Original Article

Adaptive pairs trading strategy performance in Turkish derivatives exchange with the companies listed on Istanbul stock exchange

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ABSTRACT **We implemented model-driven statistical arbitrage strategies in Turkish equities market. Trading signals are generated by optimized parameters of distance method. When the trade in signal is triggered by the model, market-neutral portfolio is created by long in the synthetic ETF, which is based on constrained least squares regression of selected Istanbul Stock Exchange stocks and short in Turkish Derivatives Exchange (Turkdex) index futures contract. We performed pairs trading strategy based on a comparative mean reversion of asset prices with daily data over the period February 2005 through July 2011 in Istanbul Stock Exchange (ISE) and Turkdex. We constructed a hypothetical ISE30 ETF Index on a daily basis in order to originate pairs trading strategy with Turkdex. Because of the leverage rule of (1–10) index futures contracts, we had to evaluate spot stock pairs formation with futures contracts pairs strategy. The results indicate that applied pairs strategy produced overall returns of 901 per cent during the**

investment period, whereas naive strategy (buy and hold ISE-30 index) return for the same period was 111 per cent. Similar outperformance was observed in the Sharpe and Sortino ratios.

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INTRODUCTION

Pairs trading strategy is a market-neutral strategy that involves identification of pairs with statistical measures and execution of pairs trading when the predefined threshold is triggered. 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 tends to fluctuate around its average in the short term, while remaining stable in the long run. In order to make money, a trader sells the main asset with the highest price and buys its pair with the lowest price with the expectation of a price decrease and an increase for the assets, respectively. The cause relationship of pairs selection from ISE30 indices, as it will be detailed further, depends on daily selections of the pairs other than setting the pairs once in the training period and monitoring these pairs during the trading period.

There are several reasons (Bolgün *et al.*, 2010) 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 as 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 rebalancing, such that actual trading can be automated and is feasibly profitable (Chng and Xia, 2007).

The term statistical arbitrage encompasses a variety of strategies and investment programs. Their common features are: (i) trading signals are systematic, or rules-based, as opposed to driven by fundamentals; (ii) the trading book is market-neutral, in the sense that it has zero β with the market; and (iii) the mechanism for generating excess returns is statistical. The idea is to make many bets with positive expected returns, taking advantage of diversification across stocks, to produce a low-volatility investment strategy, which is uncorrelated with the market. Holding periods range from a few seconds to days, weeks or even longer.

This article is an upgraded version of our previous article dated 2010. We developed an alternative short strategy by using futures contracts instead of shorting stocks separately, which is very costly in Turkey. In order to create a market-neutral portfolio, we prefer to buy synthetic ETF composed of 30 stocks. The composition of this ETF is subjective to statistical measures, and in some cases we may use less than 30 stocks. We contributed an alternative investment strategy by employing

Istanbul Stock Exchange (ISE) and Turkish Derivatives Exchange (Turkdex) instruments, and performance results showed us that this strategy is a powerful tool for asset managers.

The article proceeds as follows. In the next section, we provide a brief literature review and identify the main methods to implement pairs trading strategy. In the subsequent section, we describe the pairs trading data and methodology for the ISE30 stock & TURKDEX futures index pairs formation procedure and trading rules. In the penultimate section, we compare the performance results of pairs trading strategy. The final section concludes.

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. Gatev *et al* (2006) implemented a strategy of selecting 'pairs' of stocks according to how much stock prices have moved together in the past, and then proved this simple trading rule based on daily data that generate profits that exceed transactions costs. Nath (2003) examines the implementation of a simple pairs trading strategy with automatic extreme risk control using the entire universe of securities in the highly liquid secondary market for U.S. government debt. It documents, from a practical viewpoint, the contrasts in the generic features of pairs trading with such securities compared with equities.

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) to turn technical analysis from an art to a science.

The strategy is designed to profit from overreaction and subsequent mean reversion, that is, negative serial correlation in stock returns. Positive profits are reported in 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 per cent 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.

The study by Jegadeesh and Titman (1995) extends that of 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. Unlikely Lo and MacKinlay (1990) study, Jegadeesh and Titman (1995) indicates that stock prices overreact to firm-specific information, but react with a delay to common factors 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 (Chng and Xia, 2007).

Hogan *et al* (2004) provide a framework for testing anomalies based on the principle of statistical arbitrage. Vidyamurthy (2004) details an implementation strategy based on a cointegration-based framework, without empirical results. Elliott *et al* (2005) apply a Kalman filter to estimate 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.[1] Do *et al* (2006); Engelberg *et al* (2008) showed that profits to this strategy are lower when the initial divergence is due to value-relevant news relating to one of the stocks.

