Dynamic Pairs Trading Strategy For The Companies Listed In The Istanbul Stock Exchange

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Abstract

In this research we performed pairs trading strategy based on a comparative mean reversion of asset prices with daily data over the period 2002 through 2008 in Istanbul Stock Exchange. We did not categorize stock pairs by sectors and therefore it is possible to observe mean reversion characteristics of different stocks that are selected from ISE-30 index. The initial formation period is 125 days (approx. 6 months) while we measure the performance results daily. Then both formation process and trading strategies have been structured as dynamic (rolling windows) market trading model through 2008. The results indicate that pairs produced average returns of % 3.36 daily comparing with the naïve buy and hold strategy. However ISE30 daily average return performance % 0.038 between 2002-2008 period. Our trading constraints and trading commissions take away the excess return on pairs mostly. Furthermore, the performance analysis reveals that the pairs trading strategy yields excess returns with less volatility than the market portfolio.

Key words: mean reversion, pairs trading, distance method, market neutral portfolio, Istanbul Stock Exchange, trading strategies

JEL Classifications: G11, G12, G14.

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1 Introduction

Pairs trading is a way of trading that attempts to cover at least one long and one short position for each trade, while statistically analyzing the relationship presented.[1] It is a popular strategy that has made its reputation in the early 80's.[2]

Theoretically, the idea of pairs trading is to take advantage of market inefficiencies. An equity analyst/trader identifies two stocks that move together and trade them every time the absolute distance between the price paths is above a particular threshold value. The price relationship between the two stocks (or commodities such as gold and silver) tends to fluctuate around its average in the short term, while remaining stable in the long run. In order to make money, trader sells the main asset with highest price and buys its pair with the lowest price with the expectation of price decrease and an increase for the assets respectively. The specific details about choosing pairs and defining the threshold value in pairs trading are going to be given in the scope of the paper.

Non-traditional money managers have employed the concept of pairs trading for many years. Hedge funds and proprietary trading desks of investment banks used this statistical arbitrage strategy with an apparent degree of success. Market incompleteness such as ex-dividend date jumps, and market frictions such as transaction costs, financing costs, taxes and immediacy make the task less easy and the rewards usually lower. Also, this so-called "arbitrage" is not riskless. In practice, even in the absence of the frictions mentioned above, the arbitrage is rarely ever a "pure arbitrage", but what is often called an "expectations arbitrage". There is always some risk inherent in the strategy. This risk could be attributed to a number of areas. It might take, for instance, a microstructure nature e.g. inability to find a counterparty for an immediate sale or it might be based on pure economic fundamentals e.g. a change in investors' interest rate expectations represented by a change to the curvature of the yield curve. It

[1] Vidyamurthy, G. [2004]; Pairs Trading—Quantitative Methods and Analysis, Wiley: New York, p. 2.
[2] Perlin, M.S. [2007]; Evaluation of Pairs Trading Strategy at the Brazilian Financial Market, Unpublished Working Paper,

could be institutional in nature e.g. a sudden demand and challenge for margin payment or it could be noise trader risk where the fundamental economic values of the two securities, based on ultimate payoffs, are exactly the same, but the aggregate of informed and uninformed investors trades them at even more disparate prices than when the spread trade was opened. Usually, the pairs trader faces more than one of such risks simultaneously. [3]

As far as we know pairs trading strategy is employed by some of the Turkish investment firms. According to the quantitative analysis report of Is Investment pairs trading was a profitable strategy during 21/09/2006 and 16/09/2007.[4]

There are several reasons for the popularity of pairs-trading. First, the procedure is simple to understand and execute. Second, valuation models, which are subjected to wide error margins, are not required since pairs-trading is based on relative valuation and the position is often near market-neutral. Third, it is sufficiently flexible to accommodate various investment styles. Lastly, it normally does not evoke frequent intraday re-balancing, such that actual trading can be automated and is feasibly profitable. [5]

The structure of the research is presented as follows in the next sections. Section II provides a brief literature review and identifies the three main methods to implement pairs trading strategy. Section III describes the pair trading data and methodology for the ISE30 stock pairs formation procedure and trading rules. Section IV enables us to compare the performance results of pairs trading strategy. The empirical results are discussed in Section V and section VI contains concluding comments and further research suggestions in this area.

[3] Nath.Purnendu.[2003]; High Frequency Pairs Trading with US Treasury Securities: Risks and Rewards for Hedge Funds
[4] Is Investment [2007]; Quantitative Analysis: Pairs Trading Strategy, 25 September 2007.
[5] Chng.T.Michael,[2007]; Understanding The Risks In And Rewards For Pairs-Trading, pg.2

2 Literature Review

Pairs-trading is elusive due to the lack of academic research. Although it is based on simple contrarian principles, pairs-trading did not draw nearly as much academic attention as contrarian trading. To the best of our knowledge, Elliott et al [2005] and Gatev et at [2006] are the only two recent finance articles on pairs-trading. While the development of a structured framework that encompasses the various parameters of pairs-trading would no doubt attract practitioners' attention, that task is currently too complex. But a first step in that direction will require some understanding on the nature of pairs-trading. What are the risks involved? What are the sources of its rewards? How are the profit sources affected by the choice of parameters e.g. the types and/or number of restrictions. Price formation models, a cornerstone of the market microstructure literature, are the result of academic endeavors Glosten and Milgrom [1985]; Easley and O'Hara [1987]; Brown and Jennings [1989]; and Hasbrouck [1991, 1993, 1995] to turn technical analysis from an art to a science.

Usually contrarian pair trading stipulates selling past winners and buying past loser stocks. Its execution normally involves ranking stocks based on their time t-1 returns, then take simultaneous long and short-sell positions in say the top loser and bottom winner portfolios and hold until time t. The strategy is designed to profit from overreaction and subsequent mean-reversion i.e. negative serial correlation in stock returns. Positive profits are reported in both Jegadeesh [1990] and Lehmann [1990].

However, Lo and MacKinlay [1990] show that contrarian profits could also be driven by delayed reaction or lead-lag effects between winner and loser stocks. In brief, if stock *j* reacts in the same direction as stock *i* but with a delay, then buying (selling) *j* subsequent to an increase (decrease) in *i* should generate profits, even if neither stocks overreact. Their results show that around % 50 of contrarian profits is generated by such lead-lag effects. The essence of Lo and MacKinlay [1990] is to highlight both negative serial covariance $\sigma_{r_t^i; r_{t-1}^i} < 0$ and positive cross-serial covariance $\sigma_{r_t^i; r_{t-1}^j} > 0$ $\forall i \neq j$ in stock returns as two potential sources of contrarian profits.

Jegadeesh and Titman [1995] extends Lo and MacKinlay [1990] by associating lead-lag effects with the dynamics of price reaction to common factors. Their analysis of contrarian profits include a more detailed set of stock price reaction scenarios covering under and overreaction to common factors and idiosyncratic news. Unlike Lo and MacKinlay [1990], Jegadeesh and Titman [1995] and most of the contrarian profit is driven by overreaction to idiosyncratic news. This is consistent with the fact that overreaction to idiosyncratic news always generates contrarian profits, but overreaction to common factors may actually decrease contrarian profits. The essence of Jegadeesh and Titman [1995] is to show that common factor price reaction is a more appropriate measure of lead-lag effects than cross serial covariance in total returns.[6]

Most referenced works also include Gatev, Goetzmann and Rouwenhorst [1999], Vidyamurthy [2004], and Elliott, Van der Hoek and Malcolm [2005]. The first paper is an empirical piece of research that, using a simple standard deviation strategy, shows pairs trading after costs can be profitable. The second of these papers details an implementation strategy based on a cointegration based framework, without empirical results. The last paper applies a Kalman filter to estimating a parametric model of the spread. These methods can be shown to be applicable for special cases of the underlying equilibrium relationship between two stocks. A pairs trading strategy forcing an equilibrium relationship between the two stocks with little room for adaptation, may lead to a conclusion of "non-tradeability" at best and non-convergence at worst.[7]

Three main methods to implement pairs trading, which we label:

I. the distance method,

II. the cointegration method,

III. the stochastic spread method.

[6] Chng.T.Michael,[2007]; Understanding The Risks In And Rewards For Pairs-Trading, pg.5
[7] Do.Bihn, Faff.Robert, Hamza.Kais.[2006]; A New Approach to Modelling and Estimation for Pairs Trading,pg.2.

