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CURRENCY-ADJUSTED STOCK INDEX CAUSALITY AND COINTEGRATION: EVIDENCE FROM INTRADAY DATA

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ABSTRACT

Currency adjusted stock indices consider the impact of both stock value changes and underlying currency value changes on total wealth changes. This paper explores causality and cointegration of currency-adjusted indices using intraday data. This paper examines tick-by-tick data for seven currently available stock indexes, the Philadelphia Housing Index and the Dollar Index for the period 2002-2013. Results show cointegrating relationships between each combination of series examined. The analysis reveals a higher level of causality than found in previous research. The results show bidirectional Granger causality for every index pairwise combination examined.

JEL: F15, G11, D14

KEYWORDS: Cointegration, Stock Index, Currency-Adjusted Stock Index, Dow Jones Industrial Average

INTRODUCTION

Currency adjusted indexes control for two impacts on investor wealth. Standard stock indexes aggregate stock prices for many stocks into an index. Currency adjusted stock indexes simultaneously consider the impact of stock prices and underlying currency values. By considering both elements, currency adjusted indexes provide a measure of total portfolio value change. Many individuals live in one country but invest in another. Some authors suggest individuals do this to achieve international diversification benefits (Christoffersen, Errunza, Jacobs and Langlois, 2012; Berger, Pukthuanthong and Yang, 2011). Other motivations can drive this behavior as well. This investor behavior may be done for investment familiarity reasons, to retain an original country return option, or because of investment or tax regulations that limit the ability to relocate the funds or make such a relocation costly.

Investors living internationally but investing domestically, convert domestic investment earnings into domicile country currency for consumption. Two factors affect the purchasing power of these individuals. Purchasing power depends on performance of their investments and the exchange rate at which earnings convert to domicile country currency. Currency adjusted indices measure the combined effect of stock and currency changes on individual wealth.

Other individuals also face exposure to international markets. Individuals who use investment earnings to travel internationally, face exposure to both investment and currency risk. They wish to know the international purchasing power of their investments. Other individuals purchase items manufactured in non-domicile countries. These individuals desire to know the extent to which their domestic investments afford the international purchase. Currency adjusted indices more precisely measure the extent to which individuals achieve their goals.

This paper examines time-series properties of currency adjusted stock indices developed in Jalbert, 2012, 2014, 2015 and 2016. These earlier works make use of varying starting indexes, index observation frequencies, statistical techniques and cover different time periods. This work makes advances on the statistical sophistication of the analysis and examines a higher frequency dataset. The paper utilizes cointegration and Granger causality analyses to examine tick-by-tick trading data on a different series of indexes than examined in earlier studies. Several previous articles in this series examines close of day data. While close-of-day research is useful, news outlets regularly report index levels throughout the day. This paper provides an examination of stock indexes in a minute-by-minute setting thereby providing additional precision in the analysis.

The remainder of the paper begins with a review of the relevant literature. Next, the paper provides a description of the data and methodology used in the paper. The following section presents empirical results. The paper closes with some concluding comments.

LITERATURE REVIEW

Currency value adjusted stock indexes were first introduced by Jalbert (2012). He developed indices based on day-end closing values of existing stock indexes. He used United States Federal Reserve currency value data to adjust existing index values to reflect changes in the U.S. dollar value. Federal Reserve currency index data tracks U.S. dollar value against an international currency basket. His examination reveals large differences between original index and currency value adjusted index returns. For example, in 1981, the Standard and Poor's 500 Index produced a -10.237 percent return. However, the currency-adjusted version of the same index produced a -0.608 percent return. Similarly, in 2007, the Standard and Poor's 500 Index produced a 3.469 percent return, but the currency-adjusted version of the same index produced a -7.024 percent return. In as many as 15.49 percent of all daily returns, the original and currency-adjusted indices indicate different signs. Thus, one index indicates the market has increased but the other indicates the market has declined. He finds mixed evidence on index volatility. Currency adjusting indexes increased volatility in some instances but decreased volatility in other instances.