Gerasimos (2011), investigated the performance and the trading characteristics of 62 German Exchange-Traded Funds during the period 11 April 2000–12 September 2006. German ETFs slightly underperform their benchmarks. By regression analysis, he revealed that the tracking error is positively affected by risk. Marshall *et al* (2011) proved the arbitrage opportunities in ETFs, which are known as less expected mispricing instruments. Their findings show that economically important ETF mispricing (S&P 500) is a reasonably frequent occurrence. They analyzed more exotic ETFs such as those that seek to provide two times, three times or the inverse of underlying index performance (short ETF). Recently, Schizas *et al* (2011) examined the performance of pairs trading strategy by using international ETFs from across the world. He proved the profitability of this strategy in the context of mostly traded 22 international ETFs including SPY and MSCI country index ETFs those are listed in AMEX.

DATA & METHODOLOGY

Data

The database for this research is based on the ISE-30 index shares of ISE and Turkdex Contracts between the periods of February 2005–July 2011. Although 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 19 December 2011.

All the stocks prices we used are dividend adjusted so that we did not have to make that adjustment again. For the index futures prices, we used the daily prices of the closest maturity contract. That is, when the nearest maturity contract expires at time t, the maturity of the new nearest maturity contract will be 2 months and the new price at $t+1$ will have more interest rate effect than the price at time t. This change that occurs once in every 2 months will have minor effects on our calculations, as our methodology will be based on the log-returns of the prices instead of the prices themselves.

Pairs formation with the constrained least squares method

In this research, we implemented a stock ETF pair by regression methodology in the ISE30 stocks' daily returns and Turkdex Index, which is programmed by a pair trading model on Matlab.

Our trading rule requires taking long position on the ETF and at the same time taking short position on the stock index futures contract. As the ETF is highly correlated with the index, our portfolio will be market neutral.

In order to determine the weights in the ETF portfolio, we used the following constrained least squares regression.

$$r_t^{Index} = \beta_1 r_t^{Stock1} + \beta_2 r_t^{Stock2} + \cdots + \beta_{30} r_t^{Stock30}$$

such that

$$\sum_{i=1}^{30} \beta_i = 1 \text{ and } \beta_i \geqslant 0, \quad \forall i$$

According to the equation above, stock index's daily returns are regressed on individual stocks' daily returns for the last 125 days. The coefficients can directly be interpreted as the weights of the stocks in the ETF portfolio. In addition, applying the above constraints ensures that the sum of weights is 1 and individual stock weights are prevented to be less than 0 so that the ETF portfolio will not have any short positions.

Trading strategy and rule

After determining the weights for each stock in the ETF, we can figure out the price movements of the ETF and compare it with the index. As our trading strategy is going to be market neutral, we will buy the ETF and sell the index futures contract when the discrepancy (the futures price – ETF price difference, which from now on will be referred as *spread*) between the two increases. That is, we enter a position when the ETF is underpriced and index future is overpriced. Our main assumption is based on the fact that a relatively high spread is not sustainable. Therefore, when we observe such a case, we would expect the spread to return to its mean. That being said, the mean of the spread between the stock index and the ETF also changes because the weights in the ETF are recalculated for every trading day. Thus, we will adjust its mean by using a simple moving average for the last n days.

Specifically, we enter a position by buying the ETF and short selling the index future when the spread exceeds k standard deviation of its mean. And we close the position when the spread goes down to its mean.

At this point, one should also note that our parameters n and k (the number of days to calculate the moving average and standard deviation of it, respectively) can be optimized in order to achieve the best performing trading rule.

An example of pairs trading

The following figure illustrates the application of our trading rule.

- We developed a synthetic ETF by using constrained least squares methods as defined in section 'Pairs formation with the constrained least squares method'. This ETF composition is subject to change daily. The panel view of some coefficient calculation results is presented in Appendix B.
- We are always long in ETF and short in Turkdex index futures contract, as our model requires short constraint in the spot equities market. Generally, we do not rebalance our position until exit time. This may affect our trading profit as well.
- We enter the position when the blue line (spread) exceeds its k standard deviation and close our position when it goes below its mean.
- Although the spread is relatively volatile, it tends to go back to its moving average quickly after exceeding the k standard deviation of its mean.
- As shown in Figure 1, after the three trades, our capital increased by 27 per cent in 3 months.

