Causality And Cointegration Of Currency-Adjusted Stock Indices: Evidence From Close-Of-Day Data

Terrance Jalbert, University of Hawaii at Hilo, USA

ABSTRACT

A recent line of research develops currency adjusted stock indices. These indices incorporate the effects of both stock value changes and underlying currency value changes to measure wealth changes. This paper extends the extant literature by examining time series properties of currency-adjusted indices. This research examines daily data for eight existing stock indexes and their currency adjusted counterparts for the period 1993-2013. The paper includes cointegration and Granger causality analyses. Results show cointegration between each combination of series examined. About half the pairwise index combinations display bidirectional Granger causality.

Keywords: Currency-Adjusted Stock Indices; Stock Indices; Cointegration; Wealth Changes; Currency Values

INTRODUCTION

A recent stream of research develops a new class of stock indexes (Jalbert, 2012, 2014, 2015a and 2015b). These new indexes control for changes in stock prices and changes in underlying currency values. These indexes represent an important advancement in wealth tracking. Many U.S. citizens live outside the U.S., but make investments in the United States. They convert their investment earnings into domicile country currency for consumption needs. The purchasing power of these individuals depends on the performance of their U.S. investments and the exchange rate at which the earnings convert to the domicile country currency. Currency adjusted indices measure the combined effect of stock and currency changes on the wealth of an individual.

Those living within the U.S. also have an interest in the currency-adjusted performance of their investments. U.S. residents planning to travel internationally have an interest in the international purchasing power of their investments. Still other U.S. residents purchase items manufactured internationally for domestic use. For example, an U.S. resident who wishes to purchase an asset such as a foreign designed and manufactured automobile. Currency adjusted indices provide a more revealing measure of the extent to which the individual is achieving their goals. While the Jalbert indices adjust only U.S. stock indices, the potential for currency-adjusted indices for other countries exists, further extending the interest in this line of research. Thus, currency adjusted indices and the analysis here has a broad appeal to individuals from many nations.

This paper examines time-series properties of currency adjusted stock indices. The paper examines end-of-day trading data. This work makes advances on the statistical sophistication of the examination. The paper utilizes cointegration analysis and Granger causality to provide more insights into the analysis. The remainder of the paper follows the standard organizational approach. The next section provides a review of the relevant literature. The following section provides a description of the data and methodology used in the paper. Next, the paper presents the empirical results. The paper closes with some concluding comments and suggestions for future research.

LITERATURE REVIEW

Jalbert (2012) first developed currency adjusted stock indexes. His indexes were based on day-end closing values of eight existing stock indexes for the period 1973-2011. He used Broad and Major currency indices as complied by

the United States Federal Reserve to develop his indexes. The Broad and Major currency indexes measure the U.S. dollar value against a basket of other currencies. Empirical examination of the currency adjusted index properties demonstrate a remarkable difference between raw stock index returns and currency value adjusted index returns. For example, in 1987, the Dow Jones Industrial Average produced a 2.236 percent return. However, the currency-adjusted version of the same index produced a -15.975 percent return. Similarly, in 2007, the Dow Jones Industrial Average produced a 20.409 percent return, but the currency-adjusted version of the index produced a 30.607 percent return. Moreover, he finds evidence that index return distributions differ from raw to adjusted indexes. Finally, he finds that currency value changes explain as much as 8.4 percent of wealth changes.

Jalbert (2014) utilized the Dollar Index (DXY) to control for U.S. dollar value. This index has the advantage of public awareness, intraday quotations and the availability of options and futures. His empirical analysis examines daily data from 1993-2013. The results are similar to Jalbert (2012). However, Jalbert (2014) finds that currency value changes explain a larger portion of wealth changes than previously identified. Jalbert (2015a) extends the analysis by examining intra-tick spreads. His data includes over one million tick-by-tick data observations for each of eight stock indices from 2002-2013. He finds significant deviations from symmetry among intra tick high and low values. His results show that dollar index changes explain as much as 15.41 percent of wealth changes. Jalbert (2015b) examined cointegration and causaility of currency-adjusted indexes using intra-day data from 2001-2013. His results show bidirectional cointegration between each index pair. Moreover, bidirectional Granger causality is evident in each pairwise index combination.

A large body of literature examines relationships between stock indexes. Huang, Yang and Hu (2000) examine causality and cointegration of stock indices from six countries. They compare the relative influence of Japanese and U.S. stock price changes on indexes from the South China region. Their results show that U.S. stock price changes exhibit a stronger influence on South China Region indices.

