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Illuminating the Profitability of Pairs Trading: *A Test of the Relative Pricing Efficiency of Markets for Water Utility Stocks*

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It is difficult to evaluate whether financial markets price securities correctly, because the correct price remains unobservable. It is easier to evaluate the pricing efficiency of markets by analyzing the prices of closely related securities. Using daily data, Gatev, Goetzmann, and Rouwenhorst [2006] (GGR) examined relative prices of a pair of stocks whose returns are most closely related. They demonstrate that a trading strategy of buying the underpriced stock while simultaneously shorting the overvalued stock yields annualized excess returns of roughly 11%. Their results also show that the annualized excess return is strongest in the utility sector over any other sector analyzed. These results, derived solely from historical price dynamics and contrarian principles, are surprising and warrant further examination. Papadakis and Wysocki [2008] claimed that post-earnings drift is an important factor contributing to the profits documented by GGR.

We test the daily relative pricing efficiency of a trio of water utility stocks.[1] The first stock, Connecticut Water Service Inc. (CTWS), is a regulated water company that supplies drinking water and also provides contracted services to water and wastewater utilities and other clients. These services include the operation of water and wastewater facilities. The second stock, Aqua America Inc. (WTR), is a regulated utility that provides water or wastewater services in the United States. It serves residential, commercial, fire protection, industrial, and other water and wastewater customers. The company also provides water and wastewater services through operating and maintenance contracts with municipal authorities and other parties. The third stock, American States Water Company (AWR), provides water, electric, and contracted services in the United States. AWR engages in the purchase, production, distribution, and sale of water in California as well as the distribution of electricity in the San Bernardino Mountain communities. It also offers water and/or wastewater services, including the operation, maintenance, renewal, and replacement of the water and/or wastewater systems.

There are three main objectives of this article. The first objective is to show that a strong co-integrating relation exists between each paired combination of the three chosen securities. The second objective is to duplicate the results of GGR, who demonstrate the profitability of a pairs trading strategy. The third objective is to drill down through the profitability results to show that the co-integrating relation, coupled with the implied Granger causality, explains the profitability of the strategy.

The next section provides background information on co-integrating relations that establishes a necessary condition for a "matched pair" trading strategy. Pairs trading is introduced in the following section. Next, we describe the data and present summary statistics before presenting the time series results and establishing that co-integrating relations between CTWS, WTR, and AWR do exist. The following section describes the trading rule employed, the results of which show annualized returns as high as 24.67%, but no lower than 11.39% (before transaction costs), which corroborate the results of the GGR study. The last section concludes.

STATIONARITY, CO-INTEGRATION, AND ERROR CORRECTION

Co-integration, introduced by Granger [1981, 1986] and further developed by Engle and Granger [1987], incorporates the presence of nonstationarity, long-term relations, and short-run dynamics into the modeling process. In the case of co-integrating variables, Granger and Newbold [1974] showed that regressions can be run on levels without losing any "long-run" information and without encountering the problem of a spurious regression. Engle and Granger go on to show that if two series are co-integrated, there must exist an error correction representation; and, conversely, if an error correction representation exists, the two series are co-integrated. The existence of an error correction model implies some Granger causality between the series, which means that the error correction model can be used for forecasting.

We begin our analysis with a test for the presence of a unit root for each series, conducted by performing the following Augmented Dickey-Fuller (ADF) [1981] regression:

$$\Delta y_t = a_1 + a_y y_{t-1} + \sum_{i=1}^{p} \Psi_{y,i} \Delta y_{t-i} + u_{y,t} \tag{1a}$$

$$\Delta z_t = a_2 + a_z z_{t-1} + \sum_{i=1}^{p} \Psi_{z,i} \Delta z_{t-i} + u_{z,t} \tag{1b}$$

where enough lagged differences are added to ensure $u_{y,t}$ and $u_{z,t}$ become white noise. The null hypothesis of a unit root is tested against the alternative hypothesis of stationarity for both the level data as well as the first differenced data. The critical values are obtained from MacKinnon [1991].

Next, after testing for integration in the individual series, we test for the presence (or absence) of co-integration by testing whether there is a linear combination of y_t and z_t that is stationary. To do this, we determine the long-run relation between y_t and z_t in the form:

$$y_t = \beta_0 + \beta_1 z_t + e_t \tag{2}$$

where e_t is a disturbance term. In order to determine if the y_t and z_t series are co-integrated, we denote the estimated residual sequence from this equation by $\hat{e}_t$. The null hypothesis of no co-integration is tested by applying the ADF test to these estimated residuals.

$$\Delta \hat{e}_t = a_e \hat{e}_{t-1} + \sum_{i=1}^{p} \Psi_{e,i} \Delta \hat{e}_{t-i} + u_{e,t} \tag{3}$$

where $u_{e,t}$ is white noise. Again, the critical values are obtained from MacKinnon [1991]. Rejection of the null hypothesis implies co-integration.

Moreover, there exists a connection between co-integration and causality in that at least one Granger causal relation must exist in a co-integrated system. Causality from y to z and from z to y can be tested by using an error-correction model of the form:

$$\Delta y_t = \alpha_1 + \alpha_y (y_{t-1} - \beta_1 z_{t-1}) + \sum_{i=1} \alpha_{1,1} \Delta y_{t-i} + \sum_{i=1} \alpha_{1,2} \Delta z_{t-i} + \varepsilon_{y,t} \tag{4a}$$

$$\Delta z_t = \alpha_2 + \alpha_z (y_{t-1} - \beta_1 z_{t-1}) + \sum_{i=1} \alpha_{2,1} \Delta y_{t-i} + \sum_{i=1} \alpha_{2,2} \Delta z_{t-i} + \varepsilon_{z,t} \tag{4b}$$

where β_i are the parameters of the co-integrating vector given by Equation (2); $\varepsilon_{y,t}$ and $\varepsilon_{z,t}$ are white noise disturbances; and α_1, α_2, α_y, α_z, $\alpha_{1,1}$, $\alpha_{1,2}$, $\alpha_{2,1}$, and $\alpha_{1,2}$ are all parameters.

It should be noted that the magnitude of the residual $\hat{e}_{t-1}$, is the deviation from the long-run equilibrium in period $t-1$. Hence, it is possible to use the residuals $\hat{e}_{t-1}$ obtained from Equation (2) as an instrument for the expression $y_{t-1} - \beta_1 z_{t-1}$ from Equations (4a) and (4b). Thus, by using the residuals from the estimation of the long-run equilibrium relation, we now estimate the error-correction model as:

$$\Delta y_t = \alpha_1 + \alpha_y \hat{e}_{t-1} + \sum_{i=1} \alpha_{1,1} \Delta y_{t-i} + \sum_{i=1} \alpha_{1,2} \Delta z_{t-i} + \varepsilon_{y,t} \tag{5a}$$

$$\Delta z_t = \alpha_2 + \alpha_z \hat{e}_{t-1} + \sum_{i=1} \alpha_{2,1} \Delta y_{t-i} + \sum_{i=1} \alpha_{2,2} \Delta z_{t-i} + \varepsilon_{z,t} \tag{5b}$$

In this formulation, change in the y series is a function of the lagged equilibrium error and the lagged values of the changes in y and z price series. The error correction term measures the long-run equilibrium relation, and the lagged variables capture the short-run dynamics. If information disseminates in y first and z later (i.e., y leads z in the Granger sense), then α_y should be zero as y reflects information faster than z. Therefore, y will not adjust to the disequilibrium described by $\hat{e}_{t-1}$. Under these same circumstances, α_z is significantly positive if z follows y to reflect information, and z will adjust to the disequilibrium. Conversely, if information disseminates in z first, α_y should be significantly negative, and α_z should be nonsignificant. In sum, the higher the magnitude (with correct sign) of α_i, the slower the series i reflects information.

