0$	0.95	3.84	6.51	0.95	3.84	6.51				
Pre-Devaluation Sample										
H0	λ_{trace}	5%	1%	λ_{max}	5%	1%	VAR(p)	f_t	s_t	c
$r = 0$	13.65	19.96	24.60	10.65	15.67	20.20	1	1.0000	-1.0438	0.3280
$r \leq 0$	3.00	9.24	12.97	3.00	9.24	12.97				
Post-Devaluation Sample										
H0	λ_{trace}	5%	1%	λ_{max}	5%	1%	VAR(p)	f_t	s_t	c
$r = 0$	29.55	19.96	24.60	23.67	15.67	20.20	1	1.0000	-0.9599	-0.2642
$r \leq 0$	5.87	9.24	12.97	5.87	9.24	12.97				

Notes:

1. The (non-standard) critical values are taken from Osterwald-Lenum (1992), which differ slightly from those reported in Johansen and Juselius (1990).
2. The number of lags in unrestricted VAR is determined with Akaike Information Criteria.

The table also provides the cointegrating parameter associated with spot price when the futures coefficient value is normalized, i.e. set to unity. We can see that there is some evidence that the cointegrating vectors are not strictly (1,-1).

This is an unexpected results of the lack of cointegration in Pre-Devaluation sample. Further investigations will be carried out in the next Chapter 6.

5.4 Concluding Remarks

In this chapter both futures and spot time series were analysed for the total sample as well as the two sub-samples, namely the Pre-Devaluation and the Post-Devaluation. As it was expected both futures and spot level series were found to be non-stationary whilst their returns are stationary series. It was also noted that the distribution of both level and return series were different for the Pre-Devaluation sample as compared against the Post-devaluation sample suggesting that the devaluation of the currency has produced a notable impact on the RTS spot and futures markets. Moreover, it was discovered that in the Pre-Devaluation sample spot and futures prices are not cointegrating whilst in the Post-Devaluation they are. This provides an additional interest to investigate how the relationship between futures and spot prices changed from the Pre-Devaluation sample to the Post-Devaluation one, which will be covered in the next chapter. Since the total sample will provide just an overall result which will be a mixture of results from the two sub-samples it will not be investigated further. It is of interest of how the relationship between spot and futures changes after the significant stress in the market due to currency devaluation.

6. LEAD-LAG RELATIONSHIP

The Cost-of-Carry model implies, given absence of market frictions and transaction costs, that contemporaneous stock index and stock index futures prices should be perfectly positively correlated. Since both prices reflect the same value of the underlying stocks they should change simultaneously to reflect new information. Contrary to this prediction there is a broad conclusion in the academic literature that stock index futures markets lead underlying stock markets with a weak or no feedback from spot markets. In this chapter the lead-lag relationships between spot and futures prices are investigated by employing methods advocated by previous research and applying them to the two sub-samples relating to the periods prior to Russian Rouble devaluation and afterwards.

6.1 Vector Autoregressive (VAR) Model

A VAR Model describes a system of equations in which each variable is a function of its own lag and the lag of the other variable in the system. Let us consider the basic finite order VAR model of order p

$$y_t = v_t + A_1 y_{t-1} + \dots + A_p y_{t-p} + \varepsilon_t$$

where y_t is the K -dimensional observed time series vector $y_t = (y_{1t}, \dots, y_{Kt})$, the v_t is the intercept term vector $v_t = (v_{1t}, \dots, v_{Kt})$ and A_i are $K \times K$ coefficient matrices. The error process $\varepsilon_t = (\varepsilon_{1t}, \dots, \varepsilon_{Kt})$ is an unobservable, Gaussian, zero-mean white-noise process with time-invariant, positive-definite and non-singular covariance matrix Σ ,

$$\varepsilon_t \sim NID(0, \Sigma)$$

The present application focuses on a bivariate model comprising the futures and the spot returns (hence $y_t = [\Delta f_t, \Delta s_t]'$), which were concluded to be stationarity in the previous chapter. The lag length is chosen as per AIC criteria. The results are presented in the Table 6.2.1 below:

Table 6.1.1 Estimation Results of VAR Model.