Heilman (2010) examines linkages between stock markets using cointegration analysis. In general his evidence does not support the existence of long-run relationships between the indices examined. He finds the U.S. market influences Asian markets both in the short- and long-run. His results are robust to evaluating the indices as converted to a common US dollar denomination. K G and Tiwari (2012) use cointegration analysis to examine indexes on the Bombay Stock Exchange. They examine data from 2004-2010 finding some level of cointegration between each index examined and another index. They argue their findings imply the Bombay stock exchange is not weak form efficient. Thuan (2011) looked for relationships between U.S. and Vietnam stock markets using daily data from 2003-2009. He finds no volatility effect of U.S. indexes on the Vietnam index.

Levy and Yagil (2013) examine the impact of changing methodologies for equity indexes on the Tel-Aviv Stock Exchange. The Tel Aviv stock exchange changed construction criteria for five of its indices in 2010. They question if changing the construction of an index positively impacts a stock exchange. Their results show that the reform increased index quality and reduced return volatility. However, the mean return remained the same.

Another line of literature examines the relationships between stock prices and exchange rates. Diamandis and Drakos (2011) examine data from 1980-2009 for four Latin American countries. They use cointegration and Granger causality analysis. They find positive linkages between exchange rates and stock markets that are independent of foreign exchange restrictions. Their finding show the U.S. stock market operates as a channel for these links. Thsagkanos and Siriopoulos (2013) also examine relationships between stock prices and exchange rates. They focus on European and U.S. stock prices from 2008-2012. They use a more advanced cointegration technique than previous papers, which allows for non-linear relationships. They find a causal relationship that runs from stock prices to exchange rates. Flores (2008) examined memory length in 34 exchange rates when examined against the U.S. dollar. He examines data from 1991-2006 finding that 17 of 34 exchange rates examined have a long memory. Shocks tend to persist in these markets for long periods.

Hammes and Willis (2005) argue that gold may be a better measure of asset value then currencies. They note that after expiration of the Brenton Woods agreement in the 1970's, the U.S. dollar value floated in value relative to other currencies. Nevertheless, oil prices remained denominated in U.S. Dollars. The authors contend the decline in dollar value relative to gold and other currencies created a situation where the oil price shock of the 1970's was a

rational equalizing response by market participants. The shock served to adjust the price of oil to a constant amount of gold. Unal and Korman (2012) examine the relationship between oil price movements and Turkish Stock Index (ISE 100) returns. They examine data from 1988-2011 divided into two subsample periods. They generally find a lack of dependence between oil prices and ISE 100 returns. They find negative oil price changes impact ISE 100 index returns more than positive price movements in more recent years.

DATA AND METHODOLOGY

This research uses the same end-of-day data as Jalbert, 2014. While the same dataset was used in each analysis, the two papers use different statistical techniques to examine the data. Jalbert, 2014 used regression analysis. In contrast, the current research uses cointegration and Granger causality analysis techniques. Jalbert, 2015b also uses cointegration and Granger causality techniqes. However Jalbert 2015b, used different starting indexes and examined intraday data.

Data were collected for analysis from EODData (www.eoddata.com). The examination utilizes close-of-day time-series data for eight stock indexes. This paper uses the Dollar Index (DXY), which started in March of 1973 with an initial value of 100, to currency value adjust the stock indexes. The data covers the time-period January 1, 1993 through April 12, 2013. Stock market indices examined include the Dow Jones Industrial Average (DJI), Dow Jones Transportation Index (DJT), Dow Jones Utilities Index (DJU), Standard and Poor's 500 (SP500), Russell 3000 (RUA), Russell 1000 (RUI), NASDAQ 100 (NDX) and NYSE Composite (NYA). Data preparation involved two processes. Dollar Index data includes Saturday trading. However, stock index data were not available on Saturday because the relevant markets are not open. Data synchronization involved removing Saturday data from the Dollar Index series and eliminating reported data on non-trading days from the stock index series. The final dataset includes nine series, each with 5,107 daily observations.