PAIRS TRADING AND RELATIVE VALUE ARBITRAGE

Relative value arbitrage is the activity of taking an offsetting position in securities that are historically or mathematically related, but where the relation is temporarily distorted. Over time, these relations fluctuate around an average, moving away and then back to a mathematically determined midpoint. A strategy of this type is based on implied convergence as there is no fundamental or identified reason that the stocks involved should revert back to their historical average—rather, the expectation is based on statistical probability. This expectation is, of course, based on the assumption that the relation is not acted on by some outside force that will change the basic characteristics of its structure.

Pairs trading is a nondirectional, relative-value investment strategy that identifies two securities with similar characteristics that are currently trading at a price relation that is outside their historical trading range. In this context, pairs trading uses a statistical model as an initial screen for constructing a relative-value equity trade that consists of concurrently buying the undervalued security and short-selling the overvalued security. The pairs system is essentially an arbitrage system where the trader is able to capture profits from the divergence of two co-integrated price series.

Different volatility tends to exist within different sectors. It is our expectation that high volatility sectors will have fewer pairs than will low volatility sectors. It is also our expectation that sectors with more homogeneous operations and earnings will allow for more pairs. Conducting a pairs trade within the utility sector allows for sector neutrality. Additionally, the operations of the three chosen water utility firms (CTWS, WTR, and AWR) are relatively homogeneous.

GGR is the first study, to our knowledge, that examines pairs trading in the U.S. stock market. Papadakis and Wysocki [2007] find that the most profitable of these trades occur around earnings announcements. Andrade, Di Pietro, and Seasholes [2005] reported similar trading profits in the Taiwan stock market. There are a number of articles that have examined the spread between cash and futures markets, as well as the spreads across different futures contracts. Dwyer, Lock, and Yu [1996] and Tse [2001] examined index arbitrage. Articles that examined futures spreads and that documented significant trading profits include Johnson et al. [1991], Girma and Paulson [1999], Simon [1999], Emery and Liu [2002] and Liu [2005].

DATA AND SUMMARY STATISTICS

We conduct our analysis through the utilization of CRSP daily data for CTWS, WTR, and AWR (PERMNOs 26463, 52898, and 71475) for the period January 1, 1997 through December 31, 2008. This time period was chosen based on data availability. CTWS is listed on the NASDAQ Global Select, whereas WTR and AWR are listed on the NYSE.

Exhibit 1 provides summary statistics for daily share volume, dollar volume, and returns. From the exhibit, we see that, of the three securities, WTR is the more heavily traded, posting an average daily share volume of 309,722. AWR ranks second and CTWS ranks third with an average of 46,716 and 9,385 shares respectively. In terms of daily dollar volume, WTR averages \$6.816 million, whereas CTWS only averages \$0.246 million. In terms of volatility, as measured by the standard deviation of returns, CTWS is the riskiest stock. Using adjusted monthly values from January 2000 to December 2008, the bottom half of the exhibit provides each securities' buy-and-hold return as well as its calculated beta.

Exhibit 1
Descriptive Statistics

	Daily share volume			Daily dollar volume			Daily returns			
	CTWS	WTR	AWR	CTWS	WTR	AWR	CTWS	WTR	AWR	S&P 500
Mean	9,385	309,722	46,716	$246,134	$6,816,826	$1,546,876	0.06%	0.08%	0.06%	0.02%
Std. Dev.	24,621	472,400	59,112	$579,928	$10,094,573	$2,198,889	2.10%	1.89%	1.98%	1.28%
Median	6,275	109,550	23,800	$168,699	$2,460,841	$641,944	0.00%	0.00%	0.00%	0.05%
Max	966,638	5,578,600	626,300	$22,638,662	$147,498,187	$26,292,074	14.37%	13.13%	9.63%	11.58%
Min	0	500	200	$0	$9,938	$4,375	–13.11%	–10.57%	–9.73%	–9.03%
Buy & hold return							44.13%	121.12%	68.67%	–43.43%
Firm beta							0.095	(0.037)	0.141	

Note: Daily returns are estimated as the log difference between the daily closing price at time t, and the daily closing price at time t – 1. Share volume, dollar volume, and returns are obtained using data from January 1997 to December 2008. Buy and hold return and firm beta are calculated using adjusted monthly values from January 2000 to December 2008.

Time Series Empirical Evidence

Vidyamurthy [2004] outlined a strategy that attempts to parameterize pairs trading by exploring the possibility of co-integration. By definition, co-integration necessitates that two variables be integrated of the same order. Thus, we begin our analysis by testing all three variables to determine the order of integration for each via the Augmented Dickey-Fuller (ADF) test. The null hypothesis for the ADF test states that the time series has a unit root, whereas the alternative hypothesis claims stationarity.

Panel A of Exhibit 2 provides the results of the ADF test under the assumption that there is no linear trend in the data generating process. Pseudo t-values of the level series fail to reject the null hypothesis of a unit root for CTWS, WTR, or AWR. This implies that all three series are nonstationary; thus, necessitating the calculation of first differences. Next, the ADF test is applied to the two differenced series. Here, pseudo t-values clearly reject the null hypothesis of a unit root for each series, implying that all three differenced series are $I(0)$, which further establishes that both the original CTWS, WTR, and AWR series are $I(1)$.

Next, after testing for integration of the individual log price series, we test for co-integration between any two. When two or more series individually are integrated (following a random walk process), but there exists a linear combination of them that is stationary, the series are said to be co-integrated. Results of the test for co-integration are presented in Panel B of Exhibit 2. The ADF test rejects the null hypothesis of no co-integration at the 1% level. Stated differently, given that each individual series

Exhibit 2
Integration and Co-Integration

Panel A: Augmented Dickey-Fuller Test for integration

	CTWS	WTR	AWR
Levels	–0.31	–0.22	0.21
First difference	–48.84***	–41.83***	–42.85***

Panel B: Augmented Dickey-Fuller Test for co-integration

	Regressand	Regressand	Regressand
Regressor	WTR	AWR	AWR
CTWS	–4.29***		–3.34***
WTR		–2.86***	

Panel C: Johansen co-integration rank test

	Trace Stat	5% Value
CTWS and WTR	37.63	19.99
WTR and AWR	31.29	19.99
CTWS and AWR	30.39	19.99

Note: Augmented Dickey-Fuller test for unit roots in the autoregressive representations of the daily closing log price and on the daily closing log first differences of CTWS, WTR, and AWR. The sample period is from January 1997 to December 2008. Critical values for the significance tests are from MacKinnon [1991].

***, *** denote statistical significance at 5% and 1% levels respectively.*

is found to be $I(1)$, there exists a linear combination of any two, where the residuals are found to be $I(0)$ (stationary). As such, we can conclude that any pair of series are co-integrated with an order of (1,1). Co-integration implies that neither series will wander arbitrarily far from the other before one (or both) of them corrects. To test the robustness of the co-integration results, Panel C provides results for a second test. Here, the results for the Johansen

[1988, 1991] co-integration rank test of integrated order (1) are given. Based on these results, like the results in Panel B, any chosen pair of series are co-integrated with rank 1, indicating a common vector.

Engle and Granger [1997] showed that if a pair of series is co-integrated, then there exists an error correction representation and, conversely, an error correction representation implies that the series are co-integrated. Co-integration describes the long-run equilibrium relation between the variables, whereas an error correction mechanism forces the short-run deviation from equilibrium in one period to move towards equilibrium in the next period.

Results of the OLS estimates of the error correction models are presented in Exhibit 3. The intercept in each system is statistically nonsignificant, which confirms the assumption that the process is not generated by a linear trend. More importantly, the error correction coefficient is statistically significant in the case of ΔWTR_t, ΔAWR_t, and ΔAWR_t when paired with CTWS, WTR, and CTWS respectively. This significance shows that the previous period's disequilibrium has a significant impact on the adjustment process of the subsequent price change, back toward equilibrium. However, the error correction coefficient is statistically nonsignificant in the case of $\Delta CTWS_t$ when paired with WTR, ΔWTR_t when paired with AWR, and $\Delta CTWS_t$ when paired with AWR, which implies that price changes in these series do not respond to disequilibrium like the other in the pair does. Stated differently, CTWS appears to Granger-cause WTR, but not vice versa; WTR appears to Granger-cause AWR, but not vice versa; and CTWS appears to Granger-cause AWR, but not vice versa. This implies that WTR is predictable when paired with CTWS, AWR is predictable when paired with WTR, and AWR is predictable when paired with CTWS.