Jalbert (2014) utilizes the Dollar Index (DXY) as an alternative measure of U.S. dollar value. This index has advantages over the Federal Reserve indexes used in his earlier study. His analysis uses close-of-day data. He finds that currency value changes explain a larger portion of wealth changes than identified in Jalbert (2012). He finds currency level changes explain as much as 14.9 percent of wealth changes compared to 8.4 percent in Jalbert (2012). Jalbert (2015) examines intraday data from 2002-2013 including over one million tick-by-tick data observations for each index examined. His results show significant differences between the within-tick spreads for adjusted and raw indices. His results also show that Dollar Index changes explain more of total wealth changes than identified in his earlier works. Jalbert (2016) examined cointegration and causality between currency-adjusted indexes using close-of-day data. His results show cointegration exists between each pairwise combination of currency-adjusted indexes. His results further show that about half the pairwise combinations of currency-adjusted and raw indexes examined display bidirectional Granger causality.

The relationship between stock prices and exchange rates is relevant for the study at hand. Chien-Chung and Cheng-Few (2001) examine stock prices and exchange rates using data for G-7 countries. They find no long-run relationship between stock prices and exchange rates. They further find the relationship between stock prices and dollar values cannot be reliably used to predict future stock prices. Lin (2012) examines comovement between exchange rates and stock prices. She finds that comovement between stock prices and exchanges rates becomes stronger during crisis periods. Chkili and Nguyen (2014) examine linkages between exchange rates and stock market returns for BRICS (Brasil, Russia, India, China and South Africa). They find that stock market returns impact exchange rates, but exchange rates do not impact

stock market returns. Caporale, Hunter and Ali (2014) find univariate Granger causality from stock returns to echange rates in the U.S and U.K, but find an opposite effect for Canada.

The extant literature examines relationships between stock indexes of various exchanges and countries. Madaleno and Pinho (2012) examine correlation among four stock indexes of different countries. They find that geographically and economically closer markets display higher correlation and more short-run comovements. Wang, Podobnik, Horvatic and Stanley (2011) develop a model in which all index returns fluctuate in response to a single global factor. They find that a significant amount of index cross corelations are explainable by the global factor. Lee and Rui (2002) examine the relationship between trading volume, returns and volatility. They find trading volume does not Granger cause market returns. They further find that U.S. trading volume contains considerable predictive power for financial market variables of other countries.

Hammes and Wills (2005) examined the 1970's Oil Price Shock around the end of the Brenton Woods Agreement which implied fixed exchange rates. The end of the Brenton Woods Agreement resulted in a floating U.S. dollar value relative to other currencies. Oil prices were denominated in U.S. dollars before and after dissolution of the Brenton Woods Agreement. The authors argue these events, combined with a decline in dollar value, imply the 1970's oil price shock was a normal reaction. The shock simply maintained oil prices at approximately an equal amount of gold.

DATA AND METHODOLOGY

Data for seven U.S. Stock Indices, the Philadelphia Housing Index and the U.S. Dollar Index were obtained from Pi Trading (Pi Trading, 2013). Pi Trading provides open, high, low and close data for each minute throughout the trading day. Data for this study covers the period August 5, 2001 through April 5, 2013. Dollar Index data and stock index data were matched for each trading tick. The Dollar Index is based on U.S. dollar value relative to a basket of six major currencies. The dollar index started in March of 1973 with value of 100. Higher index levels imply a stronger dollar relative to March of 1973. The Dollar Index level displays considerable variation over time. The Index level ranges from a high of 164.72 in February 1985 to a low of 70.698 in March 2008. The index is widely quoted in the popular press. This research analyzes seven stock indices: The Dow Jones Industrial Average (DJIA), The NASDAQ Composite (COMPX), NASDAQ 100 (NDX), S&P 500 (SPX), S&P 400 (MID), Russell 3000 (RUA), and Russell 1000 (RUI). The paper also examines the Philadelphia Housing Index (HGX) which measures real estate values. The final dataset includes as many as 1,101,000 observations for each series.