Calculating the Dollar Index adjusted series, DAI_t, involves individually modifying each existing stock index, EI_t, with Dollar Index information, DI_t. Equation 1 shows the computations:

$$DAI_t = EI_t * \frac{DI_t}{100} \quad (1)$$

Consider an unadjusted index with level 10,000 at close of day t. At time t, the Dollar Index equals 104. By Equation 1, the adjusted index level equals 10,400. Raw and adjusted indices equal when the Dollar index equals 100. When the Dollar index deviates from 100, the raw and adjusted indexes will not equal. When Dollar index levels exceeding 100, adjusted index levels exceed the raw index. Dollar index levels under 100 imply an adjusted index level lower than the corresponding raw index level. The Dollar index demonstrates considerable variation over time. The Index remained below unity before March 26, 1999 and after April 11, 2003 with levels below 100. The index exceeded 100 from March 26, 1999 through April 11, 2003.

This paper examines close-of-day index levels, changes and returns. Consider a stock index with level, $Index\ Level_t$ at time t. The index level at the previous observation point equals $Index\ Level_{t-1}$. Then, computation of index changes and continuously compounded returns follow Equations 2 and 3 respectively:

$$Index\ Change\ =\ Index\ Level_t - Index\ Level_{t-1} \quad (2)$$

$$Index\ Return\ =\ ln(\frac{Index\ Level_t}{Index\ Level_{t-1}}) \quad (3)$$

RESULTS

The data analysis begins by identifying the extent of stationarity in the series as measured by the presence of unit roots in the data. Identifying the presence of unit roots involves computing Augmented Dickey-Fuller statistics without an intercept term (Dickey and Fuller 1979 & 1981). Optimal lag length for the test is determined using the Shwartz (1978) Information Criteria method and is set to a maximum of 32 lags. Table 1, Panel A presents the results for index levels. The results indicate that, in level form, the data does not reject the presence of a unit root

for any of the series. However, in first difference form, the data rejects the presence of a unit root for each data series. Table 1, Panel B presents results for currency adjusted index returns. The results indicate rejection of the null hypothesis of a unit root in both level form and first difference form. A robustness check indicates the test produces similar results with or without the intercept term. Further robustness checks indicate the Phillips and Perron test for stationarity produces similar results (Philips 1987 and Phillips and Perron 1988).

Table 1. Unit Root Tests on Currency Adjusted Stock Indexes

Variable	Level Form			First Differences		
	Lag Length	T-Statistic	Prob.	Lag Length	T-Statistic	Prob.
Panel A. Index Levels						
Currency Adjusted DJIA	1	-1.7321	0.4150	0	-76.5329	0.0001***
Currency Adjusted DJ Transport	0	1.6546	0.4544	0	-72.4879	0.0001***
Currency Adjusted DJ Utilities	0	-1.5211	0.5230	0	-74.0684	0.0001***
Currency Adjusted NASDAQ 100	30	-1.8957	0.3518	29	-11.1344	0.0000***
Currency Adjusted NYSE Composite	1	-1.7785	0.3916	0	-76.1069	0.0001***
Currency Adjusted S&P 500	1	-1.7410	0.4104	0	-76.8470	0.0001***
Currency Adjusted Russell 3000	1	-1.7111	0.4256	0	-76.1184	0.0001***
Currency Adjusted Russell 1000	1	-1.7230	0.4196	0	-78.6392	0.0001***
Dollar Index	0	-1.3996	0.5841	0	-73.8939	0.0001***
Panel B. Index Returns						
Currency Adjusted DJIA	1	24.2343	0.0001***	28	-24.1887	0.0000***
Currency Adjusted DJ Transport	0	-72.0128	0.0001***	22	-27.9586	0.0000***
Currency Adjusted DJ Utilities	0	-75.1701	0.0001***	23	-25.7456	0.0000***
Currency Adjusted NASDAQ 100	1	-55.5489	0.0001***	28	-24.3791	0.0000***
Currency Adjusted NYSE Composite	1	-54.0736	0.0001***	27	-24.7213	0.0000***
Currency Adjusted S&P 500	1	-54.6547	0.0001***	28	-24.3085	0.0000***
Currency Adjusted Russell 3000	1	-54.3182	0.0001***	28	-24.3748	0.0000***
Currency Adjusted Russell 1000	0	-80.2383	0.0001***	27	-24.7178	0.0000***
Dollar Index	0	-73.7707	0.0001***	18	-28.9082	0.0000***

Note: This table shows results of Augmented Dickey-Fuller unit root tests on currency adjusted stock indexes.*** indicates significance at the one percent level.