There is an interesting point to be made regarding the behavior of WTR. Specifically, when WTR is paired with CTWS, WTR appears to respond to disequilibrium that existed at time $t-1$; however, when WTR is paired with AWR, WTR is unresponsive to any disequilibrium. Instead, AWR is the responding series, whereas WTR appears to lead. This dual role is interesting considering WTR is the most liquid of the three firms as measured by daily share volume and daily dollar volume. In summation, liquidity is not the driving force behind whether a series is the "leader" or "follower" in the Granger sense.

EXHIBIT 3
OLS Error Correction Model

Panel A: Error correction between CTWS and WTR

	Model for $\Delta CTWS_t$		Model for ΔWTR_t	
Regressor	**Coefficient**	***t*-Value**	**Coefficient**	***t*-Value**
Intercept	–0.00006	–0.16	–0.00001	–0.01
$\hat{e}_{t-1}$	–0.00263	–1.01	–0.01134	–4.29***
$\Delta CTWS_{t-1}$	–0.22338	–12.94***	0.00471	0.27
ΔWTR_{t-1}	0.00755	0.43	–0.00340	–0.19

Panel B: Error correction between WTR and AWR

	Model for ΔWTR_t		Model for ΔAWR_t	
Regressor	**Coefficient**	***t*-Value**	**Coefficient**	***t*-Value**
Intercept	–0.00001	–0.02	0.00014	0.39
$\hat{e}_{t-1}$	–0.00201	–1.02	–0.00567	–3.10***
ΔWTR_{t-1}	–0.01314	–0.73	–0.00487	–0.29
ΔAWR_{t-1}	0.01835	0.94	–0.06043	–3.34***

Panel C: Error correction between CTWS and AWR

	Model for $\Delta CTWS_t$		Model for ΔAWR_t	
Regressor	**Coefficient**	***t*-Value**	**Coefficient**	***t*-Value**
Intercept	–0.00007	–0.17	0.00014	0.39
$\hat{e}_{t-1}$	–0.00314	–1.63	–0.00585	–3.20***
$\Delta CTWS_{t-1}$	–0.22873	–13.12***	–0.01083	–0.65
ΔAWR_{t-1}	0.03732	1.98**	–0.05842	–3.26***

Note: Estimates of the parameters and t-Values of the error correction model for Equations (4a and 4b) for each pair. Coefficients measure the speed with which the system moves toward its equilibrium relation in the long run. Statistically significant negative error term coefficients imply a restoration of the equilibrium relation in the long run. The sample period is from January 2000 to December 2008.

***, *** denote statistical significance at 5% and 1% levels respectively.*

TRADING RULE

In this section, as we establish the trading rule, only the equations for the pair consisting of CTWS with WTR will be presented. Equations for pairs WTR with AWR, and CTWS with AWR can be interpreted analogously.

To initiate our trading strategy, we first estimate the relation between CTWS and WTR over a three-year period from January 1, 1997, through December 31, 1999, using the following regression:

$$\log WTR = \alpha + \beta_1(\log CTWS) + \varepsilon \qquad (6)$$

From this regression we retain $\hat{\alpha}$, $\hat{\beta}_1$, and the standard deviation of the residual (σ_ε). Assuming this relation is maintained for the following nine years of trading, we estimate a fitted value for log WTR as follows:

$$(\log \hat{W}TR) = \hat{\alpha} + \hat{\beta}_1(\log CTWS) \tag{7}$$

Based on our estimate for the fitted value for log WTR, we determine the difference between this fitted value and the actual value:

$$\text{Diff} = \log WTR - (\log \hat{W}TR) \tag{8}$$

Next, we predetermine an upper and lower divergence threshold, measured in terms of the number of standard deviations from zero, which is used to initiate trading.

$$\textit{UpperBound} = \text{Positive Multiple of } (\sigma_\varepsilon)$$

$$\textit{LowerBound} = \text{Negative Multiple of } (\sigma_\varepsilon)$$

where multiples are set at 0.25, 0.50, and 0.75.

For simplicity, we assume that regardless of the two possible positions in each security (Long CTWS and Short WTR or Short CTWS and Long WTR), that 1,000 shares of the higher priced security (that changes through time) are bought, and the corresponding number of lower priced shares that are sold short is based upon the number that allows for dollar neutrality. So, if at the moment a trade is to occur CTWS is priced higher than WTR, then the number of WTR shares to short will be based on the result from Equation (9a). However, if at that moment WTR is priced higher than CTWS, then the number of CTWS shares to short will be based on the result from Equation (9b).

$$\text{WTR\_shares} = 1{,}000 * \left(\frac{\text{CTWS\_price}}{\text{WTR\_price}}\right) \tag{9a}$$

$$\text{CTWS\_shares} = 1{,}000 * \left(\frac{\text{WTR\_price}}{\text{CTWS\_price}}\right) \tag{9b}$$

While a degree of rounding might be required, depending on lot size restrictions, this ratio will determine the relation that should exist between the two position sizes to achieve dollar neutrality.

Limiting ourselves to only having a single position open at one time, we incorporate the following trading rule:

> If *Diff* < *LowerBound*, then short CTWS and simultaneously long WTR. Again, the number of shares for each security is the number that maintains dollar neutrality, and that relation depends on the market prices at the time of the transaction. This entire position is reversed once *Diff* reverts back up to zero. If a position is not closed out prior to December 31, 2008, then that position is not considered at all.
>
> If *Diff* > *UpperBound*, then long CTWS and simultaneously short WTR. Again, the number of shares for each security is the number that maintains dollar neutrality, and that relation depends on the market prices at the time of the transaction. This position is reversed once *Diff* reverts back down to zero. If a position is not closed out prior to December 31, 2008, then that position is not considered at all.[2]

Results: Overall Strategy Returns

A long-term relation between two price series implies that the two co-integrated prices move together through time, which means that any short-term disturbance from the long-run trend should be corrected. The absence of co-integration suggests an absence of a long-run relation, which implies, in principle, that the prices can wander arbitrarily far away from one another. With a co-integrated relation between two series, a pairs trading strategy can be expected to work.

Panel A of Exhibit 4a provides results from the trading simulations. Specifically, Panel A breaks down the number of trades generated for each of the three pairs at a trigger point of 0.25 standard deviations, as well as the cumulative nine-year returns associated with that threshold point.[3] The main point of the exhibit is to illustrate that the profits associated with the trading strategy are not solely derived from one of the possible positions irrespective of the chosen pair. As evidenced from the exhibit, regardless of the position taken, Long CTWS and Short WTR or Short CTWS and Long WTR, both sides yield comparable returns. For example, in the case of a pair consisting of CTWS with WTR, there are a total of 37 positions opened during the observed nine-year period. Nineteen of these positions are long WTR with simultaneously short CTWS, while the other 18 positions do the exact opposite. The average return for a position that is long WTR (CTWS) and short CTWS

EXHIBIT 4A
Overall Pairs Trading Strategy Returns Using 0.25 Standard Deviation Threshold

Panel A: Pairs trading returns

	37 Pairs: CTWS with WTR		25 Pairs: WTR with AWR		16 Pairs: CTWS with AWR	
	L_WTR, S_CTWS	L_CTWS, S_WTR	L_AWR, S_WTR	L_WTR, S_AWR	L_AWR, S_CTWS	L_CTWS, S_AWR
Count	19	18	13	12	7	9
Mean	6.14%	5.86%	5.33%	5.93%	8.91%	4.45%
Std. Dev.	6.05%	6.60%	6.52%	5.21%	5.81%	5.74%
Median	6.62%	4.92%	3.81%	6.05%	10.30%	6.23%
Max	15.95%	21.77%	21.29%	15.86%	15.62%	10.38%
Min	–8.34%	–6.52%	–2.30%	–3.64%	–0.46%	–6.82%
Position Total	116.58%	105.45%	69.26%	71.17%	62.40%	40.09%
Strategy Total		222.03%		140.43%		102.49%

Panel B: Length of round-trip position (in days)

	CTWS with WTR	WTR with AWR	CTWS with AWR
Count	37	25	16
Mean	38.86	42.56	60.13
Std. Dev.	76.27	87.76	107.91
Median	16.00	11.00	15.50
Max	376.00	436.00	438.00
Min	1.00	1.00	5.00

Note: Trading statistics and portfolio composition of pair formed over a three-year period and then traded over the subsequent nine-year period. We trade according to the rule that opens a position when the prices of the stocks in the pair diverge by 0.25 (0.50, 0.75) historical standard deviations and close that position when that divergence returns to zero. If a position is not closed out by December 31, 2008, then that position is not considered. The "L" indicates a long position, and "S" indicates a short position. The estimation period is from January 1, 1997, through December 31, 1999. The trading period is from January 1, 2000, through December 31, 2008. The following three pairs are constructed: CTWS with WTR, WTR with AWR, and CTWS with AWR. Exhibits 4b and 4c, which include results for 0.50 and 0.75 standard deviation thresholds, respectively, are included in the appendix.