In this research we implemented the distance methodology on the ISE30 stocks with in a programmed pair trading model on Matlab. The distance method is used in Gatev et al [1999] and Nath [2003] for empirical testing whereas the cointegration method is detailed in Vidyamurthy [2004]. Both of these are known to be widely adopted by practitioners. The stochastic spread approach is recently proposed in Elliot et al [2005].

3 Data & Methodology

3.1. Data

The database for this research is based on the ISE-30 index shares of Istanbul Stock Exchange between the periods of 2002 - 2008. While index composition is subject to change in each quarter by several criteria determined by the ISE Board of Directors, we studied the same stocks during our research. Selected stocks are presented in Appendix-A with their sectoral information and market capitalization as of December 2008.

We used daily closing prices of the selected stocks. Data is principally adjusted to represent the average dividend yields for the observation period. All data is downloaded from the Reuters 3000Xtra and analyzed with a coded programme on MATLAB software. In the research we had selected the pair trading stocks from ISE30 indices which means a number of 1,752 daily observations and the total observations amount reaches to 52,560.

3.2. Pairs Formation with the Distance Method

Pairs can be identified by taking the sum of squared differences between the two normalized price series. After the normalization, all stocks are brought to the same standard unit and this permits a quantitatively fair formation of pairs. Normalized series have been generated by the following formula;

$$P^*_{it} = \frac{P_{it} - E(P_{it})}{\sigma_i} \qquad \text{(i)}$$

P* is the normalized price of asset i at time t,

E (P) is just the expectation of P, in this case the average, and

σ is the standard deviation of the respective stock price.

Distances between the main assets and pair assets have been generated by the following formula;

$$D = PA - MA \quad \text{(ii)}$$

D = Distance between the normalized series of PA and MA

PA = Pair Asset

MA = Main Asset

$$D = \sum_{i=1}^{125} \left(PA_i - MA_i)\right) = 0 \quad \text{(iii)}$$

In this way, sum of the distances will be equal to zero. Because of this condition, we prefer to take the sum of the squares of distances. The equation then becomes as follows:

$$DS = \sum_{i=1}^{125} \left(PA_i - MA_i\right)^2 \quad \text{(iv)}$$

DS = Sum of the squares of distances

We determined the DS level as 20, which means only the 20 or less than 20 DS levels are accepted as the pair formation, while the other possible pairs easily excluded by definition. Pair formation of FINBN and PETKM are presented in Table 1 as an example for the formation methodology of this research.

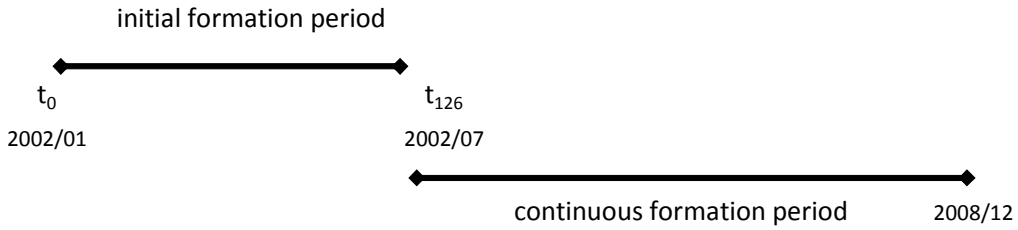
Table 1. Pairs Formation Methodology

Stock ID	PA/MA	Price (TRY)	Mean	Stdev	Distance SQR
FINBN	Main	0.12	0.17	0.04	14.87
PETKM	Pair	5.10	6.44	1.00	

Stocks are determined as pairs following the 125 days formation period. As it can be seen in from the Table 1, asset prices originally different but we rebase the series by normalization process. Starting from the day 126, we recalculate the distances for the remaining sample continuously. This process is

shown in Figure 1. We produced the distance matrices each day and then accepted the minimized distances at most 20 as the pairs. Appendix B is given as a sample DS matrix used in the research. We generated similiar kind of matrices by Matlab on each trading day (1,627 matrices, which is equal to 1,752-125). Selected pairs distance values are presented with the yellow colors in the sample matrix. FINBN-PETKM pairs distance can also seen from the matrix.

Figure 1. Pair Trading Formation Process



3.3. Trading Strategy

After the pair of each stock is identified, the trading rule is going to create a trading signal every time that the absolute distance between main asset and its pair is higher than d. The value of d is arbitrary, and it represents the filter for the creation of a trading signal. It can't be very high, otherwise only a few trading signal are going to be created and it can't be to low or the rule is going to be too flexible and it will result in too many trades and, consequently, high value of transaction costs.

After a trading sign is created, the next step is to define the positions taken on the stocks.

According to the pairs trading strategy, if the value of MA is higher (lower) than PA then a short (long) position is kept for MA and a long (short) position is made for the PA. Such position is kept until the absolute difference between the normalized prices is lower than defined treshold.

Implementing such type of strategy is based on a logic that there is a good possibility that such prices are going to converge in the future, and this can be explored for profit purposes. If the distance is positive, then the value of MA probably will reduce in the future (short position for asset MA) and the

value of PA is probably going to increase (long position for the PA). The same logic is true for the cases where the distance is negative.

3.4. Pair Trading Conditions

We actually want to open a position when the price ratio deviates with more than two and half standard deviations from the **125 days** rolling mean. It means that every business day we calculated distances and search for the pair trading opportunities in a continuous form (dynamic).

The parameters and trading rules which replicates similar market performances at most are shown on below.

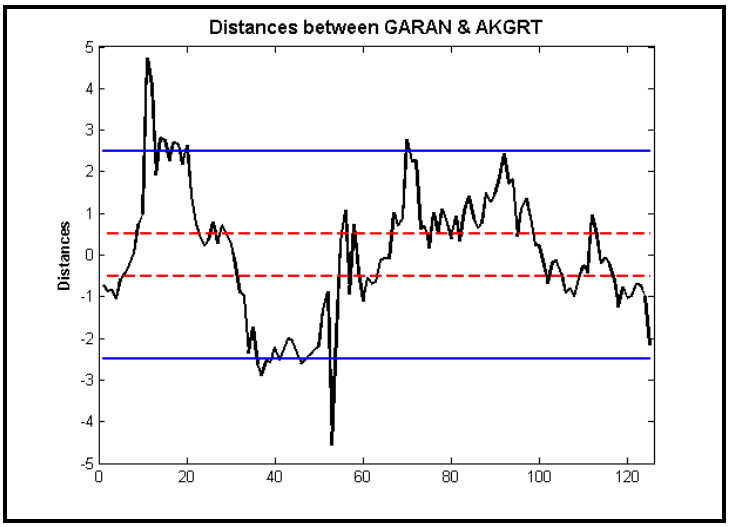
i. Related stock's daily closing price is used as trade in and out pricing.
ii. Trade in parameter is 2.5 stdev. (d=2.5)
iii. Trade out parameter is 0.5 stdev.
iv. Every pair is opened with 1000 TL. ($/TL:1.50 avg.) 1000 TL long and 1000 TL equivalent short for its pair at the execution of a pair trade.
v. Total capital is 50,000 TL.
vi. Maximum number of days for a position to be carried is 30 days.
vii. Transaction fee is calculated on the basis of 0.0021.
viii. Borrowing cost of a stock (rebate rate) is calculated as 0.05 of a short position.
ix. Margin required for the borrowing of a stock is % 110 of a short position.
x. Take profit at % 3 of initial position value
xi. Stop loss at % 2 of position value

