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EXAMINING THE RELATIONSHIP BETWEEN LIQUIDITY AND TRACKING ERROR IN EXCHANGE-TRADED FUNDS

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ABSTRACT

Recent financial studies proved that domestic exchange-traded funds control their tracking error efficiently because of constant arbitrage. The arbitrage methodology then suggests that all domestic exchange-traded funds' tracking errors should statistically be affected by liquidity unless the fund is extremely liquid or illiquid. The methodology further suggests, and recited in financial literature, that the least liquid funds have the largest tracking errors. This study provides regression results suggesting that the relationship between liquidity and tracking error is not statistically significant for all domestic exchange-traded funds. The inconsistency of the least liquid funds having the largest tracking errors further suggests a weaker than proposed relationship between liquidity and tracking error.

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I. Introduction

Exchange-traded funds are financial instruments designed to mirror the performance of a stock market or sector index. These financial instruments have become increasingly popular since first introduced to the United States in January 1993 (Bayot, National). The growth of popularity can be partially attributed to the increasing demand to invest in market and sector indexes. Despite their intended purpose to track indexes, exchange-traded funds have deviations in their performance as measured by tracking error. Exchange-traded funds attempt to control this tracking error by uniquely structuring themselves to encourage efficiency of institutional investors creating a mirror portfolio of the fund's holdings, and exchanging it for large blocks of exchange-traded fund shares. Institutional investors are attracted to participate in this exchange because of the reward of riskless profit. The arbitrage methodology thus suggests that tracking error and the illiquidity of the fund's underlying assets have a positive correlation and a statistical relationship, as long as investors continuously seek to arbitrage. The methodology further suggests, and recited in financial literature, that the least liquid exchange-traded funds have the largest tracking errors. This paper compares the least liquid funds to their tracking errors, and provides regression results suggesting that illiquidity does not always significantly contribute to tracking error as proposed.

Recent financial studies proved domestic exchange-traded funds are constantly subject to the arbitrage process to control their tracking error efficiently. Salomon Smith Barney Closed-End Funds Research Group conducted a study in October 2000 that concluded that the arbitrage process involving domestic exchange-traded funds was constant, and efficient, because the funds in the sample had relatively minute tracking

errors over periods of time. Robert Engle and Debojyoti Sarkar in their 2006 paper "Premiums-Discounts and Exchange-Traded Funds" freshly observed domestic funds over a period of time, and also supported that the arbitrage process in domestic exchange-traded funds was constant and efficient. The study similarly provided evidence that the funds in the sample had minimal tracking error over the examined period of time. Investors are constantly seeking to buy the underlying assets of domestic exchange-traded funds to engage in arbitrage and indirectly minimize tracking error. The illiquidity of underlying assets and tracking errors should thus move in unison in domestic funds.

Domestic exchange-traded funds should then exhibit a statistical significant relationship between illiquidity and tracking error, barring a fund is so liquid or illiquid that liquidity shocks have no affect on its tracking error. For example, a fund may be so liquid that it is continuously arbitraged despite a liquidity shock and tracking error remains minimal. A fund may also be so illiquid that it was never arbitraged, regardless of liquidity shocks, and tracking error remains extensive. Other domestic funds outside these extreme spectrums should have their tracking errors rise and fall in unison with illiquidity though. The more liquid the fund's underlying assets are, the more feasible the arbitrage process becomes to control tracking error (Cherkes 2009, Engle 2002, Elton 2002). This relationship cannot exist, however, if investors did not continuously seek to arbitrage domestic exchange-traded funds. Tracking error may have swelled when the underlying assets were liquid under inconsistent arbitrage, disintegrating the direct correlation between tracking error and illiquidity. Consistent arbitrage in domestic funds thus allows the arbitrage methodology to suggest, that all domestic tracking errors should be statistically affected by illiquidity unless the fund is extremely liquid or illiquid. The

arbitrage methodology further suggests, and recited by financial authors Dion and Meziani, that least liquid funds have persistent large tracking errors because the arbitrage process is less feasible in these funds.

This paper provides evidence suggesting the relationship between liquidity and tracking error is not as strong as the intuition and financial literature propose. The paper may have a relatively small sample size, but this paper utilizes a diverse sample size, innovations in liquidity measures, and innovations in joint-factor pricing to calculate regressions that suggests some domestic exchange-traded funds are inexplicably and statistically unaffected by liquidity. The inconsistent relationship between the least liquid funds having the largest tracking errors further suggests a weaker than proposed relationship between liquidity and tracking error.

The paper proceeds as follows. The next section will discuss the arbitrage methodology to further explain the intuition behind the relationship between liquidity and tracking error. Section III will define variables utilized in the paper's calculations, and Section IV presents the empirical evidence that suggests a weaker relationship between liquidity and tracking error exists. Section V concludes.