(WTR) is 6.14% (5.86%) per roundtrip. When the 19 (18) positions of this kind are summed up, the nine-year cumulative total return is 116.58% (105.45%). When all 37 positions are considered, the nine-year cumulative round-trip return is 222.03%, which corresponds to an average annual return of 24.67%. As evidenced in Exhibits 4b and 4c (located in the appendix), as the trigger points widen, fewer trades are generated; however, the average return per round trip grows, and the overall strategy remains profitable.

Panel B of Exhibit 4a provides summary statistics on the number of days a position is open for each of the three different pairs. In the case of a pair consisting of CTWS with WTR, we open 37 positions that are maintained for an average of 38.86 days, with the longest position being open for 376 days, while the shortest is only open for 1 day. Again, as we widen the threshold points, we open fewer positions that are maintained for a longer period of time.

Results: Overall Strategy Return Differential (Positive vs. Negative)

Despite the fact that the average return for the 37 positions is positive, we are next interested in learning how many times we experience a negative return, and how damaging those negative returns are to the overall performance of the strategy. Exhibit 5a drills down into the results a bit further to tell this story. Of the overall 37 positions, 19 of them go long WTR and short CTWS. Exhibit 5a shows that of those 19 positions, 17 experience a positive return and the remaining two have a negative return. The exhibit goes on to show the summary statistics, on both the positive and negative side, per round-trip transaction. Recall from Exhibit 4a that these 19 positions have an overall nine-year return of 116.58%. Exhibit 5a illustrates how that return is broken up, and shows that the 17 positive returns are responsible for 129.19%, whereas the two negative returns are responsible for -12.62%, for a cumulative net return of 116.58%.

Exhibit 5a

Positive versus Negative Return Differential by Position Using 0.25 Standard Deviation Threshold

Panel A: CTWS with WTR (37 Pairs)

	Long WTR & Short CTWS		Long CTWS & Short WTR	
	+ Return	– Return	+ Return	– Return
Count	17	2	15	3
Mean	7.60%	–6.31%	7.56%	–2.67%
Std. Dev.	4.37%	2.88%	5.71%	3.35%
Median	7.31%	–6.31%	6.32%	–1.09%
Max	15.95%	–4.27%	21.77%	–0.39%
Min	1.40%	–8.34%	0.28%	–6.52%
Total (+, –)	129.19%	–12.62%	113.45%	–8.00%
Position Total		116.58%		105.45%
Strategy Total				222.03%

Panel B: WTR with AWR (25 Pairs)

	Long AWR & Short WTR		Long WTR & Short AWR	
	+ Return	– Return	+ Return	– Return
Count	10	3	11	1
Mean	7.46%	–1.77%	6.80%	–3.64%
Std. Dev.	5.90%	0.56%	4.45%	0.00%
Median	5.12%	–1.83%	6.11%	–3.64%
Max	21.29%	–1.18%	15.86%	–3.64%
Min	1.84%	–2.30%	0.25%	–3.64%
Total (+, –)	74.57%	–5.31%	74.81%	–3.64%
Position Total		69.26%		71.17%
Strategy Total				140.43%

Panel C: CTWS with AWR (16 Pairs)

	Long AWR & Short CTWS		Long CTWS & Short AWR	
	+ Return	– Return	+ Return	– Return
Count	6	1	7	2
Mean	10.48%	–0.46%	6.71%	–3.45%
Std. Dev.	4.48%	0.00%	3.66%	4.76%
Median	10.96%	–0.46%	6.55%	–3.45%
Max	15.62%	–0.46%	10.38%	–0.08%
Min	3.52%	–0.46%	0.32%	–6.82%
Total (+, –)	62.86%	–0.46%	46.98%	–6.90%
Position Total		62.40%		40.09%
Strategy Total				102.49%

Note: Strategy return differential of pair formed over a three-year period, and then traded over the subsequent nine-year period. The "+" indicates a positive return, and "–" indicates a negative return. The estimation period is from January 1, 1997, through December 31, 1999. The trading period is from January 1, 2000, through December 31, 2008. The following three pairs are constructed: CTWS with WTR, WTR with AWR, and CTWS with AWR. Exhibits 5b and 5c, which include results for 0.50 and 0.75 standard deviation thresholds respectively, are included in the appendix.

However, the story is not complete until we analyze the remaining 18 of the original 37 positions, which do the exact opposite of the first 19. In these, we short WTR and go long CTWS. Exhibit 5a also shows that of those 18 positions, 15 experience a positive return and the remaining three have a negative return. Again recall from Exhibit 4a that the cumulative nine-year return from these 18 positions is 105.45%. Exhibit 5a shows that the 15 positive returns are responsible for 113.45%, whereas the three negative returns are responsible for -8.00%, for a cumulative net return of 105.45%.

Summing things up, in the case of the pair consisting of CTWS with WTR, our pairs trading strategy initiates 37 positions over a nine-year period. Of those 37 positions, 19 go long WTR and short CTWS, whereas the remaining 18 go short WTR and long CTWS. Of the 37 combined round-trip transactions, 32 (86.49%) of them finish with a positive return totaling 242.64%. This equates to an average round-trip return of 7.58% when the strategy works in our favor. The remaining five (13.51%) round-trip transactions finish with a negative return, for a total of -20.62%. This equates to an average return of -4.12% when the strategy works against us. The 32 positive returns totaling 242.64% less the five negative returns totaling -20.62% yields a nine-year total net return of 222.03%, or an average annual return of 24.67%.

Panels B and C of Exhibit 5a show that the pairs trading strategy consistently generates more positive returns than negative returns, resulting in overall strategy returns of 140.43% in the case of the pair consisting of WTR and AWR and 102.49% in the case of the pair consisting of CTWS and AWR.

Results: Individual Security Returns

As Exhibit 4a shows, the profits from the trading strategy are not occurring simply on one of the two possible positions (long WTR and short CTWS or short WTR and long CTWS). Exhibit 6a, however, drills down yet another level on the 37 positions associated with a 0.25 standard deviation threshold. As evidenced by Exhibit 6a, although both positions each yield healthy returns, the returns appear to be derived mostly from the position, whether long or short, in WTR. Specifically, recall that of the original 37 positions, 19 of them are long WTR and short CTWS, and generate a return of 116.58%. Exhibit 6a looks more closely at that return and finds that 102.46% of the 116.58% is coming from the long position in WTR, whereas only 14.11% of the 116.58% is from the short position in CTWS.