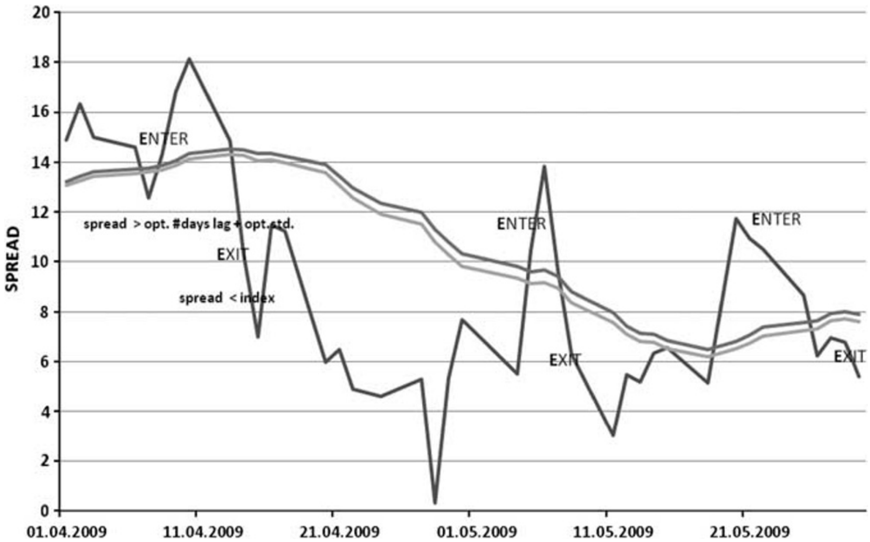

Figure 1: Pairs trade example.

- We included the daily interest income of the deposited collateral and overnight interest of our capital when we are out of trade position.
- We excluded the commission and taxes in our calculations.
- Statistical test results of implied strategy are presented in Appendix C.

PAIRS TRADING PERFORMANCE

The important decision in this trading strategy is determination of parameters. As discussed in the previous example, standard deviation of spread (k) is one of the key parameters in this alternative investment strategy. Another required parameter is the number of days (n) to implement standard deviation. The Sharpe and Sortino performance criteria of various combinations of parameters are also measured in order to determine the maximum trade profit. We optimized these measures by Matlab optimization tool. Optimization results are presented in Tables 1 and 2 for comparison purpose. As an example if we employed 1 standard deviation with 10 days lag, we could produce 0.7774 Sharpe against 1.0276 Sharpe performance measure with the 0.2 standard deviation in 10 days. It shows us that the used parameters have a big impact on performance results.

After optimizing the parameters to maximize our performance ratios, we end up with the parameters $n=19$ and $k=0.1$. In Appendix D, for a different combination of parameters both performance ratios increase almost monotonically as the parameters approach to our optimized parameters.

As presented in Table 3, our strategy's Sharpe ratio is 1.68 and Sortino ratio is 5.52. During the same period, ISE-30 stock index's Sharpe and Sortino ratios were −0.09 and −0.13, respectively.

We started with 100 capital as of 25 August 2005, which is the starting period of our investment. Remember that the first 125 days were used as the formation period of our selected pairs. Pairs trading transaction details are shown partially in Table 4.

A total of 144 trades were executed during the investment period; 128 of them were profitable

Table 1: Optimized sharpe ratios

Standard Deviation	*Lags (average days)*															
	5	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
0.1	1.1175	0.9875	0.8742	0.9287	1.0361	1.0076	1.0918	1.2488	1.2972	1.2382	1.3514	1.5091	1.5691	1.6021	1.6775	1.5070
0.2	0.9943	1.0102	0.8444	0.6446	0.9326	1.0276	1.1130	1.0539	1.2743	1.1674	1.1447	1.2344	1.3622	1.4894	1.6929	1.4579
0.3	0.9149	1.0926	0.8040	0.6331	0.8389	0.9663	1.0660	1.0489	1.1987	0.9389	1.0501	1.2472	1.3865	1.4405	1.5163	1.3655
0.4	0.8806	1.0329	0.8007	0.7091	0.8929	0.8834	0.9342	0.9050	1.0582	0.8459	0.9204	1.0940	1.2283	1.3509	1.5201	1.4058
0.5	0.9362	0.9463	0.7924	0.6223	0.9170	0.7496	0.7696	0.7514	0.9199	0.8909	0.9639	1.1416	1.3306	1.3242	1.4231	1.3704
0.6	1.0503	0.7062	0.5881	0.5735	0.8784	0.6236	0.6728	0.6967	0.8884	0.8665	0.9070	1.0529	1.1033	1.1680	1.2739	1.2195
0.7	1.0165	0.7060	0.5070	0.6535	0.7602	0.6676	0.7934	0.6278	0.9265	0.8702	0.8650	0.9953	1.1200	1.0127	1.1695	1.1852
0.8	0.6290	0.6279	0.4981	0.7074	0.8097	0.7623	0.7395	0.6718	0.9374	0.8621	0.7330	0.9458	1.0786	0.9645	1.0361	1.0779
0.9	0.4990	0.5361	0.3643	0.5140	0.9401	0.7395	0.7444	0.6684	0.8767	0.8039	0.7217	0.7647	0.9319	0.9195	1.0114	1.0276
1.0	0.5399	0.3439	0.2859	0.5137	0.8673	0.7774	0.7477	0.6560	1.0029	0.8301	0.7442	0.7561	0.9088	0.8970	0.9046	0.9199