	Pre-Devaluation				Post-Devaluation			
	Δf_t		Δs_t		Δf_t		Δs_t	
	Coefficient	<i>t-stat</i>	Coefficient	<i>t-stat</i>	Coefficient	<i>t-stat</i>	Coefficient	<i>t-stat</i>
v	-0.0018	-1.68	-0.0018	-1.75	0.0005	0.42	0.0005	0.33
Δf_{t-1}	-0.2801	-1.15	0.0125	0.05	-0.4439	-1.67 ^c	-0.0128	-0.05
Δf_{t-2}	-0.0109	-0.04	0.1603	0.68	-0.2755	-1.04	-0.0569	-0.22
Δs_{t-1}	0.3035	1.21	-0.0002	-0.00	0.4967	1.82 ^c	0.0818	0.31
Δs_{t-2}	0.0354	0.14	-0.1186	-0.48	0.1577	0.59	-0.0781	-0.30
\overline{R}^2	0.0054		0.0035		0.0263		0.0278	
Heteroscedasticity	48.36				143.20			
	(0.0023)				(0.0000)			

Notes:

1. a, b, c corresponds to the significance level at 1%, 5% and 10%, respectively.
2. Lag length is chosen with AIC.

The adequacy of the model is checked by performing the residual testing for heteroscedasticity which occurs when the variance of the error term differs across observations. White's test is employed (White(1980)) to test for heteroscedasticity in the residuals. It was found that there is a strong evidence of heteroscedasticity in both samples. The presence of heteroscedasticity is not a surprising result for the financial time series and was reported previously in the academic literature. Although the estimates are consistent in the presence heteroscedasticity, but the conventional computed standard errors are no longer valid. One suggestion to correct this

problem is to use heteroscedasticity consistent variance-covariance matrix. However, Mizon (1995) advocated against such correction.

The main result for the VAR model is that in the Pre-Devaluation sample there is no evidence of lead-lag relationship whilst in the Post-Devaluation sample there is a weak lead running from spot to futures market as well as the first futures autoregressive lag is also significant at 10% level. This is an interesting result that the spot market started to serve as a price discovery vehicle in the stressed conditions in Russia. This is in line with results reported in the section 3.2.3 for the emerging markets to which Russia also relates. Another interesting fact is that R^2 values for the VAR model in the Post-Devaluation sample increase by approximately 5 times as compared against the Pre-Devaluation sample suggesting that the lagged returns start to explain 2.5% of variation in the contemporaneous returns during the stressed conditions. Nevertheless VAR results in both samples indicate that the most of price movements are contemporaneous as suggested by the theoretical Cost-of-Carry model.

6.2 Vector Error-Correction Model (VECM) Model

The Cost-of-Carry model also implies that a unique cointegrating relationship exists with a cointegrating vector consistent with mean reversion (stationarity) of the basis. As discussed in Chapter 5 the cointegration relations were not found in the Pre-Devaluation sample, however in this section a further attempt will be done to investigate the long-run dynamics in order to apply the Vector Error-Correction Model (VECM).

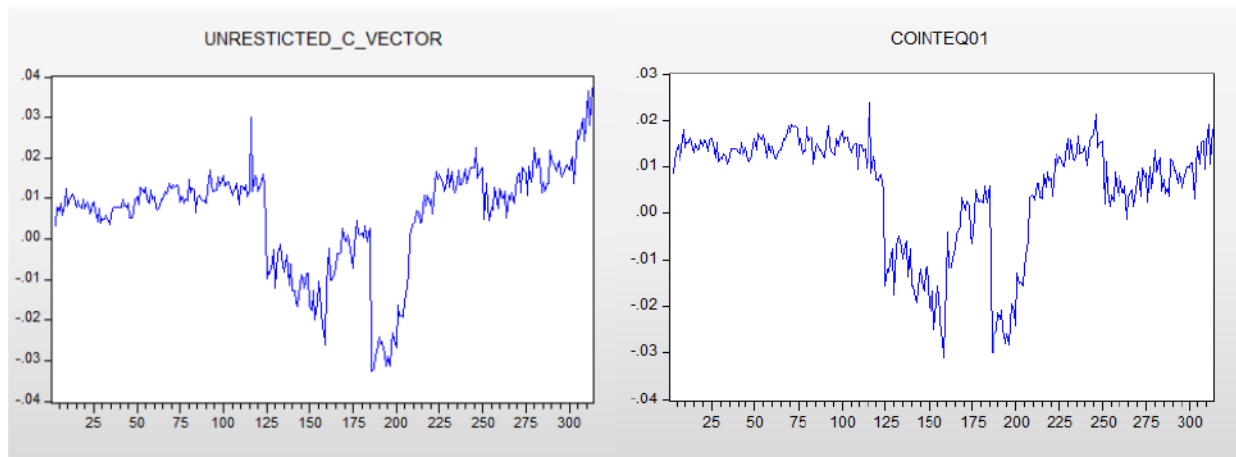
An VECM can be estimated using a two-stage-maximum-likelihood procedure. The first stage of this procedure essentially consists of the implementation of the Johansen (1988, 1991) maximum-likelihood cointegration procedure in order to test for the number of cointegrating relationships in the system and to estimate the cointegration matrix. The second stage then consists of the implementation of a maximum -likelihood