II. Arbitrage Methodology

The arbitrage process and how illiquidity should have a statistically significant relationship with tracking error can be highlighted with a simple example, and an explanation of exchange-traded fund structure.

Exchange-traded funds have a unique structure that encourages arbitrage. Exchange-traded funds are a hybrid of an open-ended fund and a close-ended fund

(Exchange). These hybrid funds allow investors to publicly trade its shares as in a close-ended fund, and offer shares to investors seeking to join the fund as in to an open-ended fund. Exchange-traded funds differ from traditional open-ended funds though because exchange-traded funds do not issue shares directly to investors (Exchange). Investors seeking to purchase shares from an exchange-traded fund must exchange a basket of securities that mirror the fund's portfolio, for a large block of shares called Creation Units priced at Net Asset Value.

Exchange-traded funds define their per-share value as Net Asset Value. Net Asset Value is the measure of the fund's underlying assets on a per-share basis.

$$NAV = \frac{\text{(asset value – liabilities)}}{\text{number of shares outstanding}}$$

Figure 1: Net Asset Value Equation.

The values of an exchange-traded fund's underlying assets are not always equal to Net Asset Value though. The fund's underlying assets, represented by the benchmark index's price sum of equities, are traded on a public market and frequently become subject to the market's supply and demand. An arbitrage opportunity is then created when Net Asset Value does not equal the fund's underlying assets.

The exchange-traded fund and the index it tracks are in equilibrium if the fund's Net Asset Value is equal to the index's price sum of equities. In this example, both the index's price sum of equities and the fund's Net Asset Value are at $100. An arbitrage opportunity is created, however, if the price sum of equities in the index drops 10% to

$90 while the exchange-traded fund drops 9% has a Net Asset Value of $91. Investors will exchange a mirror portfolio of the fund that cost $90 to replicate, for an exchange-traded fund's creation unit priced at $91. The investors sell the creation unit immediately to capture the risk free dollar. Investors may also buy the fund's shares off the market in exchange for a mirror portfolio, but this example highlights the other course of action. The buying of the mirror portfolio will push the index's price sum of equities up, and the new creation units from the fund will increase in the fund's shares outstanding, pushing the fund's Net Asset Value down. The exchange-traded fund and the value of the underlying assets will achieve equilibrium again as a result. Equilibrium also causes the discrepancy between the returns of the benchmark index and the exchange-traded fund, referred to as tracking error, to vanish. Buying the shares of a mirror portfolio may be a problem if the assets in the portfolio are illiquid though.

This arbitrage opportunity becomes less feasible as the exchange-traded fund's underlying assets become illiquid. Attaining equilibrium is complicated when an investor wishes to buy the cheaper equities, but cannot identify a seller of these assets. Tracking will then remain extensive until arbitrage is viable. The illiquidity and tracking error variables should thus move in unison and have a statistically significant relationship. This example also demonstrates how the least liquid funds will have a more challenging time conducting arbitrage and will have the largest tracking errors.

III. Variables

All variables are calculated on a monthly basis for sixty months.

Tracking Error

Tracking error is a measure of how well an exchange-traded fund tracks its benchmark index. It may be measured by two different methods, the mathematical method and the performance difference method.

Mathematically (also referred to as academically), tracking error is expressed as the standard deviation of the fund's returns and the benchmark's returns over a period of time (IShares). The standard deviation will be calculated as follows:

$$\sigma^2 = 1/(n - 1)\ \Sigma(x_i - y_i)^2$$

Figure 2: Standard Deviation Equation.

Where σ is the tracking error, n is the number of periods over which it is measured, x is the percentage return on the portfolio in period i, and y is the percentage return on the benchmark.

The Performance Difference method, however, defines tracking error as the difference between the historical performance of the fund and its benchmark. The Performance Difference method observes the difference between the net monthly cumulative returns of an exchange-traded fund and the calculated monthly returns of its

total return benchmark. The measured difference is performance difference tracking error. The total return index performances do not reflect any management fees, transaction costs or expenses (IShares).

This paper will implement both measures of tracking error to conduct all liquidity tests. Using both measures of tracking error will provide stronger empirical evidence that proposes the relationship between liquidity and tracker error is weaker than suggested.

Liquidity

Multiple strands of financial literature address the issue of measuring an exchange-traded fund's liquidity. An exchange-traded fund's liquidity should be measured by the liquidity of its underlying assets rather than its trading volume (McNally 2001, Spence 2002, Gastineau 2001). This paper will calculate the liquidity levels of the underlying assets with Amihud's measure of illiquidity, an effective liquidity measure that corresponds to liquidity shocks such as the 2008 recession and the worries of U.S. debt default in 2011. Amihud calculates illiquidity as follows (Amihud 2002):

$$ILLIQ^{i}_{t} = 1/D_{i,t}\sum^{Di,t}_{d=1}|R^{i}_{t,d}|/V^{i}_{t,d}$$

Figure 3: Amihud's Illiquidity Equation.