Table 2: Optimized sortino ratios

Standard Deviation	*Lags (average days)*															
	5	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
0.1	2.2227	2.0344	1.9378	1.9316	2.2082	2.1638	2.3474	2.7882	3.4285	3.2216	3.5738	4.5403	4.9371	4.9600	5.5208	4.4711
0.2	2.0482	2.1453	1.7426	1.2397	1.9739	2.1921	2.5263	2.1507	2.9086	2.9669	2.5201	2.8678	3.3283	3.7212	5.1267	4.0352
0.3	1.8759	2.3258	1.7341	1.2065	1.5916	1.9352	2.1970	1.9876	2.5422	1.6639	2.2028	2.7710	3.4103	3.3238	4.6416	3.7027
0.4	1.8032	2.1473	1.7350	1.4402	1.7888	1.7473	1.8888	1.5379	1.9208	1.4333	1.7092	2.0400	2.5046	3.0772	4.2208	3.4624
0.5	1.9519	1.9509	1.5454	1.2369	1.8036	1.4441	1.3667	1.2699	1.6292	1.5462	1.8705	2.3371	3.0567	3.1438	3.5776	3.5837
0.6	2.1717	1.3697	1.1006	1.0964	1.7699	1.1059	1.1470	1.1354	1.5772	1.6087	1.7532	2.2174	2.4993	2.6808	3.1189	3.0412
0.7	2.1319	1.4015	0.9490	1.2896	1.3947	1.1094	1.4129	1.0127	1.7048	1.7134	1.6644	2.0729	2.3874	2.1458	2.8695	2.9204
0.8	1.0924	1.2331	0.9512	1.3635	1.4875	1.3256	1.3148	1.0995	1.7263	1.6899	1.4253	1.9862	2.3274	1.9928	2.3662	2.5706
0.9	0.8774	0.9499	0.6681	0.8950	1.8036	1.2916	1.3236	1.1294	1.5920	1.6069	1.4233	1.5228	1.9592	1.9238	2.3382	2.5356
1.0	0.9701	0.5851	0.5157	0.9820	1.6435	1.3754	1.3059	1.1101	1.8801	1.6948	1.4884	1.5361	1.9491	2.0014	2.0147	2.0535

Table 3: Performance comparison of model portfolio and ISE 30 index

	Model	*ISE30*
Sharpe	1.67746	−0.09673
Sortino	5.52077	−0.13273

Table 4: Pairs trading log

Dates	*ETF*	*Futures*	*Capital*
25 August 2005	103.06	103.45	100.00
29 August 2005	104.53	104.29	100.61
01 September 2005	111.38	111.51	100.61
12 September 2005	114.18	114.22	100.68
11 November 2005	121.66	118.12	100.68
15 November 2005	123.21	118.74	101.43
18 November 2005	126.39	122.58	101.43
28 November 2005	130.98	127.04	101.42
05 December 2005	139.37	135.68	101.42
06 December 2005	138.68	134.54	101.77
08 December 2005	137.07	133.22	101.77
09 December 2005	133.63	129.17	102.32
………	—	—	—
………	—	—	—
18 May 2011	187.83	210.16	951.08
08 June2011	187.91	211.34	951.08
10 May 2011	188.97	210.55	960.03
04 July 2011	191.54	211.99	960.03
12 July 2011	189.13	206.42	973.52
13 July 2011	185.39	208.02	973.52
22 July 2011	176.04	196.54	978.43
25 July 2011	175.58	201.01	978.43
27 July 2011	178.93	200.91	997.56
28 July 2011	177.51	205.80	997.56

trade, and the maximum drawdown was 15.68 per cent. As can be seen in Figure 2, most of the profit was generated after 2007.

Kelly ratio, the optimal size of each bet, is calculated as 87.5 per cent. This is quite high because the number of profitable trades are notably high relative to the number of unprofitable trades.