estimation, which yields estimates of the remaining parameters of the model.

In this section a standard linear bivariate VECM for Δf_t and Δs_t is estimated. However, for the Pre-Devaluation sample there is no stationary cointegrating vector which can be legitimately used in the VECM. One of the techniques to improve the situation is to restrict the cointegrating vector to (1,-1) for futures and spot prices, respectively. This yields a vector which is visually appears to look more stationary, at least in its mean. Figure below depicts the both vectors, one unrestricted and another restricted, which are obtained from Johansen testing procedure for the Pre-Devaluation sample.

Figure 6.2.1 Vectors from Johansen Maximum-Likelihood Cointegration

Procedure for the Pre-Devaluation sample.



The bivariate VECM is estimated using the restricted vector for the Pre-Devaluation sample and unrestricted one for the Post-Devaluation sample since for the Post-Devaluation sample Johansen's statistics indicate cointegration. The traditional Vector Error Correction Models are estimated:

$$\Delta y_t = \nu + \sum_{i=1}^{p-1} \Lambda_i \Delta y_{t-i} + \Pi y_{t-p} + u_t$$

where $y_t = \{f_t, s_t\}$, assuming the same lag length suggested by the AIC.

Before examining the results several points have special attention. Lags of autoregressive coefficients are chosen according to Akaike Information Criteria. The cointegrating vectors derived from the cointegration testing procedure (Chapter 5) could be interpreted as long-run equilibrium relationship between spot and futures prices. Thus, the restricted cointegrating vectors are used as error correction terms with one lag. The adequacy of the models is checked by performing the residual testing for heteroscedasticity. As previously White's test is employed (White (1980)) to test for heteroskedasticity in the residuals. There is a strong evidence of heteroscedasticity in both models which is not corrected as per Mizon (1995). Although the corrected t-statistics might be slightly lower it does not change the general results in both samples. The results are presented in the table below:

Table 6.2.1 Estimation Results of VECM.

	Pre-Devaluation				Post-Devaluation			
	Δf_t		Δs_t		Δf_t		Δs_t	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
EQM_{t-1}	-0.2028	-2.61 ^a	-0.1692	-2.25 ^b	-0.3743	-2.51 ^a	-2760	-1.90 ^c
Δf_{t-1}	-0.1545	-0.63	0.1163	0.48	-0.2195	-0.79	0.1528	0.56
Δf_{t-2}	0.0720	0.29	0.2291	0.97	-0.1461	-0.55	0.0386	0.14
Δs_{t-1}	0.1694	0.66	-0.1094	-0.44	0.2640	0.93	-0.0898	-0.32
Δs_{t-2}	-0.0547	-0.21	-0.1917	-0.78	0.0248	0.09	-0.1760	-0.66
\overline{R}^2	0.0182		0.0099		0.0457		0.0389	
Heteroscedasticity			57.08				153.46	
			(0.0020)				(0.0000)	

Notes:

1. a, b, c corresponds to the significance level at 1%, 5% and 10%, respectively.
2. Lag length is chosen with AIC.