Consider a stock index with level, RI_t at time *t.* Consider also the Dollar Index with base level of 100 and level, DI_t at time *t.* Then the currency adjusted stock index, CAI_t, at time *t* equals:

$$CAI_t = RI_t \, X \, \frac{DI_t}{100} \qquad (1)$$

Consider an unadjusted index with a level of 1,000 occurring at the same time the Dollar Index equals 110. Equation 1 produces an adjusted index level equaling 1,100. A Dollar index of 100 results in equal raw and adjusted indices. A Dollar Index level above 100, implies currency-adjusted index levels exceed raw index levels. Similarly, Dollar Index levels below 100 imply raw index levels exceed the currency-adjusted index level.

This paper examines tick-by-tick index levels, index changes and index returns. Consider a currency-adjusted stock index level at time t, CAI_t, and previous period level, CAI_{t-1}. Computation of index changes, and returns follow Equations 2 and 3 respectively:

$$Index\ Change\ =\ CAI_t - CAI_{t-1} \quad (2)$$

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

The analysis involves calculating index changes and returns using closing data for each trading minute. The examination analyzes these figures using cointegration and Granger causality techniques.

RESULTS

Augmented Dickey-Fuller statistics (Dickey and Fuller 1979 & 1981) provide a method for examining time-series stationairity. The process tests for unit roots in the data. The analysis here allows for a maximum of 32 lags. Shwartz (1978) Information Criteria methodology is used to determine exact lag length. Augmented Dickey-Fuller results for index levels are presented in Table 1, Panel A. Level form results indicate a failure to reject the presence of a unit root for any of the stock series or the Philadelphia Housing series. It does indicate rejection of a unit root for the Dollar Index. The results show rejection of a unit root for each data series in first difference form.

Table 1: Unit Root Tests on Currency Adjusted Stock Indexes

	Level Form			First Differences		
Variable	**Lag Length**	**T-Statistic**	**Prob.**	**Lag Length**	**T-Statistic**	**Prob.**
Panel A: Index Levels						
Currency Adjusted DJIA	4	-2.1578	0.2221	3	-502.69	0.0001***
Currency Adjusted NASDAQ Composite	2	-1.4391	0.5646	1	-681.11	0.0001***
Currency Adjusted NASDAQ 100	4	-1.0379	0.7418	3	-512.05	0.0001***
Currency Adjusted S&P 500	2	-2.3057	0.1702	1	-672.80	0.0001***
Currency Adjusted S&P 400	6	-0.5456	0.8799	5	-383.22	0.0001***
Philadelphia Housing	6	-1.9525	0.3083	5	-382.57	0.0001***
Currency Adjusted Russell 3000	5	-1.8483	0.3573	4	-434.67	0.0001***
Currency Adjusted Russell 1000	5	-1.8434	0.3597	4	-436.96	0.0001***
Dollar Index	1	-3.0389	0.0314**	0	-1037.7	1.0000
Panel B: Index Returns						
Currency Adjusted DJIA	10	-311.24	0.0001***	121	-160.15	0.0001***
Currency Adjusted DJ Transport	1	-680.89	0.0001***	121	-159.01	0.0001***
Currency Adjusted DJ Utilities	6	389.60	0.0001***	121	-159.97	0.0001***
Currency Adjusted NASDAQ 100	3	-494.60	0.0001***	121	-160.98	0.0001***
Currency Adjusted NYSE Composite	5	-384.22	0.0001***	120	-153.42	0.0001***
Currency Adjusted S&P 500	14	-249.64	0.0001***	119	-144.36	0.0000***
Currency Adjusted Russell 3000	4	-435.73	0.0001***	120	-158.53	0.0001***
Currency Adjusted Russell 1000	3	-487.44	0.0001***	120	-155.87	0.0001***
Dollar Index	0	-1,036.6	1.000	121	-159.06	0.0001***