Engle and Granger (1987) first developed cointegration techniques. Refinements include work by Johansen (1991). The analysis here involves conducting standard Johanson cointegration analysis. The mathematics associated with cointegration analysis appears in the literature ad nauseam. Thus, this paper does not provide a detailed discussion of the mathematics involved. Instead, the analysis proceeds directly to the test results. The analysis proceeds by conducting pairwise cointegration tests for each two-index combination. This research uses EViews Software for data analysis. The test specification uses intercept and trend in CE and intercept in VAR. The specification uses lag intervals of 1 4. Table 2 shows results for the end-of-day index level first differences. The results indicate two cointegrating equations for each pairwise combination. In each case the, at most one cointegrating relationship test, is rejected. Table 3 shows the Johanson cointegration analysis on currency adjusted daily index returns. The tests follow the same specifications as described above. Again, for each pairwise combination of indexes the results indicate two cointegrating equations at the 5 percent level.

Granger causality tests determine the extent and direction of causality between pairwise combinations (Granger 1969). The analysis here conducts Granger causality tests on each pairwise combination of adjusted indices, with provisions for up to ten lags. Table 4, Column 3 shows results of tests on currency adjusted index level first differences. The tests determine if Index 1 Granger causes Index 2 as indicated in the first two columns. The results show thirty significant Granger causality results from fifty-six tests conducted. These results differ from Jalbert (2015b), who found each series combination he examined displayed bi-directional causality. Twelve index pairs demonstrate bidirectional causality. The results reveal an interesting pattern. The adjusted indexes based on original Dow Jones indexes are at least one element of all combinations that demonstrate bidirectional causality. The Currency Adjusted Dow Jones Industrial Average shows bidirectional causality with four other indexes. The Currency Adjusted Dow Jones Utilities show bidirectional causality with all seven other indexes. The Currency Adjusted Dow Jones Transportation Index displays bidirectional causality with two other indexes. The Currency Adjusted S&P 500, NASDAQ 100 and Russell 1000 each represent elements of two bidirectional combinations. The adjusted NYSE Composite represents an element of one bidirectional combination.

Table 2. Johanson Cointegration Analysis on Currency Value Adjusted Index Level First Difference

Index 1	Index 2	Hypothesized Relations	Eigenvalue	Trace Statistic	P-Value
DJ Industrials	DJ Transport	None	0.1911	2089.56	1.0000
		At Most 1	0.1793	1007.99	0.0000***
DJ Industrials	DJ Utilities	None	0.1890	2031.00	1.0000
		At Most 1	0.1719	962.28	0.0000***
DJ Industrials	NASDAQ 100	None	0.1894	2109.80	1.0000
		At Most 1	0.1842	1038.50	0.0000***
DJ Industrials	NYSE Comp	None	0.1897	2022.03	1.0000
		At Most 1	0.1697	948.83	0.0000***
DJ Industrials	Russell 3000	None	0.1892	2048.49	1.0000
		At Most 1	0.1746	978.73	0.0000***
DJ Industrials	Russell 1000	None	0.1978	2154.28	1.0000
		At Most 1	0.1828	1029.81	0.0000***
DJ Industrials	S&P 500	None	0.1904	2058.84	1.0000
		At Most 1	0.1750	981.57	0.0000***
DJ Transport	DJ Utilities	None	0.1838	1932.58	1.0000
		At Most 1	0.1612	896.92	0.0000***
DJ Transport	NASDAQ 100	None	0.1891	2057.87	1.0000
		At Most 1	0.1762	988.92	0.0000***
DJ Transport	NYSE Comp	None	0.1912	2063.65	1.0000
		At Most 1	0.1749	980.93	0.0000***
DJ Transport	Russell 3000	None	0.1905	2067.61	1.0000
		At Most 1	0.1763	989.45	0.0000***
DJ Transport	Russell 1000	None	0.1975	2124.71	1.0000
		At Most 1	0.1784	1002.06	0.0000***
DJ Transport	S&P 500	None	0.1926	2085.82	1.0000
		At Most 1	0.1772	994.72	0.0000***
DJ Utilities	NASDAQ 100	None	0.1862	2021.42	1.0000
		At Most 1	0.1732	970.31	0.0000***
DJ Utilities	NYSE Comp	None	0.1903	2017.68	1.0000
		At Most 1	0.1684	940.77	0.0000***
DJ Utilities	Russell 3000	None	0.1900	2031.12	1.0000
		At Most 1	0.1709	955.93	0.0000***
DJ Utilities	Russell 1000	None	0.1937	2056.94	1.0000
		At Most 1	0.1713	958.67	0.0000***
DJ Utilities	S&P 500	None	0.1916	2043.41	1.0000
		At Most 1	0.1713	958.37	0.0000***
NASDAQ 100	NYSE Comp	None	0.1902	2134.78	1.0000
		At Most 1	0.1874	1058.51	0.0000***
NASDAQ 100	Russell 3000	None	0.1898	2128.74	1.0000
		At Most 1	0.1869	1055.34	0.0000***
NASDAQ 100	Russell 1000	None	0.1949	2169.34	1.0000
		At Most 1	0.1882	1063.72	0.0000***
NASDAQ 100	S&P 500	None	0.1913	2129.05	1.0000
		At Most 1	0.1855	1046.42	0.0000***
NYSE Comp	Russell 3000	None	0.1898	2112.08	1.0000
		At Most 1	0.1842	1038.35	0.0000***
NYSE Comp	Russell 1000	None	0.2178	2325.47	1.0000
		At Most 1	0.1896	1072.09	0.0000***
NYSE Comp	S&P 500	None	0.1912	2129.05	1.0000
		At Most 1	0.1855	1046.42	0.0000***