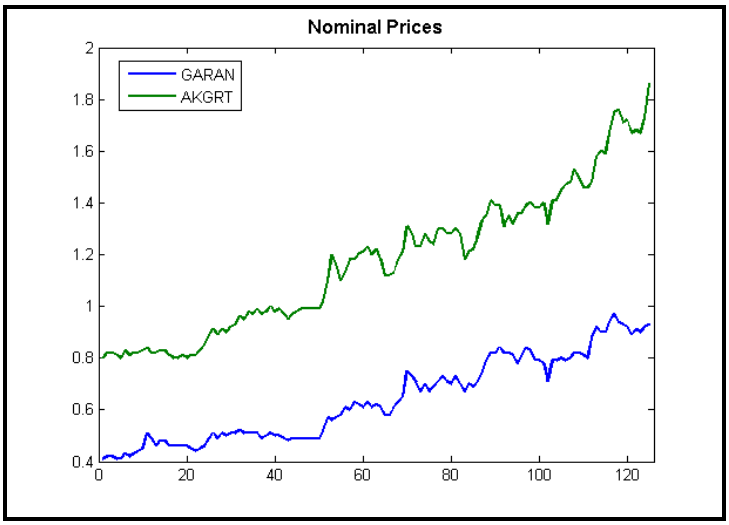
Turkish Capital Markets has some lacks on spot short stock exchange tradings. The stock exchange transactions are mostly traded on spot cash basis even though if you are willing to make a short sale you have to hold or borrow the corresponding stock before trading. But on practice it is usually hard to find the same stock available for short sale in the Takasbank Stock Borrowing Market. Short sales

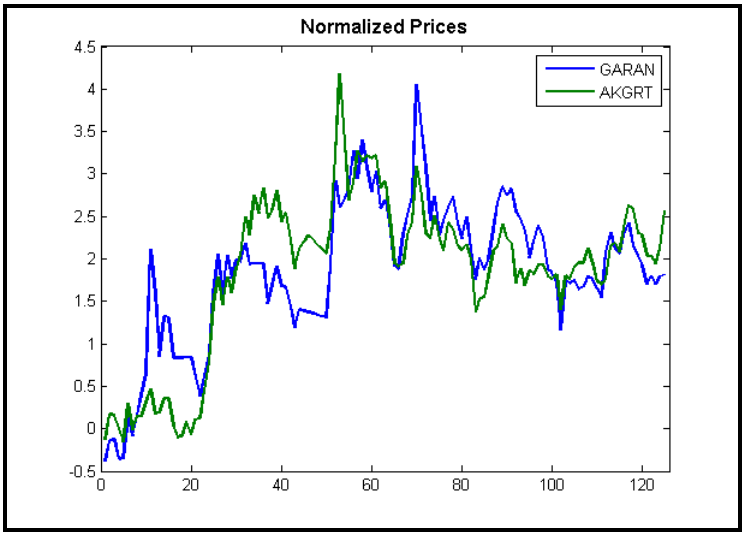
positions are extended on weekly basis margin with an average daily funding cost equivalent of Central Bank of Turkey O/N lending rate. Besides stock borrowing transactions are not working efficiently as the market is not as deep as the spot market. On the other hand in these type of trades foreign institutions takes counterparty risk seriously so it is not easy to make short sale strategy permanently if you dont have enough capital and market share.

According to our pair trading system methodology, pair of GARAN.IS & AKGRT.IS stocks in ISE30 for the sample of 2004 period is given as an example.

Figure 2. Pair Stocks on ISE30







In Figure 2 above when the distance hits 2.5 stdev treshold, trader sold MA (GARAN) and buys PA (AKGRT) at the same time. We unwind the position when the distance converged to its historical trend (at 0.5 stdev). It is observed that distances between the pairs has reached to 5 during the trading period. Table 2 shows the daily performance details of pairs trading strategy for a selected period (during May 2008). We will explain the trading history of a Position ID 4006 (from May 6th to May 14th with 8 days carry length) for better understanding of a strategy performance. Trading is executed when the distance of assets (in this case passed the 2.5 stdev threshold (in this case 2.86). Long amount and short amounts are determined by taking into account of a 1000 TL as an initial value of a trade in parameter. Transaction fee is accepted as the 0.0021 of a trading amount therefore trade in and out costs make approximately 8 TL in each trade. Position is unwind when the % 3 profit is earned (in this case (% 4.65).

Table 2. Pairs Trading Performance Details

Position ID	Date	Main Asset	Pair Asset	Main Asset Amount	Pair Asset Amount	Main Stock Price	Pair Stock Price	Distance	Carry Length (Days)	Realized Profit	Transaction Cost
3997	01.05.2008	DOHOL	VESTEL	649	-444	1.54	2.25	-2.61	1	0.00	4.20
3998	01.05.2008	TRKCM	VESTEL	578	-444	1.73	2.25	2.57	4	0.00	4.20
3999	01.05.2008	AKGRT	SISE	152	-505	6.55	1.91	-1.59	2	-27.75	4.12
4000	02.05.2008	ISCTR	GARAN	169	-249	5.65	4.07	-1.97	3	57.19	4.13
4001	02.05.2008	VESTEL	YKBNK	446	-413	2.28	2.56	-1.58	3	39.98	4.36
4002	02.05.2008	VESTEL	DOHOL	444	-649	2.28	1.53	-2.23	1	-19.81	4.21
4003	05.05.2008	VESTEL	DYHOL	446	-379	2.13	2.68	-2.21	6	64.22	4.13
4004	05.05.2008	VESTEL	TRKCM	444	-578	2.13	1.74	2.19	4	59.06	4.10
4005	05.05.2008	NETAS	DYHOL	52	-373	20.04	2.68	-2.03	7	-50.96	4.29
4006	06.05.2008	DYHOL	NETAS	379	-47	2.64	21.12	-2.86	8	0.00	4.19
4007	07.05.2008	GARAN	NETAS	261	-48	3.83	20.73	-3.32	1	0.00	4.19
4008	07.05.2008	TRKCM	NETAS	585	-48	1.71	20.73	2.66	7	0.00	4.19
4009	07.05.2008	ISGYO	NETAS	909	-48	1.10	20.73	3.20	1	0.00	4.19
4010	07.05.2008	ISCTR	DYHOL	169	-368	5.55	2.66	1.23	7	37.07	4.03
4011	08.05.2008	GARAN	AKBNK	272	-156	3.68	6.40	-2.59	19	0.00	4.20
4012	08.05.2008	NETAS	GARAN	48	-261	20.44	3.68	-3.12	1	-25.23	4.08
4013	08.05.2008	NETAS	ISGYO	48	-909	20.44	1.06	2.68	1	-22.44	4.08
4014	09.05.2008	GARAN	NETAS	274	-49	3.65	20.24	-3.32	5	0.00	4.18
4015	09.05.2008	ISGYO	NETAS	962	-49	1.04	20.24	2.84	5	0.00	4.18
4016	14.05.2008	GARAN	ISCTR	274	-174	3.65	5.75	-2.63	8	0.00	4.20
4017	14.05.2008	NETAS	DYHOL	47	-379	18.76	2.47	-2.51	8	46.49	3.82
4018	14.05.2008	NETAS	TRKCM	48	-585	18.76	1.65	2.02	7	59.46	3.92
4019	14.05.2008	NETAS	GARAN	49	-274	18.76	3.65	-2.70	5	72.52	4.03
4020	14.05.2008	NETAS	ISGYO	49	-962	18.76	1.04	2.31	5	72.52	4.03
4021	15.05.2008	YKBNK	AKSA	417	-433	2.40	2.31	-2.67	5	0.00	4.20
4022	20.05.2008	AKSA	YKBNK	433	-417	2.26	2.54	-2.33	5	80.03	4.28
4023	22.05.2008	ISCTR	GARAN	174	-274	5.15	3.42	-1.63	8	41.38	3.85
4024	23.05.2008	DOHOL	VESTEL	725	-455	1.38	2.20	-2.57	6	0.00	4.20
4025	26.05.2008	ISCTR	VESTEL	201	-455	4.98	2.20	-3.08	4	0.00	4.20
4026	27.05.2008	SISE	VESTEL	588	-450	1.70	2.22	-2.80	13	0.00	4.20
4027	27.05.2008	AKBNK	GARAN	156	-272	5.50	3.39	-0.01	19	61.52	3.74
4028	29.05.2008	VESTEL	DOHOL	455	-725	2.17	1.43	-2.37	6	49.90	4.25
4029	30.05.2008	GARAN	DOHOL	303	-676	3.30	1.48	-2.50	3	0.00	4.20
4030	30.05.2008	AKBNK	DOHOL	185	-676	5.40	1.48	2.66	3	0.00	4.20
4031	30.05.2008	VESTEL	ISCTR	455	-201	2.14	5.04	-3.03	4	39.36	4.17