CONCLUSION

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. We developed an alternative investment strategy, which is always long in selected synthetic ETF and always short in the nearest Turkdex index futures contract. Synthetic ETF is composed of a maximum of 30 stocks but not required to buy and hold all of them passively as the current sector index ETFs. It may include less than 30 stocks, and in some cases more than 50 per cent weight could be given to only one selected stock in the ETF. The results indicate that pairs produced overall returns of 901 per cent (February 2005–July 2011), whereas ISE-30 index return for the same period was 111 per cent. Keeping in mind that our strategy is market neutral, this difference is notable.

Furthermore, an academic contribution of this research can be summarized as the dynamic synthetic ETF approach for the pairs formation and usage of futures contracts as an alternative short strategy. It is observed that parameters used in this research should be optimized. In addition, we should note that outperformance of this strategy may be the selection capability of our model. We used same stock list for 27 quarters, and performance attribution of those selected stocks may have outperformed the original ISE-30 stocks.

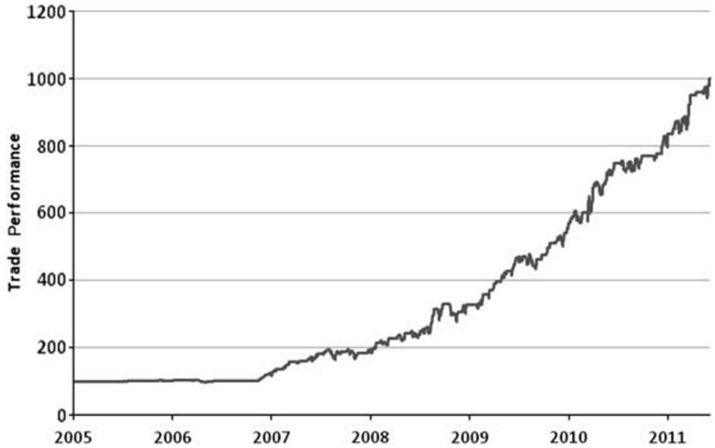

Figure 2: Pairs trading performance result.

NOTE

1. Do *et al* (2006)

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APPENDIX A

Table A1: Selected ISE 30 stocks market information

Reuters code	*Company name*	*Sector*	*Market capital (M$)*
AEFES.IS	ANADOLU EFES	MANUFACTURE OF FOOD, BEVERAGE AND TOBACCO	5444
AKBNK.IS	AKBANK[a]	BANKING	13 244
AKENR.IS	AK ENERJİ	ELECTRICITY GAS AND WATER	429
AKGRT.IS	AKSIGORTA	INSURANCE	260
AKSA.IS	AKSA	MANUFACTURE OF CHEMICALS	415
ALARK.IS	ALARKO HOLDING	HOLDING COMPANIES	358
ARCLK.IS	ARCELIK[a]	MANUFACTURE OF FABRICATED METAL PRODUCTS, MACHINERY AND EQUIPMENT	2087
DOHOL.IS	DOGAN HOLDING[a]	HOLDING COMPANIES	676
DYHOL.IS	DOGAN YAYIN HOLDING[a]	HOLDING COMPANIES	541
EREGL.IS	EREGLI DEMIR CELIK[a]	BASIC METAL INDUSTRIES	3571
FINBN.IS	FINANSBANK	BANKING	5930
FROTO.IS	FORD OTOSAN	MANUFACTURE OF FABRICATED METAL PRODUCTS, MACHINERY AND EQUIPMENT	2728
GARAN.IS	GARANTI BANK[a]	BANKING	13 327
HURGZ.IS	HURRIYET GAZETECILIK	MANUFACTURE OF PAPER AND PAPER PRODUCTS, PRINTING AND PUBLISHING	208
IHLAS.IS	IHLAS HOLDING	HOLDING COMPANIES	327
ISCTR.IS	IS BANK[a]	BANKING	8178
ISGYO.IS	IS GMYO	REAL ESTATE INVEST.TRUSTS	328
KCHOL.IS	KOC HOLDING[a]	HOLDING COMPANIES	7382

MGROS.IS	MIGROS[a]	CONSUMER TRADE	1228
NETAS.IS	NETAS TELEKOM	INFORMATION TECHNOLOGY	442
PETKM.IS	PETKIM	MANUFACTURE OF CHEMICALS AND OF CHEMICAL PETROLEUM, RUBBER AND PLASTIC PRODUCTS	1040
PTOFS	PETROL OFISI	MANUFACTURE OF CHEMICALS AND OF CHEMICAL PETROLEUM, RUBBER AND PLASTIC PRODUCTS	1223
SAHOL.IS	SABANCI HOLDING[a]	HOLDING COMPANIES	6171
SISE.IS	SISE CAM[a]	HOLDING COMPANIES	2021
TCELL.IS	TURKCELL	COMMUNICATION	10 319
TOASO.IS	TOFAS OTO FABRIKA	MANUFACTURE OF FABRICATED METAL PRODUCTS, MACHINERY AND EQUIPMENT	1533
TRKCM.IS	TRAKYA CAM	MANUFACTURE OF NON-METALLIC MINERAL PRODUCTS	810
TUPRS.IS	TUPRAS[a]	MANUFACTURE OF CHEMICALS AND OF CHEMICAL PETROLEUM, RUBBER AND PLASTIC PRODUCTS	5063
VESTEL.IS	VESTEL	MANUFACTURE OF FABRICATED METAL PRODUCTS, MACHINERY AND EQUIPMENT	310
YKBNK.IS	YAPI VE KREDI BANKASI[a]	BANKING	6320