(Table 2 continued)

Russell 3000	Russell 1000	None At Most 1	0.2811 0.1892	2753.38 1069.62	1.0000 0.0000***
Russell 3000	S&P 500	None At Most 1	0.1926 0.1719	2053.04 961.88	1.0000 0.0000***
Russell 1000	S&P 500	None At Most 1	0.2718 0.1907	2697.40 1079.36	1.0000 0.0000***

Note: This table shows cointegration test results for currency adjusted index level first differences. The results include analysis of each two-index pairwise combination. The first and second columns indicate the two series under examination. The third column indicates the hypothesized number of cointegrating relations. The fourth column shows the ordered eigenvalues. The fifth and sixth columns show the Trace statistic and P-values respectively. *** indicates significance at the one percent level.

Table 3. Johanson Cointegration Analysis on Currency Adjusted Index Returns

Index 1	Index 2	Hypothesized CE(s)	Eigenvalue	Trace Statistic	P-Value
DJ Industrials	DJ Transport	None At Most 1	0.1944 0.1761	2090.99 988.36	1.0000 0.0000***
DJ Industrials	DJ Utilities	None At Most 1	0.1835 0.1621	1972.96 902.20	1.0000 0.0000***
DJ Industrials	NASDAQ 100	None At Most 1	0.1885 0.1782	2066.23 1000.91	1.0000 0.0000***
DJ Industrials	NYSE Comp	None At Most 1	0.1917 0.1707	2040.36 954.77	1.0000 0.0000***
DJ Industrials	Russell 3000	None At Most 1	0.1902 0.1712	3034.35 957.90	1.0000 0.0000***
DJ Industrials	Russell 1000	None At Most 1	0.2064 0.1842	2217.80 1038.29	1.0000 0.0000***
DJ Industrials	S&P 500	None At Most 1	0.1920 0.1705	2040.78 953.57	1.0000 0.0000***
DJ Transport	DJ Utilities	None At Most 1	0.1813 0.1563	1887.03 806.63	1.0000 0.0000***
DJ Transport	NASDAQ 100	None At Most 1	0.1954 0.1724	2074.28 965.12	1.0000 0.0000***
DJ Transport	NYSE Comp	None At Most 1	0.1849 0.1742	2019.15 976.57	1.0000 0.0000***
DJ Transport	Russell 3000	None At Most 1	0.1939 0.1729	2067.52 968.17	1.0000 0.0000***
DJ Transport	Russell 1000	None At Most 1	0.2053 0.1753	2155.32 983.45	1.0000 0.0000***
DJ Transport	S&P 500	None At Most 1	0.1960 0.1730	2082.20 969.14	1.0000 0.0000***
DJ Utilities	NASDAQ 100	None At Most 1	0.1854 0.1659	1971.42 925.18	1.0000 0.0000***
DJ Utilities	NYSE Comp	None At Most 1	0.1922 0.1600	1978.37 889.57	1.0000 0.0000***
DJ Utilities	Russell 3000	None At Most 1	0.1909 0.1610	1975.61 895.19	1.0000 0.0000***
DJ Utilities	Russell 1000	None At Most 1	0.1958 0.1626	2016.75 905.35	1.0000 0.0000***
DJ Utilities	S&P 500	None At Most 1	0.1925 0.1613	1987.82 897.08	1.0000 0.0000***
NASDAQ 100	NYSE Comp	None At Most 1	0.1920 0.1821	2113.23 1025.53	1.0000 0.0000***
NASDAQ 100	Russell 3000	None At Most 1	0.1917 0.1818	2109.25 1023.55	1.0000 0.0000***
NASDAQ 100	Russell 1000	None At Most 1	0.2028 0.1838	2192.02 1036.56	1.0000 0.0000***