Where $D_{i,t}$ is the number of valid days in month *t* for stock *i*, and $R^{i}_{t,d}$ and $V^{i}_{t,d}$ are the stock *i*'s return and dollar volume (in millions) on day *d* in month *t* respectively. This equation measures the effect a given trading volume has on returns. This paper will take

the monthly holdings of an exchange-traded fund, and weight the illiquidity of each of the underlying assets by their market cap. The sum of these weighted illiquidity levels will provide the exchange-traded fund's monthly illiquidity measure.

Volatility

A common academic method of measuring market volatility is calculating realized volatility. Realized variance estimates have been widely used in financial literature to reduce the impact of market microstructure noise on estimates of the fundamental variance (Bandi 2008). Market microstructure noise refers to momentary fluctuations in the supply and demand of an asset due to information such as a dividend announcement. This paper will employ realized variance estimates constructed using 5-minute intervals, a common frequency seen in financial literature. The 5-minute intervals are an effective means of calculating volatility as they correlate to volatility shocks such as the 2008 recession and the worries of U.S. debt default in 2011.

The realized variance estimates will be derived from two sources: the Standard & Poor's 500 (S&P 500) and the Dow Jones Industrial Average (DJIA). The DJIA's realized variance estimates (5-minute intervals) will represent the market volatility for the S&P 500 exchange-traded fund's (IVV) statistical tests to avoid skewed data between the fund and market volatility. Skewed data would result otherwise because the S&P 500 exchange-traded fund and the S&P 500 are constructed of the same underlying assets with almost identical weights in the portfolio. All other fund's market volatility will be represented by the S&P 500's realized variance estimates using 5-minute intervals. Both

realized variance estimates constructed using 5-minute intervals were obtained from the database Oxford-Man Institute of Quantitative Finance.

IV. Data

Five exchange-traded funds have been chosen to examine the relationship between liquidity and tracking error. The selection criteria was (i) the exchange-traded fund had to be domestic because of evidence of consistent arbitrage efficiency in these funds, (ii) the exchange-traded fund had to of had five years of historical data in order to examine a statistically significant period of time, (iii) the exchange-traded fund had to be composed of equities because of the accessibility of data, and (iv) each exchange-traded fund had to be from a different level of "fund popularity" as measured by assets under management for a diverse sample size.

Table 1: Sample of Domestic Exchange-Traded Funds and their Assets Managed (As of Aug 31, 2011)

Exchange-Traded Funds	Net Assets
S&P 500 (IVV)	$26,250,084,781
Dow Jones Selected Dividend Index (DVY)	$7,124,264,416
Dow Jones U.S. Pharmaceuticals Index Fund (IHE)	$193,696,787
Dow Jones U.S. Aerospace & Defense (ITA)	$107,113,818
Dow Jones U.S. Insurance Index Fund (IAK)	$57,528,114

The selected sample was employed to test the hypothesis that the relationship between liquidity and tracking error is weaker than the arbitrage methodology and financial literature suggests. The relationship between liquidity and tracking error was explained previously by an example of exchange-traded fund arbitrage. Exchange-traded fund arbitrage becomes difficult to execute as the underlying assets become less liquid and larger tracking error is the consequence. A correlation causing a significant statistical relationship between illiquidity and tracking error should then exist for every domestic fund that isn't extremely liquid or illiquid. This statistical relationship is based on the evidence that domestic funds are persistently and efficiently arbitraged. This sample will provide data to examine if all domestic tracking errors are statistically affected by illiquidity and if the least liquid funds have the largest tracking errors.

Mathematical Tracking Error-Liquidity Regression

A regression of each fund's monthly illiquidity measures on their respective monthly mathematical measure tracking errors is utilized in order to observe if all tracking errors are statistically affected by liquidity. The regressions between illiquidity and mathematical tracking errors produce the results below, followed by each fund's average liquidity levels:

Table 2: Mathematical Tracking Error-Liquidity Regression Results

	ITA	IVV	IHE	IAK	DVY
Beta1	0.044451**	0.144752	0.226330**	0.095600**	0.014001
R-squared	0.1366	0.0561	0.3491	0.5085	0.0055

Beta1 = Illiquidity (t) coefficients
*=Significant at the 95% confidence level
**=Significant at the 99% confidence level

Table 3: Average Liquidity Levels of the Funds in Sample (Smallest to Largest)