By employing this strategy we receive following cash flow (TL):

On May 6th , 379 Long on asset 10 with price 2.64 = 1000.56

On May 14th , 379 Short on asset 10 with price 2.47 = 936.13

Realized Profit from MA = - 64.43

On May 6th , 47 Short on asset 16 with price 21.12 = 992.64

On May 14th , 47 Long on asset 16 with price 18.76 = 881.72

Realized Profit from PA = 110.92

Realized Profit from Pairs Trading Strategy = 46.49

Realized Profit after Trading Costs = 38.49

3.5. VaR Analysis of Pairs-Trades

Value-at-Risk is a potentially useful framework for evaluating pairs trading risk. The VaR is useful because it provides a gauge to the potential leverage that could be applied to these strategies. Although the lessons of recent history have taught us not to rely too heavily on historical VaR measures for gauging capital needs for exploiting convergence strategies, the pairs portfolios seem to be exposed to relatively little risk.

We have employed 3 most common methods to estimate the Value-at-Risk figures of the pairs trading portfolio which are also used by most practitioners in the banks and hedge funds.

The first one is the Variance Covariance (VCV) method which is a parametric estimation of risk. Under normality assumption of the daily returns of the portfolio we have calculated risk figures with % 99 confidence level. Thus we had $VaR^{99\%} = \Pi \times 2.33 \times \sigma_{\Pi}$ where Π is the portfolio value, and σ_{Π} is the portfolio standard deviation. The second one, Historical Simulation (HS) method, is one of the non-parametric methods in which we have calculated the portfolio values with the historical returns of the individual stocks using 252 as the sample size. In the end, the difference between the 3rd worst portfolio value and the current portfolio value is taken as our VaR estimate. The last VaR method is called the Monte Carlo methodology. This framework is also used in a bunch of different disciplines such as physics, genetics and insurance. The main idea behind this framework is the random number generation process with respect to some predefined distribution. After generating the random numbers, which can also be interpreted as the shocks or news to a given firm, we calculated after-shock price of the stock by utilizing the Geometric Brownian Motion. The problem here is that the shocks generated "randomly" by the computer are originally uncorrelated. But the returns of the stocks we have in our portfolio are correlated to each other at some level. That's why by using Cholesky Decomposition, we transformed the originally uncorrelated random numbers to correlated ones in order to be consistent

with the correlations we already had. At the last step, just like in HS method, we calculated the portfolio value with the new prices generated and took the difference between the worst 3rd portfolio value and the current portfolio value as our VaR estimate.

The following figures presented in Table 3 show us our VaR estimates calculated by the methods discussed above and the returns caused by the actual changes in the stock prices. The days in which estimated VaR is higher than the actual loss are counted for each method and we have the following performance summary table for the methods in estimating VaR.

Table 3. VaR Performance Summary

Method	VarCovar	Historical Simulation	Monte Carlo Sim.
# Days VaR Exceeded	15	8	28
Observations	1627	1627	1627
Percentage	0.92%	0.49%	1.72%

We can see from the Table 3 that the best method in VaR estimation for our pairs trading portfolio is the Historical Simulation method which underestimated loss only for 8 days during the whole trading period. Pair trading backtest results are plotted in Appendix D.

VaR calculations have been performed with the following parameters:

Number of trials in Monte Carlo simulation = 1000

Sample size for VaR calculations = 252

Confidence level for VaR calculations = 0.99

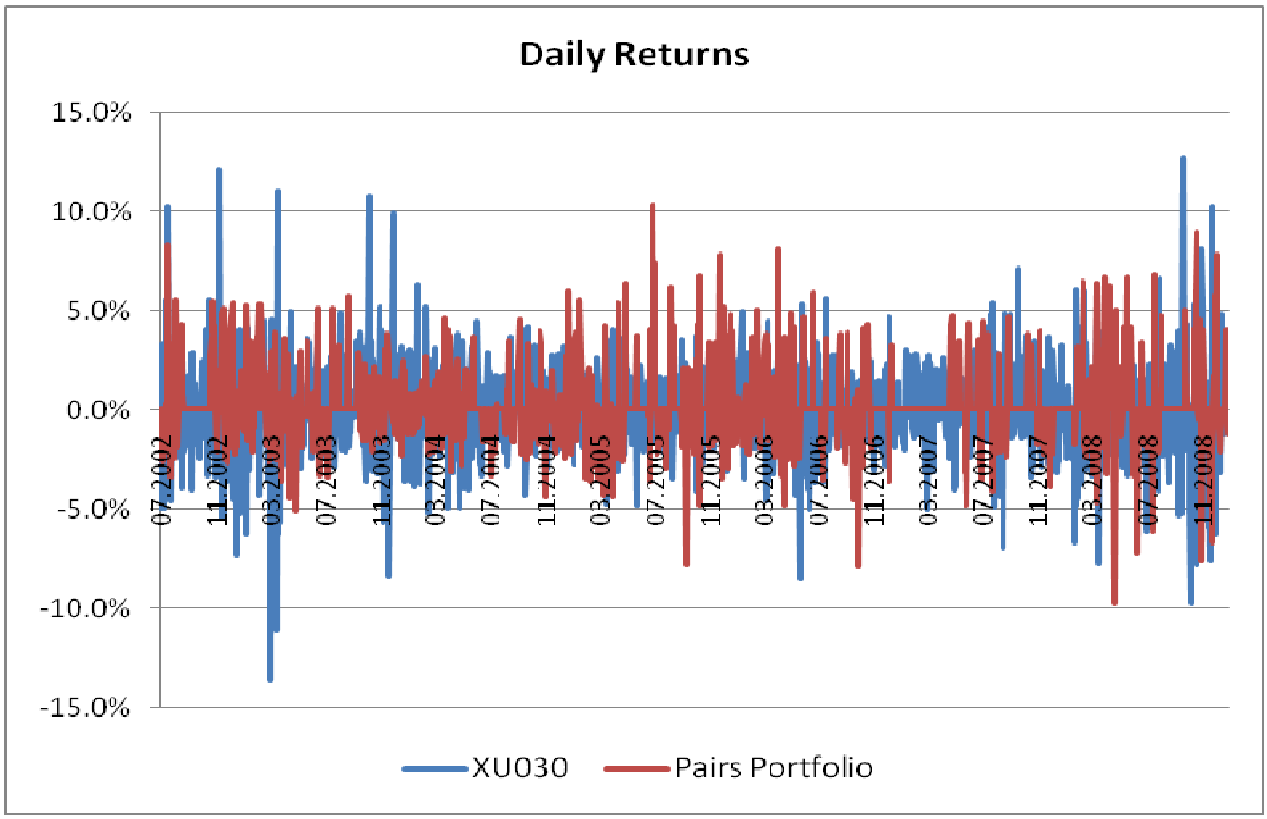
Lambda parameter for EWMA = 0.94

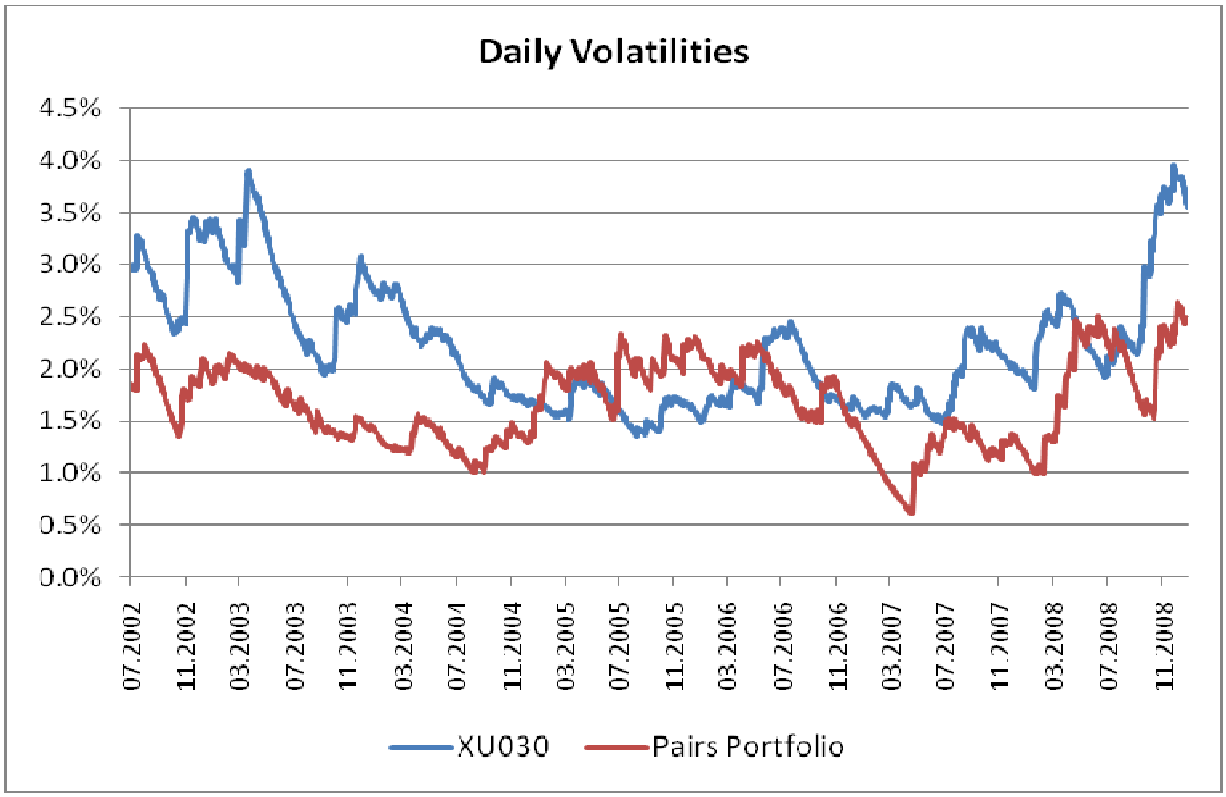
4 Pairs Trading Strategy & Benchmark Performances

As a result of an applied pairs trading strategy we observed that selected pairs produced annualized excess returns of up to % 3.32 comparing with the naïve buy and hold strategy. ISE-30 index underperformed against pairs portfolio both in terms of return and volatility. Daily return and volatility of a benchmark index presented in Figure 3. Daily volatilities are estimated by EWMA(0.98). Volatility chart below helps us to see that on average our pairs trading portfolio returns are less volatile

compared to IMKB-30 returns. To be more precise, between the dates 02/07/2002 and 29/12/2009 in which we have applied our trading algorithm, IMKB-30's average daily return is 0.06% whereas our pairs trading portfolio has an average daily return of 0.12%. If we compare average daily volatilities, IMKB-30 has an average of 2.20% whereas our portfolio has 1.67% as the average daily volatility. Using these figures we can conclude that our pairs trading algorithm lets us to take the advantage of building a portfolio which has a higher Sharpe Ratio compared to a replicating portfolio of IMKB-30 benchmark..

Figure 3. Daily Return & Volatility Results (IMKB 2002-2008)





Further to applying pairs trading strategy, we invested remaining capital in the interbank (o/n) money market based on a reference bid rate of a Central Bank. P&L figures and cumulative returns of a pairs portfolio are presented yearly in Table 3.

Table 3. Pairs Portfolio Performance Results

	2002	2003	2004	2005	2006	2007	2008
No of pairs trading	272	1249	1518	320	403	64	318
Pairs Trading P&L	783	1512	-691	688	-172	163	1453
Interest Rate Income	7522	10362	5592	4976	5070	5942	5285
Interest Rate Expense	45	266	376	60	66	13	50
Trading Commission	1133	5266	6380	1347	1695	268	1332

5 Some Empirical Results

Daily pairs trading maximum profit is 990 TL on the other hand maximum loss amount is 692 TL. More favorable profit results can be achieved with tight pairs trading constraints. Our trading constraints and trading commissions take away the excess return on pairs mostly. Furthermore, the performance analysis reveals that the pairs trading strategy yields excess returns with less volatility than the market portfolio.

Figure 8. Pair Trading P/L Result

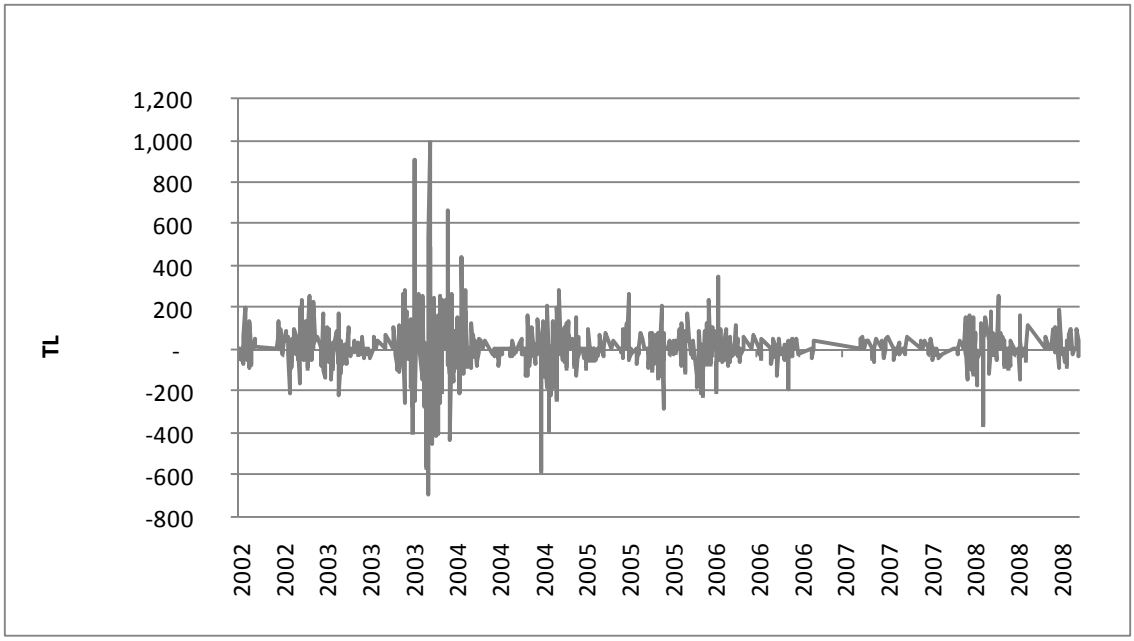
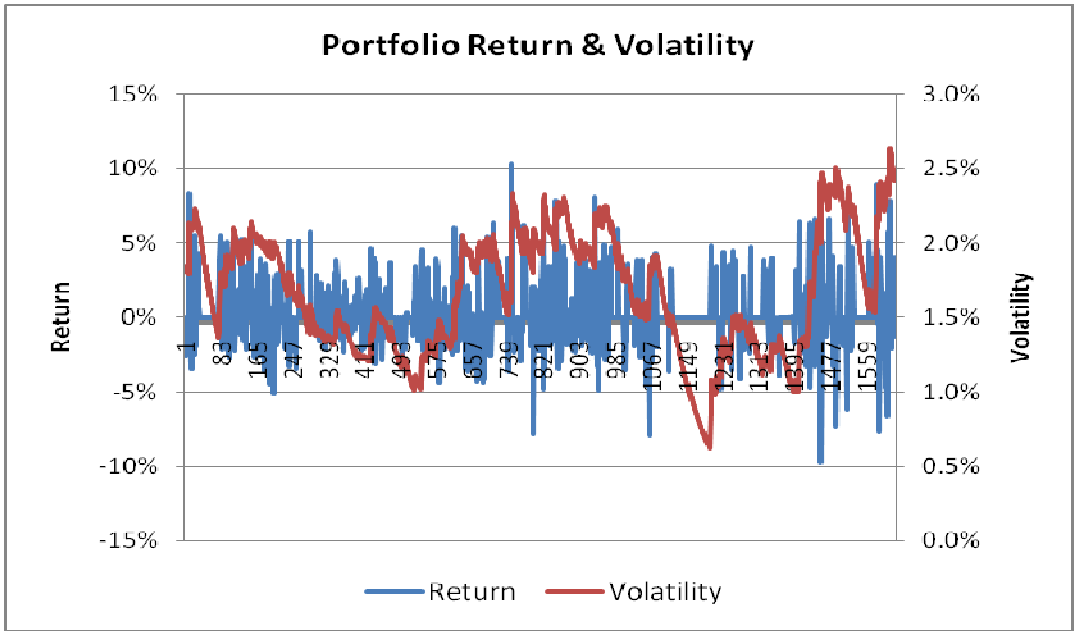