(Table 3 continued)

NASDAQ 100	S&P 500	None	0.1929	2107.95	1.0000
		At Most 1	0.1804	1014.86	0.0000***
NYSE Comp	Russell 3000	None	0.1917	2110.26	1.0000
		At Most 1	0.1820	1024.77	0.0000***
NYSE Comp	Russell 1000	None	0.2404	2484.20	1.0000
		At Most 1	0.1910	1081.49	0.0000***
NYSE Comp	S&P 500	None	0.1923	2121.89	1.0000
		At Most 1	0.1832	1032.47	0.0000***
Russell 3000	Russell 1000	None	0.2830	2771.57	1.0000
		At Most 1	0.1899	1074.45	0.0000***
Russell 3000	S&P 500	None	0.2769	2738.00	1.0000
		At Most 1	0.1915	1084.26	0.0000***
Russell 1000	S&P 500	None	0.1947	2064.38	1.0000
		At Most 1	0.1715	959.78	0.0000***

Note: This table shows cointegration test results for currency adjusted index level returns. The results include analysis of each two-index pairwise combination. The first and second columns indicate the two series under examination. The third column indicates the hypothesized number of cointegrating relations. The fourth column shows the ordered eigenvalues. The fifth and sixth columns show the Trace statistic and P-values respectively. *** indicates significance at the one percent level.

Table 4. Granger Causality Test Results on Currency Adjusted Stock Indexes

Index 1	Index 2	Index Changes	Index Returns	Index 1	Index 2	Index Changes	Index Returns
		F Statistic	F Statistic				
DJ Transport	DJ Industrials	1.0732	0.9497	NYSE Comp	DJ Utilities	10.0173***	7.4551***
DJ Industrials	DJ Transport	1.4840	1.7525	DJ Utilities	NYSE Comp	2.6846**	3.0273***
DJ Utilities	DJ Industrials	3.4174***	4.3567	Russell 3000	DJ Utilities	11.5696***	8.4941***
DJ Industrials	DJ Utilities	11.6260***	8.7557***	DJ Utilities	Russell 3000	2.3946**	2.5461*
NASDAQ 100	DJ Industrials	2.4412*	0.6168	Russell 1000	DJ Utilities	9.9950***	7.4718***
DJ Industrials	NASDAQ 100	1.9348*	2.7988**	DJ Utilities	Russell 1000	1.9749*	4.1604***
NYSE Comp	DJ Industrials	1.8010	2.8817**	S&P 500	DJ Utilities	11.7124***	8.8492***
DJ Industrials	NYSE Comp	0.4733	0.7958	DJ Utilities	S&P 500	2.7764**	2.9034*
Russell 3000	DJ Industrials	2.5928*	2.3865**	NYSE Comp	NASDAQ 100	0.7431	2.4562*
DJ Industrials	Russell 3000	1.5837	1.1220	NASDAQ 100	NYSE Comp	0.8365	0.7417
Russell 1000	DJ Industrials	2.8445**	2.8115**	Russell 3000	NASDAQ 100	0.6172	2.6642*
DJ Industrials	Russell 1000	8.2402***	19.8492***	NASDAQ 100	Russell 3000	0.9327	1.4865
S&P 500	DJ Industrials	2.5935**	2.8227**	Russell 1000	NASDAQ 100	0.8820	3.2905***
DJ Industrials	S&P 500	1.9279*	1.2271	NASDAQ 100	Russell 1000	2.1541*	12.1344***
DJ Utilities	DJ Transport	5.3701***	4.8264***	S&P 500	NASDAQ 100	0.8679	2.8294*
DJ Transport	DJ Utilities	3.5337***	2.8163**	NASDAQ 100	S&P 500	1.1156	0.8214
NASDAQ 100	DJ Transport	1.5331	0.9303	Russell 3000	NYSE Comp	1.1966	1.1963
DJ Transport	NASDAQ 100	0.2338	0.2098	NYSE Comp	Russell 3000	1.3443	1.3091
NYSE Comp	DJ Transport	4.0050***	3.1493***	Russell 1000	NYSE Comp	0.5091	0.7149
DJ Transport	NYSE Comp	2.5671**	2.5752**	NYSE Comp	Russell 1000	8.9264***	24.0218***
Russell 3000	DJ Transport	2.2808**	2.5232**	S&P 500	NYSE Comp	1.3270	1.3825
DJ Transport	Russell 3000	1.3560	2.0180*	NYSE Comp	S&P 500	2.0937*	2.0155*
Russell 1000	DJ Transport	3.1941***	3.20259***	Russell 1000	Russell 3000	0.7791	1.3233
DJ Transport	Russell 1000	5.9422***	11.8712***	Russell 3000	Russell 1000	19.7253***	35.2875***
S&P 500	DJ Transport	1.4924	2.0696*	S&P 500	Russell 1000	0.8956	0.3998
DJ Transport	S&P 500	1.2912	1.9688*	Russell 1000	S&P 500	1.2078	0.7198
NASDAQ 100	DJ Utilities	9.2370***	5.7869***	S&P 500	Russell 3000	19.7356***	34.1270***
DJ Utilities	NASDAQ 100	2.1715*	3.5249***	Russell 3000	S&P 500	0.9570	1.0265