On the other side of this same coin, the remaining 18 of the original 37 positions are short WTR and

EXHIBIT 6A

Individual Security Returns Using 0.25 Standard Deviation Threshold

	Panel A: CTWS with WTR (37 Pairs)				Panel B: WTR with AWR (25 Pairs)				Panel C: CTWS with AWR (16 Pairs)			
	L_WTR	S_CTWS	L_CTWS	S_WTR	L_AWR	S_WTR	L_WTR	S_AWR	L_AWR	S_CTWS	L_CTWS	S_AWR
Count	19	19	18	18	13	13	12	12	7	7	9	9
Mean	5.39%	0.74%	0.41%	5.45%	6.39%	–1.06%	–1.13%	7.06%	5.75%	3.17%	–2.38%	6.83%
Std. Dev.	1.62%	5.89%	5.17%	2.24%	4.65%	10.70%	7.46%	3.06%	0.94%	6.03%	7.39%	2.25%
Median	5.10%	0.72%	0.59%	4.86%	4.90%	–1.09%	–0.03%	5.63%	5.39%	4.65%	0.00%	6.43%
Max	7.91%	11.21%	12.82%	10.77%	15.98%	20.61%	10.30%	14.78%	6.97%	10.23%	4.82%	12.28%
Min	2.78%	–15.54%	–9.83%	3.32%	0.68%	–17.15%	–18.41%	4.51%	4.43%	–5.45%	–19.10%	4.90%
Security Total	102.46%	14.11%	7.33%	98.13%	83.01%	–13.75%	–13.55%	84.71%	40.22%	22.18%	–21.39%	61.48%
Position Total		116.58%		105.45%		69.26%		71.17%		62.40%		40.09%
Strategy Total				222.03%				140.43%				102.49%

Note: Individual security returns of pair formed over a three-year period, and then traded over the subsequent nine-year period. The "L" indicates a long position, and "S" indicates a short position. The estimation period is from January 1, 1997, through December 31, 1999. The trading period is from January 1, 2000, through December 31, 2008. The following three pairs are constructed: CTWS with WTR, WTR with AWR, and CTWS with AWR. Exhibits 6b and 6c, which include results for 0.50 and 0.75 standard deviation thresholds respectively, are included in the appendix.

long CTWS, which is the exact opposite of the first 19 transactions. Again, Exhibit 6a shows that WTR is the driving force behind the overall return of 105.45%. The results show that 98.13% of the 105.45% is derived from the short position in WTR, whereas only 7.33% is from the long position in CTWS.

This result is intriguing because Exhibit 3 notes that WTR responds to the relation disequilibrium, while CTWS does not. Stated differently, disequilibrium occurs due to an independent movement of CTWS, which is ultimately restored by a WTR response. As the trading strategy goes, we are not able to foresee the movement of CTWS; however, that move generates a predictable Granger-caused response from WTR, which the trading strategy is capitalizing on, regardless of whether we are long or short WTR.

The story surrounding the explanation of the strategy's returns becomes even more intriguing when you analyze the other two constructed pairs, whose results also appear in Exhibit 6a. In both of the other two cases, the lion's share of the returns is coming from only one of the two securities within the pair. As was the case with the first pair (CTWS with WTR), the majority of returns from the two remaining pairs are also coming from the security that Exhibit 3 labels as the Granger follower. It is worth noting that CTWS is labeled as the Granger leader in both pairs it is a part of. The results from Exhibit 6a show that in neither of those pairs is CTWS the security responsible for the majority of the returns. Conversely, Exhibit 3 labels AWR as the Granger follower in both of its constructed pairs. Here, Exhibit 6a shows that AWR is in fact the security that is responsible for the bulk of the returns in both of its pairs. WTR, on the other hand, is unique in the fact that Exhibit 3 labels it as the Granger follower when paired with CTWS, but the Granger leader when paired with AWR. True to form, Exhibit 6a shows that WTR is only responsible for the vast amount of a pair's returns only when it is the Granger follower in that pair.

Results: Individual Security Return Differential (Positive vs. Negative)

The final layer of analysis regarding the source of the overall returns is conducted in Exhibit 7a. In pairs trading, the purpose of simultaneously going long in one security while shorting the other is to neutralize much of the systematic risk. However, if movement in the Granger leader is generating a predictable response from the Granger follower, then it is fair to assume that when looked at individually, a long or short position in the Granger follower should perform better than the corresponding short or long position in the Granger leader. Exhibit 7a views the positions for the three constructed pairs under the 0.25 standard deviation threshold point to analyze this matter.

Exhibit 7a differentiates performance by security, position (short or long), and by return (positive or negative). The main take away from Exhibit 7a is how often we are on the correct side of the transaction with regard to the Granger follower versus how many times we are on the correct side of the transaction with regard to the Granger

EXHIBIT 7A

Positive versus Negative Return Differential by Security Using 0.25 Standard Deviation Threshold

Panel A: CTWS with WTR (37 Pairs)

	19–Long WTR & Short CTWS				18–Long CTWS & Short WTR			
	+L_WTR	–L_WTR	+S_CTWS	–S_CTWS	+L_CTWS	–L_CTWS	+S_WTR	–S_WTR
Count	19	–	10	9	11	7	18	–
Mean	5.39%	0.00%	4.58%	–3.52%	3.31%	–4.16%	5.45%	0.00%
Std. Dev.	1.62%	0.00%	3.60%	4.97%	4.02%	3.01%	2.24%	0.00%
Median	5.10%	0.00%	3.96%	–1.54%	2.39%	–3.64%	4.86%	0.00%
Max	7.91%	0.00%	11.21%	–0.12%	12.82%	–1.38%	10.77%	0.00%
Min	2.78%	0.00%	0.72%	–15.54%	0.21%	–9.83%	3.32%	0.00%
Total (+, –)	102.46%	0.00%	45.83%	–31.71%	36.42%	–29.09%	98.13%	0.00%
Security Total		102.46%		14.11%		7.33%		98.13%
Position Total				116.58%				105.45%
Strategy Total								222.03%

Panel B: WTR with AWR (25 Pairs)

	13–Long AWR & Short WTR				12–Long WTR & Short AWR			
	+L_AWR	–L_AWR	+S_WTR	–S_WTR	+L_WTR	–L_WTR	+S_AWR	–S_AWR
Count	13	–	5	8	6	6	12	–
Mean	6.39%	0.00%	9.61%	–7.73%	3.83%	–6.09%	7.06%	0.00%
Std. Dev.	4.65%	0.00%	6.57%	6.27%	4.07%	6.84%	3.06%	0.00%
Median	4.90%	0.00%	8.55%	–6.40%	1.88%	–3.71%	5.63%	0.00%
Max	15.98%	0.00%	20.61%	–0.38%	10.30%	–0.33%	14.78%	0.00%
Min	0.68%	0.00%	2.90%	–17.15%	0.27%	–18.41%	4.51%	0.00%
Total (+, –)	83.01%	0.00%	48.07%	–61.82%	23.01%	–36.55%	84.71%	0.00%
Security Total		83.01%		–13.75%		–13.55%		84.71%
Position Total				69.26%				71.17%
Strategy Total								140.43%

Panel C: CTWS with AWR (16 Pairs)

	7–Long AWR & Short CTWS				9–Long CTWS & Short AWR			
	+L_AWR	–L_AWR	+S_CTWS	–S_CTWS	+L_CTWS	–L_CTWS	+S_AWR	–S_AWR
Count	7	–	5	2	4	5	9	–
Mean	5.75%	0.00%	6.13%	–4.24%	2.74%	–8.08%	6.83%	0.00%
Std. Dev.	0.94%	0.00%	3.92%	1.71%	1.89%	7.86%	2.25%	0.00%
Median	5.39%	0.00%	4.91%	–4.24%	2.94%	–6.19%	6.43%	0.00%
Max	6.97%	0.00%	10.23%	–3.02%	4.82%	–0.85%	12.28%	0.00%
Min	4.43%	0.00%	0.95%	–5.45%	0.24%	–19.10%	4.90%	0.00%
Total (+, –)	40.22%	0.00%	30.65%	–8.47%	10.95%	–32.34%	61.48%	0.00%
Security Total		40.22%		22.18%		–21.39%		61.48%
Position Total				62.40%				40.09%

Note: Individual security return differential of pair formed over a three-year period and then traded over the subsequent nine-year period. The "L" indicates a long position, and "S" indicates a short position. The "+" indicates a positive return, and "–" indicates a negative return. The estimation period is from January 1, 1997, through December 31, 1999. The trading period is from January 1, 2000, through December 31, 2008. The following three pairs are constructed: CTWS with WTR, WTR with AWR, and CTWS with AWR. Exhibits 7b and 7c, which include results for 0.50 and 0.75 standard deviation thresholds respectively, are included in the appendix.

leader. We begin our analysis in Panel A of Exhibit 7a. Recall that of the original 37 positions, 19 of them are long WTR and short CTWS. The next issue to address is how the 19 long positions in WTR perform relative to the corresponding 19 short positions in CTWS. The results show that, of the 19 long positions in WTR, 19 of the round-trip transactions result in positive returns, whereas zero result in a negative return. Conversely, the 19 short positions in CTWS result in 10 positive and 9 negative returns.