Figure 9. Pair Trading Portfolio Return & Volatility Comparison



6 Concluding Remarks

Pairs trading is particularly powerful when markets are volatile and do not show an overall trend. It is based on identifying pairs of assets whose prices move together systematically.

We worked with equities that are cited in the ISE-30 index. We analyzed all possible pairs that can be formed but we focused only the assets whose prices are closely related statistically and/or fundamentally. We applied a distance method to measure the co-movement of assets' prices. Our program signals to open a trade when this distance is above its historical averages. We sell the relatively overpriced asset and buy the relatively underpriced one. We unwind the position when this distance converged to the pre-determined level. Additionally we applied stop-loss and take profit rules as a trading rule apart from the distance rule. Furthermore an academic contribution of this research can be summarized as the dynamic approach for the pairs formation and cost evaluation of pairs trading strategy. It is observed that parameters used in this research should be optimized. We also take into consideration of all possible costs for full evaluation and comparative analysis of pairs trading strategy.

Empirical results indicated that trading commissions and stock borrowing costs generally greater than the profits generated from the pair trades. The results also indicated that pairs produced average returns of % 3.36 daily comparing with the naïve buy and hold strategy. However ISE30 daily average return performance % 0.038 between 2002-2008 period.

As explained above, pairs trading tries to exploit the co-movement of the prices of a pair of assets. It assumes that the relation that has been measured historically is stable. However, it might happen that the nature of the relation between the pairs changes due to fundamental reasons. If the relative mispricing is caused by fundamental changes in the relation, our underlying assumptions are not satisfied, hence the distance method that we have been using does not reflect the new relation and should be updated. Because of this reason we applied stop-loss and take profit rules as a trading rule.

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APPENDIX-A. ISE 30 Stocks Market Information

Reuters Code	Company Name	Sector	Market Cap (M$)
AEFES.IS	ANADOLU EFES	MANUFACTURE OF FOOD, BEVERAGE AND TOBACCO	2,858
AKBNK.IS	AKBANK*	BANKING	8,463
AKENR.IS	AK ENERJİ	ELECTRICITY GAS AND WATER	243
AKGRT.IS	AKSIGORTA	INSURANCE	487
AKSA.IS	AKSA	MANUFACTURE OF CHEMICALS	105
ALARK.IS	ALARKO HOLDING	HOLDING COMPANIES	220
ARCLK.IS	ARCELIK*	MANUFACTURE OF FABRICATED METAL PRODUCTS, MACHINERY AND EQUIPMENT	495
DOHOL.IS	DOGAN HOLDING*	HOLDING COMPANIES	973
DYHOL.IS	DOGAN YAYIN HOLDING*	HOLDING COMPANIES	272
EREGL.IS	EREGLI DEMIR CELIK*	BASIC METAL INDUSTRIES	2860
FINBN.IS	FINANSBANK	BANKING	3,954
FROTO.IS	FORD OTOSAN	MANUFACTURE OF FABRICATED METAL PRODUCTS, MACHINERY AND EQUIPMENT	848
GARAN.IS	GARANTI BANK*	BANKING	5,536
HURGZ.IS	HURRIYET GAZETECILIK*	MANUFACTURE OF PAPER AND PAPER PRODUCTS, PRINTING AND PUBLISHING	177
IHLAS.IS	IHLAS HOLDING	HOLDING COMPANIES	50
ISCTR.IS	IS BANK*	BANKING	6,688
ISGYO.IS	IS GMYO	REAL ESTATE INVEST.TRUSTS	180
KCHOL.IS	KOC HOLDING*	HOLDING COMPANIES	3,152
MIGRS.IS	MIGROS*	CONSUMER TRADE	1,411
NETAS.IS	NETAS TELEKOM	INFORMATION TECHNOLOGY	48
PETKM.IS	PETKIM	MANUFACTURE OF CHEMICALS AND OF CHEMICAL PETROLEUM, RUBBER AND PLASTIC PRODUCTS	471
PTOFS	PETROL OFISI	MANUFACTURE OF CHEMICALS AND OF CHEMICAL PETROLEUM, RUBBER AND PLASTIC PRODUCTS	990
SAHOL.IS	SABANCI HOLDING*	HOLDING COMPANIES	3,638
SISE.IS	SISE CAM*	HOLDING COMPANIES	670
TCELL.IS	TURKCELL	COMMUNICATION	11,656
TOASO.IS	TOFAS OTO FABRIKA*	MANUFACTURE OF FABRICATED METAL PRODUCTS, MACHINERY AND EQUIPMENT	340
TRKCM.IS	TRAKYA CAM	MANUFACTURE OF NON-METALLIC MINERAL PRODUCTS	295
TUPRS.IS	TUPRAS*	MANUFACTURE OF CHEMICALS AND OF CHEMICAL PETROLEUM, RUBBER AND PLASTIC PRODUCTS	2,161
VESTEL.IS	VESTEL*	MANUFACTURE OF FABRICATED METAL PRODUCTS, MACHINERY AND EQUIPMENT	94
YKBNK.IS	YAPI VE KREDI BANKASI*	BANKING	5,516