*This table shows Augmented Dickey-Fuller unit root test results on currency adjusted stock indexes and the Philadelphia Housing Index. *** indicates significance at the 1 percent level.*

Table 1, Panel B shows results for currency-adjusted index returns. The results indicate rejection of a unit root, for each series, in both level form and first difference form. To confirm result robustness, the analysis is completed with and without an intercept term. The results of the two methodologies are not discernably different. Phillips (1987) and Phillips and Perron (1988) developed an alternate test specification for detecting unit roots in data. Tests results using the Augmented Dickey Fuller test and the Phillips and Perron test produce similar results, further attesting to the robustness of the findings. Based on these results, the remaining analysis examines index level changes and index returns without adjustment.

Table 2: Johanson Cointegration Analysis on Currency Value Adjusted Index Level Changes

Index 1	Index 2	Hypothesized Relations	Eigenvalue	Trace Statistic	P-Value
DJ Industrials	NASDAQ Comp	None	0.1930	400,820	1.0000
		At Most 1	0.1591	179,108	0.0000***
DJ Industrials	S&P 400	None	0.2018	388,610	1.0000
		At Most 1	0.1429	157,855	0.0000***
DJ Industrials	NASDAQ 100	None	0.1883	400,654	1.0000
		At Most 1	0.1638	184,924	0.0000***
DJ Industrials	Phil. Housing	None	0.1762	347,839	1.0000
		At Most 1	0.1507	159,068	0.0000***
DJ Industrials	Russell 3000	None	0.2141	419,059	1.0000
		At Most 1	0.1524	170,524	0.0000***
DJ Industrials	Russell 1000	None	0.2188	427,900	1.0000
		At Most 1	0.1549	173,444	0.0000***
DJ Industrials	S&P 500	None	0.2271	444,258	1.0000
		At Most 1	0.1579	177,766	0.0000***
NASDAQ Comp	S&P 400	None	0.2095	399,809	1.0000
		At Most 1	0.1440	159,134	0.0000***
NASDAQ Comp	NASDAQ 100	None	0.1996	396,156	1.0000
		At Most 1	0.1482	165,893	0.0000***
NASDAQ Comp	Phil. Housing	None	0.1711	342,838	1.0000
		At Most 1	0.1515	160,078	0.0000***
NASDAQ Comp	Russell 3000	None	0.2021	405,937	1.0000
		At Most 1	0.1544	173,063	0.0000***
NASDAQ Comp	Russell 1000	None	0.1989	402,745	1.0000
		At Most 1	0.1555	174,205	0.0000***
NASDAQ Comp	S&P 500	None	0.1981	405,629	1.0000
		At Most 1	0.1575	177,245	0.0000***
S&P 400	NASDAQ 100	None	0.2048	393,813	1.0000
		At Most 1	0.1441	159,214	0.0000***
S&P 400	Phil. Housing	None	0.1621	323,013	1.0000
		At Most 1	0.1460	152,282	0.0000***
S&P 400	Russell 3000	None	0.2015	387,983	1.0000
		At Most 1	0.1434	158,079	0.0000***
S&P 400	Russell 1000	None	0.1996	384,458	1.0000
		At Most 1	0.1428	157,251	0.0000***
S&P 400	S&P 500	None	0.1970	383,222	1.0000
		At Most 1	0.1434	158,476	0.0000***
NASDAQ 100	Phil. Housing	None	0.1768	349,477	1.0000
		At Most 1	0.1514	159,954	0.0000***
NASDAQ 100	Russell 3000	None	0.1954	396,749	1.0000
		At Most 1	0.1540	172,480	0.0000***
NASDAQ 100	Russell 1000	None	0.1937	396,362	1.0000
		At Most 1	0.1557	174,487	0.0000***
NASDAQ 100	S&P 500	None	0.1935	401,569	1.0000
		At Most 1	0.1590	179,175	0.0000***
Phil. Housing	Russell 3000	None	0.1647	335,197	1.0000
		At Most 1	0.1517	160,088	0.0000***
Phil. Housing	Russell 1000	None	0.1661	336,165	1.0000
		At Most 1	0.1515	159,642	0.0000***
Phil. Housing	S&P 500	None	0.1703	341,784	1.0000
		At Most 1	0.1513	159,898	0.0000***
Russell 3000	Russell 1000	None	0.2778	506,729	1.0000
		At Most 1	0.1532	171,348	0.0000***
Russell 3000	S&P 500	None	0.2614	484,587	1.0000
		At Most 1	0.1534	171,894	0.0000***
Russell 1000	S&P 500	None	0.3020	545,842	1.0000
		At Most 1	0.1562	175,086	0.0000***