The consistency of these results persists when we look at the remaining 18 positions in which we are short WTR and long CTWS. Notice again that the number of times in which we are on the correct side of WTR dominates the number of times we are not. However, this dominance does not exist when we analyze CTWS.

Summarizing the findings of Panel A, we see that over a nine-year period we take a total of 37 positions in WTR, 19 long and 18 short. Of those 37 positions, every single one of them yields a positive return for a combined total of 200.59%. Conversely, of the 37 corresponding positions in CTWS, 21 of them yield a positive return for a combined total of 82.25%, whereas the remaining 16 yield negative returns totaling -60.81%. This translates into a combined net return of 21.44% from CTWS.

When we turn our attention to the two other pairs in Panels B and C, we see that this story continues to hold. When all possible pairs are considered, we open a combined total of 78 positions over a nine-year period. Of those 78 positions, we never experience a negative return from the Granger follower, regardless of whether we happen to be long or short in that particular security. On the other hand, we experience a positive return 41 times and a negative return 37 times with our position in the Granger leader, regardless of whether we are long or short in that particular security.

With regard to the Granger follower, the fact that the bulk of the strategy's return is coming from it, coupled with the regularity with which we are able to be on the correct side of the transaction (long or short), points to the idea that we are able to consistently anticipate the direction that the Granger follower will take in order to restore an equilibrium between itself and the Granger leader, whenever that relation is disrupted.

CONCLUDING REMARKS

This study shows that the profitability of the strategy hinges on a co-integrated relation, which Engle and Granger [1987] showed also implies an error-correcting relation. Simply stated, the most important feature of arbitrage, particularly in terms of how it relates to pairs trading, is the convergence of a temporary pricing flaw back to its expected values. The results of this study show that although a trader might not be able to foresee the movement of the co-integrating leader, that move generates a predictable response from the co-integrating follower, which the pairs trading strategy is able to capitalize on and profit from.

APPENDIX

EXHIBIT 4B
Overall Pairs Trading Strategy Returns Using 0.50 Standard Deviation Threshold

Panel A: Pairs trading returns

	29 Pairs: CTWS with WTR		13 Pairs: WTR with AWR		8 Pairs: CTWS with AWR	
	L_WTR, S_CTWS	L_CTWS, S_WTR	L_AWR, S_WTR	L_WTR, S_AWR	L_AWR, S_CTWS	L_CTWS, S_AWR
Count	11	18	8	5	4	4
Mean	7.57%	7.84%	8.00%	8.43%	14.45%	5.70%
Std. Dev.	6.79%	7.67%	4.18%	6.31%	1.72%	8.09%
Median	7.08%	7.60%	6.96%	9.16%	13.91%	8.75%
Max	19.18%	22.70%	15.89%	14.61%	16.94%	11.28%
Min	–8.34%	–12.28%	4.23%	–1.03%	13.04%	–5.97%
Position Total	83.29%	141.07%	63.98%	42.16%	57.80%	22.82%
Strategy Total		224.36%		106.14%		80.62%

Panel B: Length of round-trip position (in days)

	CTWS with WTR	WTR with AWR	CTWS with AWR
Count	29	13	8
Mean	50.00	67.38	98.13
Std. Dev.	82.75	114.25	139.78
Median	15.00	37.00	57.50
Max	356.00	435.00	436.00
Min	4.00	4.00	8.00

EXHIBIT 4C

Overall Pairs Trading Strategy Returns Using 0.75 Standard Deviation Threshold

Panel A: Pairs trading returns

	15 Pairs: CTWS with WTR		7 Pairs: WTR with AWR		6 Pairs: CTWS with AWR	
	L_WTR, S_CTWS	L_CTWS, S_ WTR	L_AWR, S_WTR	L_WTR, S_ AWR	L_AWR, S_CTWS	L_CTWS, S_ AWR
Count	5	10	4	3	3	3
Mean	7.09%	9.13%	11.70%	9.80%	17.81%	9.44%
Std. Dev.	12.27%	12.56%	4.64%	7.99%	0.73%	7.94%
Median	8.62%	10.87%	9.72%	7.78%	17.85%	13.31%
Max	22.42%	23.81%	18.56%	18.61%	18.52%	14.72%
Min	–11.69%	–20.66%	8.78%	3.02%	17.06%	0.31%
Position Total	35.47%	91.29%	46.79%	29.40%	53.43%	28.33%
Strategy Total		126.76%		76.19%		81.76%

Panel B: Length of round-trip position (in days)

	CTWS with WTR	WTR with AWR	CTWS with AWR
Count	15	7	6
Mean	76.53	103.57	107.83
Std. Dev.	102.03	146.79	161.24
Median	14.00	55.00	47.00
Max	343.00	433.00	433.00
Min	5.00	13.00	6.00

EXHIBIT 5B

Positive versus Negative Return Differential Using 0.50 Standard Deviation Threshold

Panel A: CTWS with WTR (29 Pairs)

	Long WTR & Short CTWS		Long CTWS & Short WTR	
	+ Return	– Return	+ Return	– Return
Count	10	1	17	1
Mean	9.16%	–8.34%	9.02%	–12.28%
Std. Dev.	4.50%	0.00%	5.98%	0.00%
Median	7.75%	–8.34%	7.85%	–12.28%
Max	19.18%	–8.34%	22.70%	–12.28%
Min	4.20%	–8.34%	0.12%	–12.28%
Total (+, –)	91.63%	–8.34%	153.35%	–12.28%
Position Total		83.29%		141.07%
Strategy Total				224.36%

Panel B: WTR with AWR (13 Pairs)

	Long AWR & Short WTR		Long WTR & Short AWR	
	+ Return	– Return	+ Return	– Return
Count	8	–	4	1
Mean	8.00%	0.00%	10.80%	–1.03%
Std. Dev.	4.18%	0.00%	3.98%	0.00%
Median	6.96%	0.00%	11.30%	–1.03%
Max	15.89%	0.00%	14.61%	–1.03%
Min	4.23%	0.00%	5.98%	–1.03%
Total (+, –)	63.98%	0.00%	43.19%	–1.03%
Position Total		63.98%		42.16%
Strategy Total				106.14%

Panel C: CTWS with AWR (8 Pairs)

	Long AWR & Short CTWS		Long CTWS & Short AWR	
	+ Return	– Return	+ Return	– Return
Count	4	–	3	1
Mean	14.45%	0.00%	9.59%	–5.97%
Std. Dev.	1.72%	0.00%	2.70%	0.00%
Median	13.91%	0.00%	11.03%	–5.97%
Max	16.94%	0.00%	11.28%	–5.97%
Min	13.04%	0.00%	6.47%	–5.97%
Total (+, –)	57.80%	0.00%	28.78%	–5.97%
Position Total		57.80%		22.82%
Strategy Total				80.62%

EXHIBIT 5C

Positive versus Negative Return Differential Using 0.75 Standard Deviation Threshold

Panel A: CTWS with WTR (15 Pairs)