** represents the stocks listed in ISE-30 in all 28 quarters.*

APPENDIX-B. DS Matrix Methodology

	.XU030	AKBNK	GARAN	ISCTR	YKBNK	FINBN	EREGL	TCELL	MIGRS	AKENR	DOHOL	DYHOL	KCHOL	SAHOL	SISE	ALARK	IHLAS	NETAS	AKGRT	TUPRS	PTOFS	PETKM	AKSA	ARCLK	TOASO	VESTL	FROTO	AEFES	TRKCM	HURGZ	ISGYO
.XU030	0	140.51	41.01	14.44	33.20	20.21	61.29	10.69	18.07	65.42	39.73	210.18	24.53	10.45	16.03	33.76	46.68	28.05	60.53	54.26	49.97	13.98	54.05	166.60	17.28	19.23	183.37	106.85	17.81	322.70	15.36
AKBNK	140.51	0	169.80	156.20	155.40	151.10	216.55	161.35	182.59	273.08	74.25	66.79	132.85	131.23	165.69	190.81	178.01	212.72	85.11	232.12	227.99	177.78	252.01	56.61	160.92	156.25	179.30	123.37	134.94	119.26	196.32
GARAN	41.01	169.80	0	33.79	26.46	89.51	97.90	55.21	84.34	96.38	73.69	193.01	87.70	77.08	70.67	84.16	119.57	88.55	90.76	126.66	127.93	77.30	111.47	214.45	64.05	66.10	147.25	152.73	78.56	275.46	75.43
ISCTR	14.44	156.20	33.79	0	20.46	51.11	79.37	32.54	44.04	85.35	45.08	184.80	65.25	39.11	43.64	48.98	88.33	54.84	80.51	99.30	93.51	45.30	88.04	207.60	25.67	36.38	146.52	135.20	48.39	290.83	37.50
YKBNK	33.20	155.40	26.46	20.46	0	76.98	126.26	49.50	79.07	126.64	52.75	165.46	85.94	63.45	71.34	96.97	98.79	98.19	67.47	135.12	125.39	74.72	130.28	191.00	52.16	78.80	162.93	127.29	54.66	260.36	74.05
FINBN	20.21	151.10	89.51	51.11	76.98	0	62.55	21.49	25.14	76.76	62.30	231.69	30.44	18.63	19.02	55.76	25.79	30.41	58.27	30.53	26.87	14.88	49.02	136.38	32.04	39.90	244.12	112.13	21.00	345.72	24.05
EREGL	61.29	216.55	97.90	79.37	126.26	62.55	0	59.16	66.34	47.53	127.49	274.77	83.36	80.12	44.24	60.11	94.34	43.69	135.27	45.01	60.28	55.45	46.86	235.63	51.99	44.62	222.54	200.20	88.51	358.60	47.29
TCELL	10.69	161.35	55.21	32.54	49.50	21.49	59.16	0	26.50	69.31	60.92	230.19	31.33	19.00	23.20	48.94	40.02	34.03	63.70	45.76	43.05	20.38	52.56	162.63	20.85	35.70	197.00	109.08	19.01	337.47	22.66
MIGRS	18.07	182.59	84.34	44.04	79.07	25.14	66.34	26.50	0	40.80	80.11	280.77	20.17	12.20	23.82	14.79	46.33	9.86	109.84	33.24	27.63	6.95	24.66	197.57	40.02	21.04	204.60	110.50	30.81	384.74	7.27
AKENR	65.42	273.08	96.38	85.35	126.64	76.76	47.53	69.31	40.80	0	149.16	350.88	71.30	73.60	52.15	28.35	92.81	18.99	193.86	42.29	47.60	42.35	10.59	292.04	73.49	43.80	209.64	202.93	100.24	423.20	32.47
DOHOL	39.73	74.25	73.69	45.08	52.75	62.30	127.49	60.92	80.11	149.16	0	105.70	68.04	44.64	59.39	93.61	85.02	96.79	48.04	131.62	124.12	71.08	136.11	110.64	48.21	61.15	165.55	135.18	53.39	216.61	76.85
DYHOL	210.18	66.79	193.01	184.80	165.46	231.69	274.77	230.19	280.77	350.88	105.70	0	256.03	225.44	236.82	287.97	247.56	303.16	110.97	325.40	321.10	271.72	349.19	107.36	197.02	239.71	172.16	213.47	214.95	45.49	277.09
KCHOL	24.53	132.85	87.70	65.25	85.94	30.44	83.36	31.33	20.17	71.30	68.04	256.03	0	12.42	30.38	37.36	46.38	31.63	88.89	44.42	39.64	16.41	46.17	147.04	56.20	31.34	220.23	91.70	24.93	348.49	26.40
SAHOL	10.45	131.23	77.08	39.11	63.45	18.63	80.12	19.00	12.20	73.60	44.64	225.44	12.42	0	20.07	31.17	37.35	25.81	70.02	47.14	40.82	11.26	49.60	144.56	32.58	24.46	198.47	92.81	15.37	333.73	16.82
SISE	16.03	165.69	70.67	43.64	71.34	19.02	44.24	23.20	23.82	52.15	59.39	236.82	30.38	20.07	0	39.91	33.97	17.75	74.06	26.29	26.81	11.76	36.38	172.84	20.94	19.05	232.25	150.21	29.56	351.44	13.23
ALARK	33.76	190.81	84.16	48.98	96.97	55.76	60.11	48.94	14.79	28.35	93.61	287.97	37.36	31.17	39.91	0	89.69	14.94	153.77	56.75	56.95	26.25	27.95	241.87	56.48	17.48	160.61	145.84	63.82	375.67	18.88
IHLAS	46.68	178.01	119.57	88.33	98.79	25.79	94.34	40.02	46.33	92.81	85.02	247.56	46.38	37.35	33.97	89.69	0	49.24	65.78	35.36	27.39	29.51	60.76	127.31	49.69	74.39	286.89	124.59	31.63	351.34	42.82
NETAS	28.05	212.72	88.55	54.84	98.19	30.41	43.69	34.03	9.86	18.99	96.79	303.16	31.63	25.81	17.75	14.94	49.24	0	128.40	19.27	18.95	8.91	8.29	224.79	39.51	17.35	220.57	154.22	49.38	402.30	5.57
AKGRT	60.53	85.11	90.76	80.51	67.47	58.27	135.27	63.70	109.84	193.86	48.04	110.97	88.89	70.02	74.06	153.77	65.78	128.40	0	122.60	116.76	89.07	164.25	65.56	64.93	106.76	240.16	104.11	49.45	212.06	105.66
TUPRS	54.26	232.12	126.66	99.30	135.12	30.53	45.01	45.76	33.24	42.29	131.62	325.40	44.42	47.14	26.29	56.75	35.36	19.27	122.60	0	4.13	20.66	17.24	200.76	57.91	49.32	292.45	158.68	53.38	418.26	24.47
PTOFS	49.97	227.99	127.93	93.51	125.39	26.87	60.28	43.05	27.63	47.60	124.12	321.10	39.64	40.82	26.81	56.95	27.39	18.95	116.76	4.13	0	16.80	20.28	195.38	56.51	49.71	292.33	146.97	46.73	419.78	21.64
PETKM	13.98	177.78	77.30	45.30	74.72	14.88	55.45	20.38	6.95	42.35	71.08	271.72	16.41	11.26	11.76	26.25	29.51	8.91	89.07	20.66	16.80	0	22.65	178.89	31.28	20.71	228.97	117.15	22.33	379.25	5.48
AKSA	54.05	252.01	111.47	88.04	130.28	49.02	46.86	52.56	24.66	10.59	136.11	349.19	46.17	49.60	36.38	27.95	60.76	8.29	164.25	17.24	20.28	22.65	0	247.69	63.69	38.24	243.38	174.09	72.41	430.16	19.63
ARCLK	166.60	56.61	214.45	207.60	191.00	136.38	235.63	162.63	197.57	292.04	110.64	107.36	147.04	144.56	172.84	241.87	127.31	224.79	65.56	200.76	195.38	178.89	247.69	0	173.85	204.66	270.22	114.99	128.16	156.03	210.12
TOASO	17.28	160.92	64.05	25.67	52.16	32.04	51.99	20.85	40.02	73.49	48.21	197.02	56.20	32.58	20.94	56.48	49.69	39.51	64.93	57.91	56.51	31.28	63.69	173.85	0	32.27	196.93	150.07	37.80	311.46	25.73
VESTL	19.23	156.25	66.10	36.38	78.80	39.90	44.62	35.70	21.04	43.80	61.15	239.71	31.34	24.46	19.05	17.48	74.39	17.35	106.76	49.32	49.71	20.71	38.24	204.66	32.27	0	181.55	150.27	51.16	344.44	15.39
FROTO	183.37	179.30	147.25	146.52	162.93	244.12	222.54	197.00	204.60	209.64	165.55	172.16	220.23	198.47	232.25	160.61	286.89	220.57	240.16	292.45	292.33	228.97	243.38	270.22	196.93	181.55	0	214.69	217.58	180.07	212.63
AEFES	106.85	123.37	152.73	135.20	127.29	112.13	200.20	109.08	110.50	202.93	135.18	213.47	91.70	92.81	150.21	145.84	124.59	154.22	104.11	158.68	146.97	117.15	174.09	114.99	150.07	150.27	214.69	0	79.67	263.21	134.88
TRKCM	17.81	134.94	78.56	48.39	54.66	21.00	88.51	19.01	30.81	100.24	53.39	214.95	24.93	15.37	29.56	63.82	31.63	49.38	49.45	53.38	46.73	22.33	72.41	128.16	37.80	51.16	217.58	79.67	0	321.43	32.96
HURGZ	322.70	119.26	275.46	290.83	260.36	345.72	358.60	337.47	384.74	423.20	216.61	45.49	348.49	333.73	351.44	375.67	351.34	402.30	212.06	418.26	419.78	379.25	430.16	156.03	311.46	344.44	180.07	263.21	321.43	0	384.81
ISGYO	15.36	196.32	75.43	37.50	74.05	24.05	47.29	22.66	7.27	32.47	76.85	277.09	26.40	16.82	13.23	18.88	42.82	5.57	105.66	24.47	21.64	5.48	19.63	210.12	25.73	15.39	212.63	134.88	32.96	384.81	0