*This table shows Johanson cointegration test results for currency-adjusted index changes. 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-value respectively. ***, ** and * indicate significance at the one, five and ten percent levels respectively.*

Table 3: Johanson Cointegration Analysis on Currency Adjusted Index Returns

Index 1	Index 2	Hypothesized Relations	Eigenvalue	Trace Statistic	P-Value
DJ Industrials	NASDAQ Comp	None	0.1997	409,782	1.0000
		At Most 1	0.1594	179,501	0.0000***
DJ Industrials	S&P 400	None	0.2129	403,516	1.0000
		At Most 1	0.1434	158,444	0.0000***
DJ Industrials	NASDAQ 100	None	0.1934	407,865	1.0000
		At Most 1	0.1643	185,614	0.0000***
DJ Industrials	Phil. Housing	None	0.1784	354,288	1.0000
		At Most 1	0.1539	162,838	0.0000***
DJ Industrials	Russell 3000	None	0.2224	430,769	1.0000
		At Most 1	0.1530	171,269	0.0000***
DJ Industrials	Russell 1000	None	0.2264	438,634	1.0000
		At Most 1	0.1554	174,117	0.0000***
DJ Industrials	S&P 500	None	0.2322	451,768	1.0000
		At Most 1	0.1585	178,457	0.0000***
NASDAQ Comp	S&P 400	None	0.2141	406,640	1.0000
		At Most 1	0.1448	160,054	0.0000***
NASDAQ Comp	NASDAQ 100	None	0.2007	398,890	1.0000
		At Most 1	0.1492	167,166	0.0000***
NASDAQ Comp	Phil. Housing	None	0.1760	351,581	1.0000
		At Most 1	0.1541	163,042	0.0000***
NASDAQ Comp	Russell 3000	None	0.2062	412,015	1.0000
		At Most 1	0.1550	173,807	0.0000***
NASDAQ Comp	Russell 1000	None	0.2033	409,073	1.0000
		At Most 1	0.1560	174,787	0.0000***
NASDAQ Comp	S&P 500	None	0.2034	413,083	1.0000
		At Most 1	0.1580	177,914	0.0000***
S&P 400	NASDAQ 100	None	0.2074	398,135	1.0000
		At Most 1	0.1449	160,193	0.0000***
S&P 400	Phil. Housing	None	0.1695	333,034	1.0000
		At Most 1	0.1473	153,768	0.0000***
S&P 400	Russell 3000	None	0.2140	404,819	1.0000
		At Most 1	0.1440	158,799	0.0000***
S&P 400	Russell 1000	None	0.2115	400,445	1.0000
		At Most 1	0.1434	157,967	0.0000***
S&P 400	S&P 500	None	0.2094	399,882	1.0000
		At Most 1	0.1440	159,230	0.0000***
NASDAQ 100	Phil. Housing	None	0.1802	357,335	1.0000
		At Most 1	0.1547	163,781	0.0000***
NASDAQ 100	Russell 3000	None	0.1978	401,094	1.0000
		At Most 1	0.1549	173,679	0.0000***
NASDAQ 100	Russell 1000	None	0.1997	401,016	1.0000
		At Most 1	0.1565	175,447	0.0000***
NASDAQ 100	S&P 500	None	0.1967	406,841	1.0000
		At Most 1	0.1600	180,303	0.0000***
Phil. Housing	Russell 3000	None	0.1684	343,025	1.0000
		At Most 1	0.1548	163,605	0.0000***
Phil. Housing	Russell 1000	None	0.1692	343,492	1.0000
		At Most 1	0.1548	163,395	0.0000***
Phil. Housing	S&P 500	None	0.1731	349,188	1.0000
		At Most 1	0.1548	163,907	0.0000***
Russell 3000	Russell 1000	None	0.3002	540,264	1.0000
		At Most 1	0.1540	172,380	0.0000***
Russell 3000	S&P 500	None	0.2809	513,145	1.0000
		At Most 1	0.1541	172,758	0.0000***
Russell 1000	S&P 500	None	0.3166	568,357	1.0000
		At Most 1	0.1568	175,826	0.0000***