The results are quite similar across all the samples. Consider firstly the long-run relationships depicted by error correction coefficients. If the cointegrated variables adjust towards the long-run equilibrium, the error correction coefficients are expected to be negative for the own-market equilibrium error term and positive for the cross-market equilibrium error term. By virtue of construction/restriction of cointegrating vectors they can be regarded as the futures market equilibrium terms. In both samples the coefficients in futures regressions for error correction terms have the expected signs whilst they have unexpected signs for the spot regressions suggesting the spot market does not adjust to the expected direction when error in the equilibrium occurs. The error correction coefficients for all regressions are statistically significant in all samples. Therefore, in both samples it means that when the cointegrating relationship is perturbed by arrival of news, both spot and futures adjust to restore equilibrium. Furthermore, in the Post-Devaluation sample the significance of the error correction coefficient is only at 10% level suggesting that the spot market reacts slower with respect to futures market in the stress conditions. With respect to the relationships between the spot and futures captured by lagged returns we can see no significant lag terms.

Most of price movements are contemporaneous as suggested by theoretical model and is supported by the low regression R^2 values. As suggested by R^2 values, the VEC models explain more than twice of the variations both returns during stressed conditions as compared against the Pre-Devaluation period. The lower R^2 values for the spot regressions suggest that the spot market plays a leading role in incorporating new information because lagged variables can explain only a very small portion of the current changes.

6.3 Granger Causality Test

In the next section another formal test, namely Granger causality test, will be conducted to conclude on the lead-lag relationship between stock index spot and stock index futures returns.

This test commonly used in examining lead-lag relationship between economic variables is referred to as Granger causality test. This test is quite close to the Wald test performed in the previous section but still worth performing with different specifications of lags. Also the residuals from the regression used in this testing methodology will be used in the nonlinear tests. The Granger (1969) approach to the question of whether Y causes X is to see how much of the current X can be explained by past values of X and then to see whether adding lagged values of Y can improve the explanation. X is said to be Granger-caused by Y if Y helps in the prediction of X, or equivalently if the coefficients on the lagged Y's are statistically significant. The statement "Y Granger causes X" does not imply that X is the effect or the result of Y. Granger causality measures precedence and information content but does not by itself indicate causality in the more common use of the term.

To test whether causality runs from series $\{Y_t\}$ to $\{X_t\}$ (i.e. "one-way" causality), the following pair of models is specified:

$$X_t = c_{10} + \sum_{j=1}^p a_{1j} X_{t-j} + e_{1t} \quad (6.3.1)$$

$$X_t = c_{20} + \sum_{j=1}^p a_{2j} X_{t-j} + \sum_{k=1}^q b_{2k} Y_{t-k} + e_{2t} \quad (6.3.2)$$

where the a_{1j} and a_{2j} are the parameters which relate X_t to past values of X_t and the b_{2k} are parameters relating X_t to past values of Y_t , and e_{1t} and e_{2t} are iid residuals. This approach is used to test the causality between spot and futures returns. A lag length $p = q$ in is chosen for both return series as per

AIC criteria for the VAR Model in order to be consistent. The null hypothesis to be tested is:

$$b_{21} = \dots = b_{2q} = 0$$

The reported F-statistics are the Wald statistics:

$$F^* = \frac{SSE(1) - SSE(2)/q}{SSE(2)/N - p - q - 1} \sim F(q, N - p - q - 1)$$

where SSE(1) and SSE(2) are the sum of squared residuals obtained from OLS regressions on equations (6.3.1) and (6.3.2), respectively, and N is a number of observations. When F^* is significantly large, the null hypothesis that B does not granger cause A is rejected. Results are presented in the Table 6.3.1.

Table 6.3.1: Granger Causality Tests.

Lag length: p, q	Pre-Devaluation		Post-Devaluation	
	F-Statistic	Probability	F-Statistic	Probability
<i>Futures Do Not Granger Cause Spot</i>				
2	0.2395	0.7871	0.0251	0.9752
<i>Spot Do Not Granger Cause Futures</i>				
2	0.7410	0.4775	1.6651	0.1909

Notes:

1. Lag length is chosen as per VAR specification in the section 6.1.

Interestingly enough the results indicate that Granger causality does not run from neither spot nor futures in both samples which is in line with VECM Model, but opposite to the VAR Model result in the Post-Devaluation sample where was a weak evidence of spot leading futures. Again the results

of the Granger causality test is contrary to many empirical studies which found leadership of futures markets and this re-confirms the conclusion for the Vector Error-Correction models.