Note: This table shows Granger causality test results. The table shows results for each pairwise combination of currency value adjusted indexes. The results labeled Index Changes show the results for tests on index level first differences. Results labeled Index Returns shows results of tests based on Equation 3 ***, ** and * indicate significance at the one, five and ten percent levels respectively.

Six tests show one-way causality. The Currency Adjusted Russell 1000 index shows one-way causality with three other indexes. The Currency Adjusted NYSE composite index shows one-way causality with two other indexes. The Currency Adjusted Dow Jones Industrial, Currency Adjusted Dow Jones Transportation, Currency Adjusted NASDAQ 100, and Currency Adjusted S&P 500 Indices have one-way causality with one other index each.

Table 4, Column 4, shows Granger Causality test results for daily currency adjusted index returns. Much like the index level results, eleven of twelve bidirectional causality pairs include a currency adjusted Dow Jones index. These include six pairs based on the Currency Adjusted Dow Jones Utility Index, four based on the Currency Adjusted Dow Jones Transportation Index and one based on the Currency Adjusted Dow Jones Industrial. The Currency Adjusted Russell 1000 and Currency Adjusted NASDAQ 100 indices form the only bidirectional causality pair that does not include a Currency Adjusted Dow Jones Index component.

The Currency Adjusted Dow Jones indexes show one-way causality with five other indexes. The Currency Adjusted Dow Jones Industrial Granger causes the Currency Adjusted Dow Jones Utility and Currency Adjusted NASDAQ 100. The Currency Adjusted NYSE Composite, Currency Adjusted Russell 3000 and Currency Adjusted S&P 500 Granger cause the Currency Adjusted Dow Jones Industrial. The Currency Adjusted NYSE Composite Granger causes the Currency Adjusted Dow Jones Industrials and Currency Adjusted Russell 1000. The Currency Adjusted NYSE Composite, Currency Adjusted Russell 3000 and Currency Adjusted S&P 500 all Granger cause the NASDAQ 100. The Currency Adjusted S&P 500 Granger causes the Currency Adjusted Russell 3000. Finally, the Currency Adjusted Russell 3000 granger causes the Currency Adjusted Russell 1000. Combined, the results show that there exist important elements of granger causality in the series. This causality exists both in the index level first differences and in index returns.

CONCLUDING COMMENTS

Recent studies introduce currency adjusted stock indexes to the extant literature. These indexes provide new measures of wealth change effects. The indexes involve adjusting existing indexes to reflect changes in value of the underlying currency. This paper extends the analysis of these indexes by examining time series properties of the indexes. This research examines daily data for eight stock indexes and the Dollar Index from 1993-2013. The calculations adjust existing indexes to reflect changing values of the U.S. dollar. The paper examines the indexes in level form, and daily return form.

The data analysis includes calculations of unit root, cointegration and Granger causality tests. In level form, the data does not reject the presence of a unit root for any currency-adjusted series. However, in first difference form, the data rejects the presence of a unit root for each data series. For the return series, the data rejects the presence of a unit root for each series without further adjustments. Thus, the analysis bases index level analysis on first differences and return series analysis on series without adjustment. The results show the existence of cointegrating relationships between the indexes in first difference form and in daily return form. Granger Causality tests show causality relationships with about half of those relationships showing bidirectional causation.