*This table shows Johanson cointegration test results for currency-adjusted index returns. 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-value respectively. *** indicates significance at the one percent level.*

This paper conducts Johanson cointegration analysis (Johanson, 1991). The methodology involves pairwise cointegration tests of each two-index pairwise currency adjusted index combination. The test specification incorporates EViews software options of intercept, trend in CE intercept in VAR and Lag intervals equaling 1 4. The analysis uses MacKinnon, Haug and Michelis (1999) p-values. Table 2 shows results for tick-by-tick currency-adjusted index level changes. The results reveal two cointegrating equations for each index combination. For each index combination the data rejects the test for at most one cointegrating relationship. Table 3 shows results of cointegration analysis on currency adjusted tick-by-tick index returns. The results here also show two cointegrating equations for each pairwise combination of indexes.

The next analysis involves conducting Granger causality tests between pairwise combinations of adjusted indices (Granger 1969). The test specification permits up to ten lags. Table 4, shows results of tests on currency adjusted index level changes and returns. The tests determine if the index listed in column, Index 1, Granger causes the index listed in column, Index 2. The analysis involved conducting fifty-six pairwise tests. The results show bi-directional causality for each index pair. These findings differ from those of Jalbert (2016), who found, using daily data and a different combination of indexes, that about half of all index combinations display bi-directional causality. The combined results show more pronounced elements of Granger causality in higher frequency series. This causality exists in both index-level changes and index returns.