6.4 Sims Methodology

And finally let us examine lead-lag relationship by employing technique based on Sims (1972). This methodology investigates the temporal relationship by estimating the regression which does not contain autoregressive terms:

$$\Delta s_t = a_0 + \sum_{k=-5}^{k=5} b_k \Delta f_{t+k} + u_t$$

where Δs_t and Δf_t are the spot and futures logarithmic returns at time t. The coefficients with negative sign in front of k are the lag coefficients and the coefficients with positive sign are lead coefficients. If in this regression the lag coefficients are significantly different from zero then futures returns lead spot returns and if lead coefficients are significantly different from zero then spot returns lead futures returns. If both lags and leads are significantly different from zero then, causality is bi-directional. If neither lags nor leads are significantly different from zero then there is no lead-lag relationship, which is consistent with prediction of cost-of-carry model if there is strong positive contemporaneous correlation.

The above model is estimated using OLS. The t-statistics is calculated using Newey and West (1987) variance-covariance matrix which does not change the point estimates of the parameters but only the estimated standard errors. Newey and West (1987) covariance estimator is consistent in the presence of both heteroskedasticity and autocorrelation of unknown form. The Newey-West estimator is given by

$$\bar{\Sigma}_{NW} = \frac{T}{T-k} (X'X)^{-1} \bar{\Omega} (X'X)^{-1}$$

where

$$\bar{\Omega} = \frac{T}{T-k} \left\{ \sum_{t=1}^T u_t^2 x_t x_t' + \sum_{v=1}^q \left(\left(1 - \frac{v}{q+1} \right) \sum_{t=v+1}^T (x_t u_t u_{t-v} x_{t-v}' + x_{t-v} u_{t-v} u_t x_t') \right) \right\}$$

and q , the truncation lag, is a parameter representing the number of autocorrelations used in evaluating the dynamics of the OLS residuals

Following the suggestion of Newey and West we set q to $q = \text{floor}(4(T/100)^{\frac{2}{9}})$. This therefore should give some comfort regarding the t-statistics and thus test results. The results are presented in the Table 6.4.1.

Table 6.4.1: Parameter estimates from regression of stock index returns on lagged, contemporaneous and leading futures returns.

	Pre-Devaluation			Post-Devaluation		
	Coefficient	St. Error	t-Statistic	Coefficient	St. Error	t-Statistic
c	-9.96E-05	0.0002	-0.17	-4.93E-05	0.0002	-0.27
β_{+2}	-0.0040	0.0133	-0.30	-0.0071	0.0132	-0.54
β_{+1}	0.0162	0.01967	0.82	0.02611	0.0121	2.16 ^b
β_0	0.9324	0.0374	24.93 ^a	0.9426	0.0133	71.00 ^a
β_{-1}	0.0058	0.0257	0.23	0.0388	0.0176	2.20 ^b
β_{-2}	0.0272	0.0117	2.30 ^b	-0.0288	0.0251	-1.15
χ^2_{lead}	0.78			4.73		
(p-value)	(0.6786)			(0.0938)		
χ^2_{lag}	6.01			5.29		
(p-value)	(0.0495)			(0.0701)		
R ²	0.94			0.95		

Notes:

1. The reported t-statistics correspond to the null that the parameter estimate equals zero and are calculated using Newey and West (1987) variance-covariance matrix.
2. The χ^2_{lead} and χ^2_{lag} are Wald tests of joint significance of lag and lead terms and are distributed χ^2 under the null hypothesis that the relevant coefficients are zero.
3. a, b, c corresponds to the significance level at 1%, 5% and 10%, respectively.

It is interesting finding that when the past autoregressive terms are not included in the model than the results are indicating that in the Pre-Devaluation sample there is a lead from the futures market at 5% significance level as per Wald test statistics. In the Post-Devaluation sample there a weak bi-directional causality running in both directions. The above conclusions are also supported by significance of lead/lag coefficients in the OLS regressions. The results from this section are rather different from the VAR, VECM and Granger causality methods and require further investigation.

6.4 Concluding Remarks

In this chapter the academic literature standard approaches, namely VAR Model, VECM, Granger causality test and Sims Methodology were used. The results are not fully conclusive or completely confirming each other:

- (1) VAR Model suggested a weak causality running from spot to futures in the Post-Devaluation sample, but no other lead-lag relationships;
- (2) VECM results suggested that both markets adjust to equilibrium (the past day error), however there are unexpected signs for the error correction terms in spot regressions, less significant t-statistics and lower R² provides a basis for the need of further research to understand better the relationship and dynamics of both markets.
- (3) Granger causality test suggested that there is no Granger causality in any sample;
- (4) Sims Methodology results indicated that there is a leadership of the futures markets in the Pre-Devaluation period whilst a bi-directional causality exists in the Post-Devaluation sample.