APPENDIX-C. Statistical Test Results

Panel A: Pair Trading Data Description

Total days in sample	1752
Days in each formation period	125
Days in each trading period	30
Number of trading periods in sample	54
Total trading days in sample	1627
Days lost due to initial formation period	125
Days lost at end of sample (unused data)	-
Check of total days	1752 (125+30*54+7)

Panel B: Description of Pairs Trading Strategy

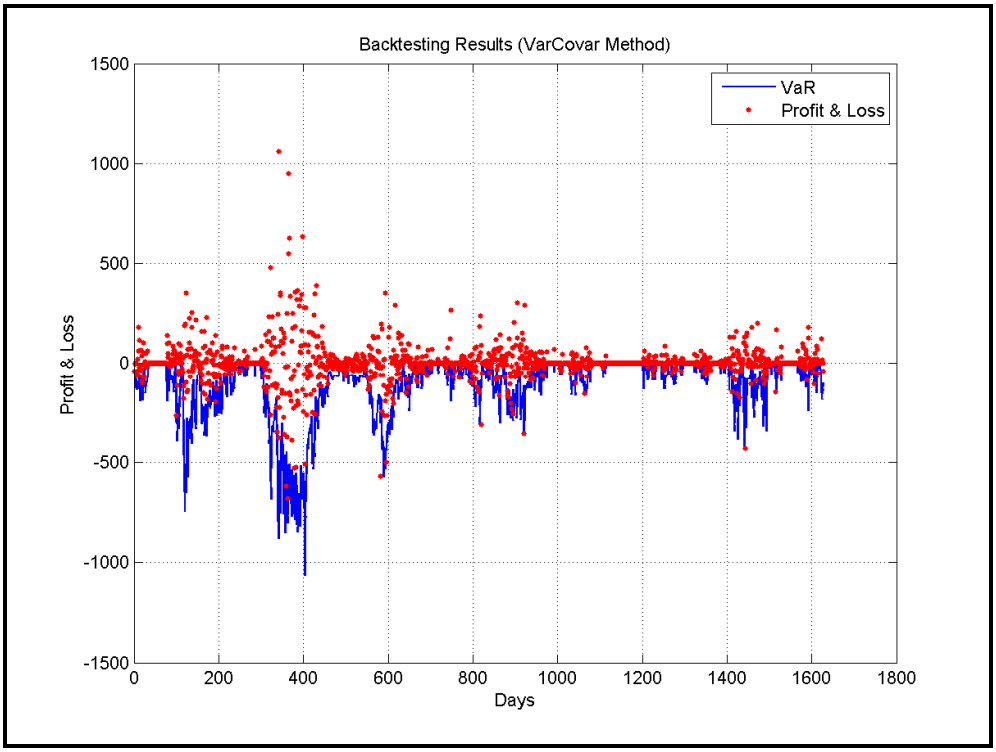
Max number of pairs during one day	23
Max number of open pair days	30
Average number of open pair days	5
Number of pair positions opened during trading period	2072
Number of pairs that never open	100
Average trigger value (2.5 stdev)- absolute value	2.75
Average number of days a position is open	5
Average number of positions opened during one day	2

Panel C: Overview of Pairs Trading Profits

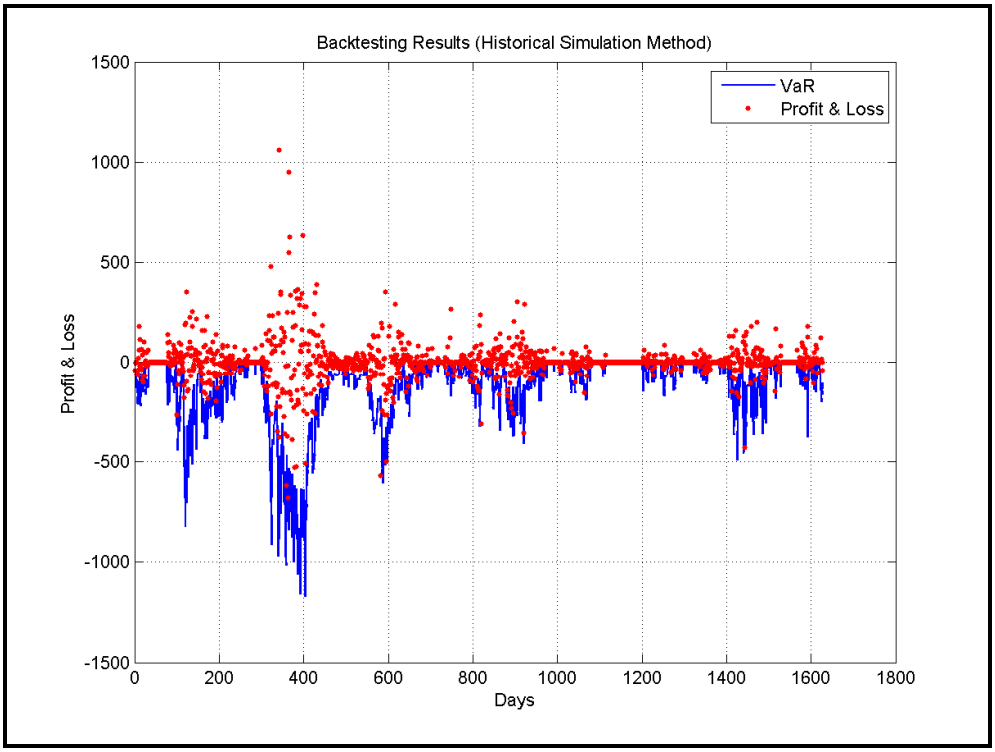
Average daily return of one pair during one day	GARAN & AKGRT
Average daily return of pairs trading portfolio	0.003
Stdev of daily returns	0.012
Sharpe ratio of returns (daily)	0.001
Sortino ratio	0.002
Jensen alpha	-0.149
Average return of pairs trading portfolio	0.033
Stdev of return (annualized)	0.042
Sharpe ratio of returns (annualized)	0.014
Sortino ratio	0.016
Jensen alpha	-1.36

APPENDIX-D

1. Pair Trading Backtest Results (VCV)



2. Pair Trades Backtest Results (HS)



3. Backtesting Result (MC)