[a]represents the stocks listed in ISE-30 in all 27 quarters.

APPENDIX B

Table B1: Panel view of selected coefficients

	AEFES (%)	*AKBNK* (%)	*AKENR* (%)	*AKGRT* (%)	*AKSA* (%)	*ALARK* (%)	*ARCLK* (%)	*DOHOL* (%)	*DYHOL* (%)	*EREGL* (%)	*FINBN* (%)	*FROTO* (%)	*GARAN* (%)	*HURGZ* (%)
23 August 2005	6.09	9.31	1.46	1.07	0.36	2.36	2.35	2.02	0.27	9.93	4.43	2.66	10.55	5.47
24 August 2005	5.91	9.56	1.65	0.85	0.13	2.37	2.66	2.00	0.30	9.60	4.50	2.73	10.90	5.38
25 August 2005	5.93	9.70	1.52	0.84	0.14	2.28	2.57	2.08	0.11	9.52	4.59	2.70	10.96	5.38
26 August 2005	5.83	9.94	1.46	0.56	0.01	2.26	2.37	2.32	0.21	9.37	4.62	2.56	11.02	5.47
29 August 2005	5.79	10.00	1.39	0.46	0.03	2.27	2.39	2.37	0.23	9.21	4.67	2.64	11.10	5.43
31 August 2005	6.00	10.17	1.46	0.71	0.45	2.61	2.47	2.08	0.25	8.91	4.51	2.74	11.25	5.56
01 September 2005	6.11	10.40	1.33	1.12	0.75	2.98	2.37	1.79	0.00	8.68	4.18	3.20	11.42	5.40
02 September 2005	6.45	10.83	1.27	1.07	0.62	2.85	2.17	1.52	0.02	8.74	4.14	3.28	11.16	5.30
05 September 2005	6.38	10.66	1.20	1.16	0.89	2.79	2.29	1.47	0.16	8.70	4.18	3.27	10.95	5.17
06 September 2005	6.29	10.74	1.25	1.26	0.89	2.83	2.25	1.60	0.12	8.80	4.18	3.28	10.89	5.24
07 September 2005	6.04	10.94	1.20	1.05	1.11	2.47	2.67	1.58	0.11	8.86	4.15	3.30	10.94	5.15
02 January 2009	5.90	0.00	26.66	0.00	0.00	0.00	0.00	0.00	0.00	3.21	0.00	20.52	0.00	0.00
05 January 2009	5.91	0.00	26.66	0.00	0.00	0.00	0.00	0.00	0.00	3.19	0.00	20.59	0.00	0.00
06 January 2009	3.42	0.00	26.80	0.00	0.00	0.00	0.00	0.00	0.00	3.27	0.00	22.40	0.00	0.00
07 January 2009	2.87	0.00	28.06	0.00	0.00	0.00	0.00	0.00	0.00	2.19	0.00	23.46	0.00	0.00
08 January 2009	2.76	0.00	28.09	0.00	0.00	0.00	0.00	0.00	0.00	2.21	0.00	23.66	0.00	0.00
09 January 2009	3.36	0.00	25.94	0.00	0.00	0.00	0.00	0.00	0.00	4.86	0.00	21.11	0.00	0.00
12 January 2009	3.34	0.00	25.85	0.00	0.00	0.00	0.00	0.00	0.00	4.83	0.00	21.40	0.00	0.00
13 January 2009	2.49	0.00	25.69	0.00	0.00	0.00	0.00	0.00	0.00	4.38	0.00	20.81	0.00	0.00
14 January 2009	0.96	0.00	25.21	0.00	0.00	0.00	0.00	0.00	0.00	4.17	0.00	20.68	0.00	0.00
15 January 2009	2.07	0.00	24.73	0.00	0.00	0.00	0.00	0.00	0.00	4.97	0.00	19.51	0.00	0.00
16 January 2009	3.80	0.00	23.65	0.00	0.00	0.00	0.00	0.00	0.00	5.59	0.00	18.93	0.00	0.00
15 July 2011	0.00	0.00	0.00	0.00	24.13	0.00	0.00	0.00	0.00	17.81	1.92	20.33	0.00	0.00
18 July 2011	0.00	0.00	0.00	0.00	24.79	0.00	0.00	0.00	0.00	15.19	1.71	21.82	0.00	0.00
19 July 2011	0.00	0.00	0.00	0.00	23.66	0.00	0.00	0.00	0.00	15.33	2.42	21.65	0.00	0.00
20 July 2011	0.00	0.00	0.00	0.00	23.71	0.00	0.00	0.00	0.00	16.00	1.66	21.72	0.00	0.00
21 July 2011	0.00	0.00	0.00	0.00	23.85	0.00	0.00	0.00	0.00	15.76	1.42	22.27	0.00	0.00
22 July 2011	0.00	0.00	0.00	0.00	22.74	0.00	0.00	0.00	0.00	13.97	2.50	24.42	0.00	0.00
25 July 2011	0.00	0.00	0.00	0.00	20.78	0.00	0.00	0.00	0.00	12.42	0.69	26.04	0.00	0.00
26 July 2011	0.00	0.00	0.00	0.00	26.76	0.00	0.00	0.00	0.00	8.60	5.17	24.52	0.00	0.00
27 July 2011	0.00	0.00	0.00	0.00	26.66	0.00	0.00	0.00	0.00	8.11	5.52	25.13	0.00	0.00
28 July 2011	0.00	0.00	0.00	2.48	26.93	0.00	0.00	0.00	0.00	11.35	8.89	21.59	0.00	0.00
29 July 2011	0.00	0.00	0.00	6.20	28.53	0.00	0.00	0.00	0.00	2.25	8.11	25.67	0.00	0.00