	Long WTR & Short CTWS		Long CTWS & Short WTR	
	+ Return	– Return	+ Return	– Return
Count	4	1	9	1
Mean	11.79%	–11.69%	12.44%	–20.66%
Std. Dev.	7.33%	0.00%	7.37%	0.00%
Median	9.47%	–11.69%	13.14%	–20.66%
Max	22.42%	–11.69%	23.81%	–20.66%
Min	5.79%	–11.69%	2.34%	–20.66%
Total (+, –)	47.15%	–11.69%	111.96%	–20.66%
Position Total		35.47%		91.29%
Strategy Total				126.76%

Panel B: WTR with AWR (7 Pairs)

	Long AWR & Short WTR		Long WTR & Short AWR	
	+ Return	– Return	+ Return	– Return
Count	4	–	3	–
Mean	11.70%	0.00%	9.80%	0.00%
Std. Dev.	4.64%	0.00%	7.99%	0.00%
Median	9.72%	0.00%	7.78%	0.00%
Max	18.56%	0.00%	18.61%	0.00%
Min	8.78%	0.00%	3.02%	0.00%
Total (+, –)	46.79%	0.00%	29.40%	0.00%
Position Total		46.79%		29.40%
Strategy Total				76.19%

Panel C: CTWS with AWR (6 Pairs)

	Long AWR & Short CTWS		Long CTWS & Short AWR	
	+ Return	– Return	+ Return	– Return
Count	3	–	3	–
Mean	17.81%	0.00%	9.44%	0.00%
Std. Dev.	0.73%	0.00%	7.94%	0.00%
Median	17.85%	0.00%	13.31%	0.00%
Max	18.52%	0.00%	14.72%	0.00%
Min	17.06%	0.00%	0.31%	0.00%
Total (+, –)	53.43%	0.00%	28.33%	0.00%
Position Total		53.43%		28.33%
Strategy Total				81.76%

EXHIBIT 6B
Individual Security Returns Using 0.50 Standard Deviation Threshold

	Panel A: CTWS with WTR (29 Pairs)				Panel B: WTR with AWR (13 Pairs)				Panel C: CTWS with AWR (8 Pairs)			
	L_WTR	S_CTWS	L_CTWS	S_WTR	L_AWR	S_WTR	L_WTR	S_AWR	L_AWR	S_CTWS	L_CTWS	S_AWR
Count	11	11	18	18	8	8	5	5	4	4	4	4
Mean	7.69%	–0.12%	–0.78%	8.62%	10.54%	–2.54%	–1.55%	9.98%	9.66%	4.79%	–5.04%	10.74%
Std. Dev.	0.91%	6.30%	6.27%	3.39%	3.02%	6.65%	9.93%	4.11%	1.49%	2.58%	10.69%	2.70%
Median	7.68%	0.55%	–0.61%	7.70%	11.42%	–5.25%	2.46%	10.09%	9.44%	5.14%	–0.78%	9.53%
Max	9.79%	9.39%	11.56%	19.89%	13.77%	11.75%	7.44%	16.33%	11.68%	7.52%	2.14%	14.78%
Min	6.36%	–15.54%	–17.98%	5.70%	4.13%	–8.69%	–17.36%	6.00%	8.09%	1.36%	–20.74%	9.14%
Security Total	84.57%	–1.28%	–14.04%	155.11%	84.33%	–20.35%	–7.73%	49.89%	38.64%	19.16%	–20.15%	42.97%
Position Total		83.29%		141.07%		63.98%		42.16%		57.80%		22.82%
Strategy Total				224.36%				106.14%				80.62%

EXHIBIT 6C
Individual Security Returns Using 0.75 Standard Deviation Threshold

	Panel A: CTWS with WTR (15 Pairs)				Panel B: WTR with AWR (7 Pairs)				Panel C: CTWS with AWR (6 Pairs)			
	L_WTR	S_CTWS	L_CTWS	S_WTR	L_AWR	S_WTR	L_WTR	S_AWR	L_AWR	S_CTWS	L_CTWS	S_AWR
Count	5	5	10	10	4	4	3	3	3	3	3	3
Mean	10.39%	–3.30%	–2.83%	11.96%	13.63%	–1.93%	–6.61%	16.41%	16.26%	1.55%	–6.17%	15.62%
Std. Dev.	1.59%	11.36%	10.27%	4.36%	6.18%	10.39%	13.21%	5.22%	2.67%	2.84%	12.28%	4.35%
Median	9.44%	–0.83%	–0.95%	10.56%	14.99%	–6.13%	–10.24%	18.02%	15.15%	1.91%	0.23%	13.13%
Max	12.67%	9.75%	8.11%	22.77%	19.30%	13.31%	8.03%	20.64%	19.30%	4.20%	1.59%	20.64%
Min	9.08%	–21.00%	–28.70%	8.03%	5.25%	–8.78%	–17.62%	10.58%	14.32%	–1.46%	–20.33%	13.08%
Security Total	51.97%	–16.50%	–28.31%	119.60%	54.52%	–7.74%	–19.83%	49.24%	48.78%	4.65%	–18.52%	46.85%
Position Total		35.47%		91.29%		46.79%		29.40%		53.43%		28.33%
Strategy Total				126.76%				76.19%				81.76%

EXHIBIT 7B
Positive versus Negative Return Differential by Security Using 0.50 Standard Deviation Threshold

Panel A: CTWS with WTR (29 Pairs)

	11–Long WTR & Short CTWS				18–Long CTWS & Short WTR			
	+L_WTR	–L_WTR	+S_CTWS	–S_CTWS	+L_CTWS	–L_CTWS	+S_WTR	–S_WTR
Count	11	–	6	5	8	10	18	–
Mean	7.69%	0.00%	3.60%	–4.57%	3.59%	–4.28%	8.62%	0.00%
Std. Dev.	0.91%	0.00%	3.41%	6.26%	1.01%	5.59%	3.39%	0.00%
Median	7.68%	0.00%	2.40%	–2.06%	2.66%	–1.28%	7.70%	0.00%
Max	9.79%	0.00%	9.39%	–0.63%	11.56%	–0.40%	19.89%	0.00%
Min	6.36%	0.00%	0.55%	–15.54%	0.05%	–17.98%	5.70%	0.00%
Total (+, –)	84.57%	0.00%	21.59%	–22.87%	28.73%	–42.77%	155.11%	0.00%
Security Total		84.57%		–1.28%		–14.04%		155.11%
Position Total				83.29%				141.07%
Strategy Total								224.36%

Panel B: WTR with AWR (13 Pairs)

	8–Long AWR & Short WTR				5–Long WTR & Short AWR			
	+L_AWR	–L_AWR	+S_WTR	–S_WTR	+L_WTR	–L_WTR	+S_AWR	–S_AWR
Count	8	–	2	6	3	2	5	–
Mean	10.54%	0.00%	6.54%	–5.57%	4.81%	–11.07%	9.98%	0.00%
Std. Dev.	3.02%	0.00%	7.38%	2.65%	2.51%	8.89%	4.11%	0.00%
Median	11.42%	0.00%	6.54%	–6.01%	4.52%	–11.07%	10.09%	0.00%
Max	13.77%	0.00%	11.75%	–0.98%	7.44%	–4.79%	16.33%	0.00%
Min	4.13%	0.00%	1.32%	–8.69%	2.46%	–17.36%	6.00%	0.00%
Total (+, –)	84.33%	0.00%	13.07%	–33.43%	14.42%	–22.15%	49.89%	0.00%
Security Total		84.33%		–20.35%		–7.73%		49.89%
Position Total				63.98%				42.16%
Strategy Total								106.14%

Exhibit 7B (continued)

Panel C: CTWS with AWR (8 Pairs)

	4–Long AWR & Short CTWS				4–Long CTWS & Short AWR			
	+ L_AWR	– L_AWR	+ S_CTWS	– S_CTWS	+ L_CTWS	– L_CTWS	+ S_AWR	– S_AWR
Count	4	–	4	–	2	2	4	–
Mean	9.66%	0.00%	4.79%	0.00%	1.69%	–11.77%	10.74%	0.00%
Std. Dev.	1.49%	0.00%	2.58%	0.00%	0.63%	12.69%	2.70%	0.00%
Median	9.44%	0.00%	5.14%	0.00%	1.69%	–11.77%	9.53%	0.00%
Max	11.68%	0.00%	7.52%	0.00%	2.14%	–2.80%	14.78%	0.00%
Min	8.09%	0.00%	1.36%	0.00%	1.25%	–20.74%	9.14%	0.00%
Total (+, –)	38.64%	0.00%	19.16%	0.00%	3.39%	–23.54%	42.97%	0.00%
Security Total		38.64%		19.16%		–20.15%		42.97%
Position Total				57.80%				22.82%