Conclusion and recommendations

During the recent crisis Russia suffer severe currency devaluation as well as capital outflow from financial market. The relationship between futures and spot prices were tested during this period. The period was divided into sample periods, namely the Pre devaluation sample and the Post devaluation sample. For the purpose of the dissertation, the whole period were analysed and tested as well as two samples periods, namely the Pre-Devaluation and the Post-Devaluation. As it was expected both futures and spot level series were found to be non-stationary whilst their returns are stationary series. Almost during the whole tested period relationship between two prices features with negative basis. Average arithmetic of basis gave negative value for both samples. Tremendous difference in kurtosis between two samples was also discovered and it was also noted that the distribution of both level and return series were different for the Pre-Devaluation sample as compared against the Post-devaluation sample suggesting that the devaluation of the currency has produced a notable impact on the RTS spot and futures markets.

Augmented Dickey-Fuller (ADF) test was used to test cointegration. Discovered coitegration between prices in the Post Devaluation compared to the Pre Devaluation sample outcomes that the crisis and rubble devaluation causes cointegration. Stress condition increases relationship between the two markets. These results approve the theory stated by Kawaller, Koch and Koch 1992 that relationship between future and spot prices will not only pro long in stress conditions but will be strong. Moreover, it outcomes that futures market stated to play its social role of the risk transferring instrument. Market participants started to use futures market for its natural purposes and as the result increase the relation between futures and spot prices.

To test causality relationship between two market VAR Model, VECM, Granger causality test and Sims Methodology were used. The main result for the VAR model is that in the Pre-Devaluation sample there is no evidence of

lead-lag relationship whilst in the Post-Devaluation sample there is a weak lead running from spot to futures market as well as the first futures autoregressive lag is also significant at 10% level. This is an interesting result that the spot market started to serve as a price discovery vehicle in the stressed conditions in Russia. Another interesting fact is that R^2 values for the VAR model in the Post-Devaluation sample increase by approximately 5 times as compared against the Pre-Devaluation sample suggesting that the lagged returns start to explain 2.5% of variation in the contemporaneous returns during the stressed conditions. Nevertheless VAR results in both samples indicate that the most of price movements are contemporaneous as suggested by the theoretical Cost-of-Carry model. VECM results suggested that both markets adjust to equilibrium (the past day error), however there are unexpected signs for the error correction terms in spot regressions, less significant t-statistics and lower R^2 provides a basis for the need of further research to understand better the relationship and dynamics of both markets. Granger causality test suggested that there is no Granger causality in any sample. The results of the Granger causality test is contrary to many empirical studies which found leadership of futures markets and this re-confirms the conclusion for the Vector Error-Correction models. Sims Methodology results are indicating that in the Pre-Devaluation sample there is a lead from the futures market at 5% significance level as per Wald test statistics. In the Post-Devaluation sample there a weak bi-directional causality running in both directions.

The results of dissertation open the field for further investigations. A further research is required to understand the dynamics between the RTS spot and futures markets. I have three recommendations for further analysis: (1) With the modern trading technology it is not expected that the lead-lag relationship should extend beyond one day. Most probably if a strong evidence of lead-lag exist it would be measured in hours or perhaps minutes even in emerging markets. Therefore, my recommendation is to conduct a further investigation using intraday data. (2) The models employed in this study are all linear models. However, the academic literature reported existence of non-linearities in the financial data, so the full spectrum of

relationships between spot and futures markets might not be uncovered by linear models. Therefore, my recommendation is to employ non-linear models in order to uncover potentially non-linear dynamics between the two markets. (3) In Chapter 6 the most used models in the lead-lag academic research were employed and yet the results had some discrepancies between the models. Therefore, further research should aim to report results complemented by several models in order to support the findings. Moreover, further studies could compare more stable periods with the recent crisis. Since the difference between futures and spot prices gives the arithmetic average negative basis during two sample periods, previous years should be tested for search of different pattern since those results are controversial with theoretical difference between futures and spot prices that was approved by all major theories and studies

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