The currency adjusted stock index topic offers many opportunities for additional research. Examinations of univariate index properties offer opportunities for further research. Currency-adjusted indices developed to date examine only U.S. stock indexes. Future research might examine currency adjust indexes of other countries.

AUTHOR BIOGRAPHY

Terrance Jalbert is Professor of Finance at University of Hawaii at Hilo. His research appears in journals such as: *International Journal of Finance*, *Financial Services Review*, *Journal of Emerging Markets*, *Journal of Accounting Education*, *Journal of Personal Finance* and *The International Journal of Business and Finance Research*. He can be contacted at: University of Hawaii at Hilo, College of Business and Economics, 200 West Kawili St., Hilo, HI 96720. Email: jalbert@hawaii.edu

REFERENCES

Diamandis, P. F. and A. A. Drakos (2011). Financial liberalization, exchange rates and stock prices: Exogenous shocks in four Latin America countries. *Journal of Policy Modeling,* Vol. 33, 381-394.

Dicky, D. A. and W. A. Fuller (1979). Distribution of estimators for time series regressions with unit root. *Journal of the American Statistical Association,* Vol. 74, 427-431.

Dicky, D. A. and W. A. Fuller (1981). The likelihood ratio statistics for autoregressive time-series with a unit root. *Econometrica*, Vol. 49, 1057-1072.

Engle, R. F., and C. W. J. Granger (1987) Cointegration and error correction: Representation, estimation and testing. *Economitrica,* Vol. 55, 251-276.

Flores, C, (2008). Long memory in exchange rates: International evidence, *The International Journal of Business and Finance Research,"* Vol. 2(1) 31-39.

Granger, C. W. J. (1969). Investigating casual relations by econometric models and cross-spectral methods. *Econometrica,* Vol. 37, 424-439.

Hammes, D. and D Willis (2005). Black gold: The end of Bretton Woods and the oil-price shocks of the 1970s. *The Independent Review*, Vol. 9(4) 501-511.

Heilmann, K. (2010). Stock market linkages – A cointegration approach. Dissertation at the University of Nottingham

Huang, BN., CW. Yang and J. WS. Hu (2000). Causality and cointegration of stock markets among the United States, Japan and the South China growth triangle. *International Review of Financial Analysis,* Vol. 9(3) 281-297.

Jalbert, T. (2012). The performance of currency value adjusted stock indices. *Journal of Index Investing,* Vol. 3(2) 34-48.

Jalbert, T. (2014) "Dollar index adjusted stock indices" *Journal of Applied Business Research,* Vol. 30(1) p. 1-14.

Jalbert, T. (2015a). Intraday index volatility: Evidence from currency adjusted stock indices. *Journal of Applied Business Research,* Vol. 31(1, January/February) 17-28.

Jalbert, T. (2015b). Currency adjusted stock index causality and cointegration: Evidence from intraday data. *The International Journal of Business and Finance Research*, Vol. 9(5), 83-91

Johansen, S. (1991). Estimatio and hypthesis testing of cointegration vectors in gaussian vector autoregressive models. *Econometrica,* Vol. 59, 1551-1580.

K.G, S. and A. K. Tiwari (2012). Long run and short run linkages between stock indices in Bombay Stock Exchange: A structural cointegration approach. *Journal of Quantitative Economics,* Vol. 10(1, January) 177-181.

Levy, T. and J. Yagil (2015). Changing the methodology of equity indices – The case of the Tel-Aviv Stock Exchange. *Journal of International Financial Markets, Institutions & Money,* Vol. 26, 91-99

Phillips, P. C. B. (1987) "Time series regression with a unit root" Econometrica, Vol. 55, 277-301

Philips, P. C., and P. Perron (1988). Testing for a unit root in time series regression. *Biometrika*, 75, 335-346.

Schwartz, G. (1978). Estimating the dimension of a model. *Annals of Statistics*, Vol. 6, 461-464.

Thuan, L. T. (2011). The relationship between the United States and Vietnam stock markets. *The International Journal of Business and Finance Research*, Vol. 5(1) 77-89.

Tsagkanos A. and C. Siriopoulos (2013). A Long-run Relationship between Stock Price Index and Exchange Rate: A Structural Nonparametric Cointegrating Regression Approach. *Journal of International Financial Markets, Institutions & Money,* Vol. 25. 106-118.

Unal, Gozde and D. Korman (2012). Analysis of Extreme Dependence between Istanbul Stock Exchange and Oil Returns. *The International Journal of Business and Finance Research,* Vol. 6(4) 113-124.

NOTES