Exhibit 7C

Positive versus Negative Return Differential by Security Using 0.75 Standard Deviation Threshold

Panel A: CTWS with WTR (15 Pairs)

	5–Long WTR & Short CTWS				10–Long CTWS & Short WTR			
	+ L_WTR	– L_WTR	+ S_CTWS	– S_CTWS	+ L_CTWS	– L_CTWS	+ S_WTR	– S_WTR
Count	5	–	2	3	4	6	10	–
Mean	10.39%	0.00%	5.50%	–9.16%	4.29%	–7.58%	11.96%	0.00%
Std. Dev.	1.59%	0.00%	6.01%	10.53%	3.01%	10.80%	4.36%	0.00%
Median	9.44%	0.00%	5.50%	–5.67%	4.00%	–2.92%	10.56%	0.00%
Max	12.67%	0.00%	9.75%	–0.83%	8.11%	–0.78%	22.77%	0.00%
Min	9.08%	0.00%	1.25%	–21.00%	1.04%	–28.70%	8.03%	0.00%
Total (+, –)	51.97%	0.00%	10.99%	–27.49%	17.15%	–45.46%	119.60%	0.00%
Security Total		51.97%		–16.50%		–28.31%		119.60%
Position Total				35.47%				91.29%
Strategy Total								126.76%

Panel B: WTR with AWR (7 Pairs)

	4–Long AWR & Short WTR				3–Long WTR & Short AWR			
	+ L_AWR	– L_AWR	+ S_WTR	– S_WTR	+ L_WTR	– L_WTR	+ S_AWR	– S_AWR
Count	4	–	1	3	1	2	3	–
Mean	13.63%	0.00%	13.31%	–7.02%	8.03%	–13.93%	16.41%	0.00%
Std. Dev.	6.18%	0.00%	0.00%	2.62%	0.00%	5.22%	5.22%	0.00%
Median	14.99%	0.00%	13.31%	–8.26%	8.03%	–13.93%	18.02%	0.00%
Max	19.30%	0.00%	13.31%	–4.01%	8.03%	–10.24%	20.64%	0.00%
Min	5.25%	0.00%	13.31%	–8.78%	8.03%	–17.62%	10.58%	0.00%
Total (+, –)	54.52%	0.00%	13.31%	–21.05%	8.03%	–27.86%	49.24%	0.00%
Security Total		54.52%		–7.74%		–19.83%		49.24%
Position Total				46.79%				29.40%
Strategy Total								76.19%

Panel C: CTWS with AWR (6 Pairs)

	3–Long AWR & Short CTWS				3–Long CTWS & Short AWR			
	+ L_AWR	– L_AWR	+ S_CTWS	– S_CTWS	+ L_CTWS	– L_CTWS	+ S_AWR	– S_AWR
Count	3	–	2	1	2	1	3	–
Mean	16.26%	0.00%	3.05%	–1.46%	0.91%	–20.33%	15.62%	0.00%
Std. Dev.	2.67%	0.00%	1.62%	0.00%	0.96%	0.00%	4.35%	0.00%
Median	15.15%	0.00%	3.05%	–1.46%	0.91%	–20.33%	13.13%	0.00%
Max	19.30%	0.00%	4.20%	–1.46%	1.59%	–20.33%	20.64%	0.00%
Min	14.32%	0.00%	1.91%	–1.46%	0.23%	–20.33%	13.08%	0.00%
Total (+, –)	48.78%	0.00%	6.11%	–1.46%	1.81%	–20.33%	46.85%	0.00%
Security Total		48.78%		4.65%		–18.52%		46.85%
Position Total				53.43%				28.33%

ENDNOTES

[1]In this context, the method used to choose the security pair differs from the GGR "matched pairs" procedure. GGR form their pairs using an entire universe of stocks by constructing a cumulative returns index for each stock and finding a pair that minimizes the sum of the squared deviations between the two normalized price series.

[2]To test the robustness of the results, the above procedure was duplicated using a rolling three-year estimation window to trade in the subsequent year. In this case, using standard deviation as a measure of volatility, upper and lower bounds adjust themselves to the prevailing volatility within the market. They widen during volatile market periods and contract during less volatile periods. Qualitatively, the results are unchanged using this approach as opposed to the base case approach.

[3]The results for the 0.50 and 0.75 standard deviation threshold points are available in the appendix.

REFERENCES

Andrade, S., V. Di Pietro, and M. Seasholes. "Understanding the Profitability of Pairs Trading." Working paper, UC Berkeley, 2005.

Dickey, D., and W. Fuller. "The Likelihood Ratio Statistics for Autoregressive Time Series With a Unit Root." *Econometrica*, 49 (1981), pp. 1057-1072.

Dwyer, G.P.J., P. Lock, and W. Yu. "Index Arbitrage and Nonlinear Dynamics Between the S&P500 Futures and Cash." *Review of Financial Studies*, 9 (1996), pp. 301-332.

Emery, G.W., and Q. Liu. "An Analysis of the Relationship Between Electricity and Natural Gas Futures Prices." *Journal of Futures Markets*, 22 (2002), pp. 95-122.

Engle, R.E., and C.W.J. Granger. "Cointegration and Error Correction: Representation, Estimation, and Testing." *Econometrica*, 55 (1987), pp. 251-276.

Gatev, E.G., W.N. Goetzmann, and K.G. Rouwenhorst. "Pairs Trading: Performance of a Relative Value Arbitrage Rule." *Review of Financial Studies*, 19 (2006), pp. 797-827.

Girma, P.B., and A.S. Paulson. "Risk Arbitrage Opportunities in Petroleum Futures Spreads." *Journal of Futures Markets*, 19 (1999), pp. 931-955.

Granger, C. "Some Properties of Time Series Data and Their Use in Econometric Model Specification." *Journal of Econometrics*, 16 (1981), pp. 121-130.

——. "Developments in the Study of Co-Integrated Economic Variables." *Oxford Bulletin of Economics and Statistics*, 48 (1986), pp. 213-228.

Granger, C., and P. Newbold. "Spurious Regressions in Econometrics." *Journal of Econometrics*, 2 (1974), pp. 111-120.

Johansen, S. "Statistical Analysis of Co-integration Vectors." *Journal of Economic Dynamics and Control*, 12 (1988), pp. 231-254.

——. "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models." *Econometrica*, 59 (1991), pp. 1551-1581.

Johnson, R.L., C.R. Zulauf, S.H. Irwin, and M.E. Gerlow. "The Soybean Complex Spread: An Examination of Market Efficiency from the Viewpoint of the Production Process." *Journal of Futures Markets*, 11 (1991), pp. 25-37.

Liu, Q. "Price Relations among Hog, Corn and Soybean Meal Futures." *Journal of Futures Markets*, 25 (2005), pp. 491-514.

MacKinnon, J. "Critical Values for Co-integration Tests." In *Long-Run Economic Relationships Readings in Cointegration*, edited by R. Engle and C. Granger, pp. 267-276. New York: Oxford University Press, 1991.

Papadakis, G., and P. Wysocki. "Pairs Trading and Accounting Information." Working paper, MIT, 2007.

Simon, D.P. "The Soybean Crush Spread: Empirical Evidence and Trading Strategies." *Journal of Futures Markets*, 19 (1999), pp. 271-289.

Tse, Y. "Index Arbitrage with Heterogeneous Investors: A Smooth Transition Error Correction Analysis." *Journal of Banking and Finance*, 25 (2001), pp. 1829–1855.

Vidyamurthy, G. *Pairs Trading, Quantitative Methods and Analysis*. New York: John Wiley & Sons, 2004.