	IHLAS (%)	ISCTR (%)	ISGYO (%)	KCHOL (%)	MIGRS (%)	NETAS (%)	PETKM (%)	PTOFS (%)	SAHOL (%)	SISE (%)	TCELL (%)	TOASO (%)	TRKCM (%)	TUPRS (%)	VESTEL (%)	YKBNK (%)
23 August 2005	1.07	17.66	4.44	0.00	3.16	0.00	0.50	0.00	8.93	0.01	0.00	3.10	0.00	0.00	2.80	0.00
24 August 2005	0.94	17.22	4.37	0.00	3.27	0.00	0.17	0.00	9.47	0.00	0.00	3.08	0.00	0.00	2.97	0.00
25 August 2005	0.85	17.25	4.41	0.00	3.22	0.00	0.15	0.00	9.56	0.00	0.00	3.14	0.00	0.00	3.11	0.00
26 August 2005	0.89	17.26	4.50	0.00	3.18	0.00	0.50	0.00	9.35	0.00	0.00	3.25	0.00	0.00	3.06	0.00
29 August 2005	0.90	17.26	4.51	0.00	3.14	0.00	0.43	0.00	9.46	0.00	0.00	3.21	0.00	0.00	3.10	0.00
31 August 2005	0.84	17.00	4.20	0.00	3.14	0.00	0.15	0.00	9.28	0.04	0.00	3.00	0.00	0.00	3.20	0.00
01 September 2005	0.85	17.15	4.14	0.00	2.25	0.00	0.87	0.00	8.87	0.02	0.02	2.68	0.00	0.00	3.40	1.00
02 September 2005	0.79	17.55	4.12	0.00	2.20	0.00	0.87	0.00	8.77	0.01	0.07	2.47	0.00	0.00	3.70	0.02
05 September 2005	0.79	17.23	4.04	0.00	2.27	0.00	1.12	0.00	8.82	0.03	0.45	2.25	0.00	0.00	3.72	0.00
06 September 2005	0.79	17.17	3.84	0.00	2.43	0.00	1.07	0.00	8.92	0.01	0.47	2.35	0.00	0.00	3.35	0.00
07 September 2005	0.82	16.94	3.76	0.00	2.47	0.00	0.93	0.00	8.90	0.00	0.71	2.06	0.00	0.00	3.83	0.00
02 January 2009	10.52	0.00	0.00	0.75	17.43	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00
05 January 2009	10.51	0.00	0.00	0.73	17.40	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.01
06 January 2009	9.66	0.00	0.00	2.11	16.11	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.68
07 January 2009	9.48	0.00	0.00	1.06	16.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.02
08 January 2009	9.20	0.00	0.00	1.01	17.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.99
09 January 2009	8.19	0.00	0.00	2.12	16.51	0.00	0.00	2.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.79
12 January 2009	8.19	0.00	0.00	1.58	16.46	0.00	0.00	2.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.70
13 January 2009	7.84	0.00	0.00	2.42	16.87	0.00	0.00	4.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.94
14 January 2009	8.07	0.00	0.00	1.91	17.80	0.00	0.00	4.25	0.00	0.00	0.00	0.03	0.00	0.00	0.00	16.91
15 January 2009	7.79	0.00	0.00	2.02	17.49	0.00	0.00	4.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.91
16 January 2009	7.34	0.00	0.00	1.51	16.88	0.00	0.00	5.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.66
15 July 2011	0.00	0.00	0.00	0.00	11.33	0.00	0.00	13.01	5.66	0.00	1.14	0.00	0.00	0.00	0.00	4.66
18 July 2011	0.00	0.00	0.00	0.00	11.89	0.00	0.00	12.53	5.55	0.00	0.00	0.00	0.00	0.00	0.00	6.51
19 July 2011	0.00	0.00	0.00	0.00	10.81	0.00	0.00	12.49	6.23	0.00	0.00	0.00	0.00	0.00	0.00	7.42
20 July 2011	0.00	0.00	0.00	0.00	9.75	0.00	0.00	12.07	6.83	0.00	0.22	0.00	0.00	0.00	0.00	8.05
21 July 2011	0.00	0.00	0.00	0.00	9.59	0.00	0.00	12.04	7.02	0.00	0.48	0.00	0.00	0.00	0.00	7.57
22 July 2011	0.00	0.00	0.00	0.00	9.20	0.00	0.00	12.16	7.00	0.00	2.07	0.00	0.00	0.00	0.00	5.94
25 July 2011	0.00	0.00	0.00	0.00	8.90	0.00	5.27	11.37	5.68	0.00	0.21	0.00	0.00	0.00	0.00	8.62
26 July 2011	0.00	0.00	0.00	0.00	11.57	0.00	9.01	11.27	2.36	0.00	0.00	0.00	0.00	0.00	0.00	0.84
27 July 2011	0.00	0.00	0.00	0.00	11.82	0.00	9.15	11.36	2.03	0.00	0.00	0.00	0.00	0.00	0.00	0.22
28 July 2011	0.00	0.00	0.00	2.74	10.36	0.00	3.71	11.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29 July 2011	0.00	0.00	0.00	0.00	10.63	0.00	4.18	14.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX C