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			F Statistic	F Statistic
NASDAQ Cp	DJ Industrials	341.30***	433.37***	Phil. Housing	S&P 400	4,749.02***	6,567.20***
DJ Industrials	NASDAQ Cp	687.02***	886.09***	S&P 400	Phil. Housing	91.23***	48.05***
S&P 400	DJ Industrials	101.46***	63.35***	Russell 3000	S&P 400	7,009.48***	8,116.25***
DJ Industrials	S&P 400	9,167.36***	11,086.3***	S&P 400	Russell 3000	319.42***	267.50***
NASDAQ 100	DJ Industrials	381.20***	485.71***	Russell 1000	S&P 400	6,599.67***	7,712.67***
DJ Industrials	NASDAQ 100	459.43***	577.03***	S&P 400	Russell 1000	280.02***	215.47***
Phil. Housing	DJ Industrials	46.89***	62.14***	S&P 500	S&P 400	5,463.24***	6,785.80***
DJ Industrials	Phil. Housing	548.66***	712.20***	S&P 400	S&P 500	256.32***	182.00***
Russell 3000	DJ Industrials	16.50***	9.953***	Phil. Housing	NASDAQ 100	101.34***	111.07***
DJ Industrials	Russell 3000	4,410.22***	5,011.87***	NASDAQ 100	Phil. Housing	303.41***	475.97***
Russell 1000	DJ Industrials	25.61***	16.55***	Russell 3000	NASDAQ 100	31.39***	44.95***
DJ Industrials	Russell 1000	4657.36***	5,291.46***	NASDAQ 100	Russell 3000	1426.45***	1,520.70***
S&P 500	DJ Industrials	43.70***	44.19***	Russell 1000	NASDAQ 100	22.72***	28.26***
DJ Industrials	S&P 500	5,738.73***	6,101.28***	NASDAQ 100	Russell 1000	1,381.03***	1,511.11***
S&P 400	NASDAQ Cp	39.36***	25.06***	S&P 500	NASDAQ 100	13.83***	22.86***
NASDAQ Cp	S&P 400	5,616.26***	5,825.10***	NASDAQ 100	S&P 500	1,830.83***	19,33.36***
NASDAQ 100	NASDAQ Cp	250.78***	288.91***	Russell 3000	Phil. Housing	86.88***	183.13***
NASDAQ Cp	NASDAQ 100	19.70***	28.92***	Phil. Housing	Russell 3000	246.68***	385.35***
Phil. Housing	NASDAQ Cp	204.72***	247.88***	Russell 1000	Phil. Housing	95.07***	176.45***
NASDAQ Cp	Phil. Housing	246.16***	426.49***	Phil. Housing	Russell 1000	212.47***	355.82***
Russell 3000	NASDAQ Cp	91.75***	133.35***	S&P 500	Phil. Housing	73.60***	154.42***
NASDAQ Cp	Russell 3000	1,384.11***	1,523.54***	Phil. Housing	S&P 500	252.88***	327.12***
Russell 1000	NASDAQ Cp	74.50***	100.77***	Russell 1000	Russell 3000	312.50***	334.58***
NASDAQ Cp	Russell 1000	1276.06***	1,462.80***	Russell 3000	Russell 1000	265.13***	441.15***
S&P 500	NASDAQ Cp	45.48***	77.53***	S&P 500	Russell 1000	224.47***	313.10***
NASDAQ Cp	S&P 500	1,635.04***	1,804.79***	Russell 1000	S&P 500	1,087.25***	1,167.34***
NASDAQ 100	S&P 400	5,675.94***	5,704.49***	S&P 500	Russell 3000	210.98***	319.44***
S&P 400	NASDAQ 100	41.069***	33.70***	Russell 3000	S&P 500	1,319.91***	1.245.54***

*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 changes as specified in Equation 2. Results labeled Index Returns shows results of tests based on Equation 3. ***, ** and * indicate significance at the one, five and ten percent levels respectively.*

CONCLUDING COMMENTS

This paper examines currency-adjusted stock indexes. The construction of these indexes begins with an existing index and adjusts it to reflect changes in underlying currency value. The methodology involves

determining the U.S. dollar value as compared to a basket of six currencies using the DXY Dollar Index. This paper extends the analysis by using cointegration and Granger causality statistical techniques and by using tick-by-tick trading data. This paper examines tick-by-tick data for seven stock indexes, the Philadelphia Housing Index and the Dollar Index from 2001-2013 including more than 1,000,000 observations for each series.

In level form, for all series examined, the data fails to reject the presence of a unit root. But, in first difference form, the data rejects a unit root for each series. In contrast, the data rejects the presence of a unit root for each index return series without adjustment. The results show cointegrating relationships between pairwise index combinations of index changes and returns. Granger causality tests show bi-directional causality between each pairwise combination of indexes.

Currency value adjusting stock indexes and other asset values provides opportunities for additional research. Examining index arbitrage opportunities created by currency value adjustments might lead to interesting insights. In addition, currency adjusted examinations of real estate values may provide interesting insights.

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