Table C1: Statistical test results

Sample period	*25 February 2005–29 July 2011*
Panel-A: Pairs trading data description	
Number of days in the sample	2345
Number of business days in the sample	1622
Number of days in the formation period	125
Number of days in the trading period	1497
Days lost due to initial formation period	125
Days lost at the end of the sample	—
Panel-B: Pairs trading strategy results	
Number of trades	144
Number of profitable trades	128
Number of unprofitable trades	16
Average profit per trade (%)	2.13
Average loss per trade (%)	2.20
Maximum drawdown (%)	15.68
Expected duration of a position (days)	6.72
Kelly ratio of the strategy (%)	87.5
Sharpe ratio	1.67746
Sortino ratio	5.52077

APPENDIX D

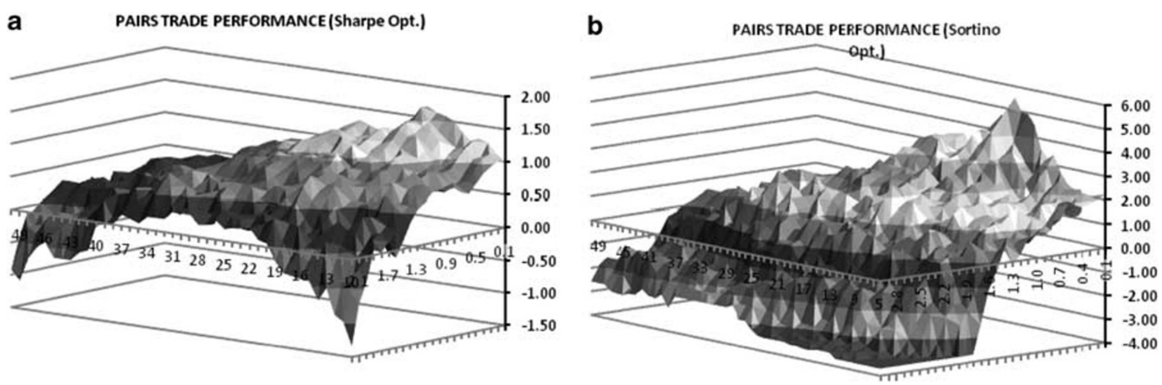

Figure D1: (**a**) Optimized Sharpe ratios. (**b**) Optimized Sortino ratios.