Exchange-Traded Funds	Illiquidity
S&P 500 (IVV)	0.003337
Dow Jones U.S. Pharmaceuticals Index Fund (IHE)	0.013111
Dow Jones Selected Dividend Index (DVY)	0.03056
Dow Jones U.S. Aerospace & Defense (ITA)	0.033597
Dow Jones U.S. Insurance Index Fund (IAK)	0.061116

The above results indicate that the illiquidity of domestic exchange-traded funds does not always significantly contribute to tracking errors. The data should show that all domestic tracking errors have a direct correlation with the underlying assets' illiquidity levels, causing a significant statistical relationship between the two variables. This is the case with the Dow Jones U.S. Insurance Index Fund (IAK). The R-squared of the Dow Jones U.S. Insurance Index Fund (IAK) contributes 50.85% of its large mathematical tracking error to illiquidity. The S&P 500's (IVV) and the Dow Jones Selected Dividend

Index's (DVY) liquidity variables are not statistically significant though. The S&P 500 (IVV) fund is affected by liquidity when the confidence intervals are expanded to 90%, however, the data is not convincing enough for a statistically concrete relationship between liquidity and tracking error for the fund. One possible explanation for the fund's weak relationship is that it may be so liquid that any slight increases in illiquidity do not affect tracking error. It does have the lowest average illiquidity levels as seen in Table 3 for ease of arbitrage and the lowest tracking error to support the proposal of heavy arbitrage. The Dow Jones Selected Dividend Index's (DVY) liquidity levels are almost identical to the liquidity-affected Dow Jones U.S. Aerospace & Defense fund (ITA) though, and therefore cannot be subject to the possibility of liquidity levels that make it immune to illiquidity spikes. The Dow Jones Selected Dividend Index (DVY) should have its tracking error affected by liquidity. The fact that its variables do not have a statistically significant relationship suggests that some exchange-traded funds are not affected by liquidity, and the relationship between liquidity and tracking is weaker than suggested. The regression results do not discredit the proposed relationship to the extent that less liquid funds have larger tracking errors.

Average mathematical tracking error was computed and compared to the average liquidity levels to examine the relationship between less liquid funds and larger tracking errors. The table below lists the average mathematical tracking errors for each exchange-traded fund in the sample:

Table 4: Average Mathematical Tracking Error of Funds in Sample (Smallest to Largest)

Exchange-Traded Funds	Tracking Error
Dow Jones U.S. Aerospace & Defense (ITA)*	0.001441
S&P 500 (IVV)	0.001448
Dow Jones U.S. Pharmaceuticals Index Fund (IHE)*	0.001836
Dow Jones U.S. Insurance Index Fund (IAK)*	0.004128
Dow Jones Selected Dividend Index (DVY)	0.004216

*=liquidity was statistically significant

Note that the Dow Jones Insurance Index Fund (IAK) and the Dow Jones Selected Dividend Index (DVY) are the exchange-traded funds with the two largest mathematical tracking errors. The Dow Jones Insurance Index Fund (IAK), the most illiquid fund as measured by its average illiquidity level, has the second largest mathematical tracking error of the sample. This observation supports the idea that less liquid funds have larger tracking errors. The Dow Jones Selected Dividend Index (DVY), however, is not as illiquid as the Dow Jones Insurance Index Fund (IAK) and has relatively the same large mathematical tracking error. The Dow Jones Dividend Index's (DVY) liquidity levels instead resemble the relatively liquid Dow Jones U.S. Aerospace & Defense (ITA). The data suggests that the largest tracking errors are not always a result of being the most illiquid of funds. The relationship between liquidity and tracking error proposed by arbitrage methodology, and recited in financial literature, may be weaker than alleged.

Performance Difference Tracking Error-Liquidity Regression

A regression of each fund's monthly illiquidity measures on their monthly tracking errors is utilized in order to observe if all tracking errors are affected by liquidity again. These regressions, however, replace mathematical tracking error with performance difference tracking error. The regressions between illiquidity and performance difference tracking error produce the results below, followed by each fund's average liquidity levels again:

Table 5: Performance Difference Tracking Error-Liquidity Regression Results

	ITA	IVV	IHE	IAK	DVY
Beta1	-0.001452	0.022393**	0.023051*	-0.000267	0.029944**
R-squared	0.0026	0.2078	0.0981	0.0012	0.2542

Beta1 = Illiquidity (t) coefficients
*=Significant at the 95% confidence level
**=Significant at the 99% confidence level

Table 3: Average Liquidity Levels of the Funds in Sample (Smallest to Largest)

Exchange-Traded Funds	Illiquidity
S&P 500 (IVV)	0.003337
Dow Jones U.S. Pharmaceuticals Index Fund (IHE)	0.013111
Dow Jones Selected Dividend Index (DVY)	0.03056
Dow Jones U.S. Aerospace & Defense (ITA)	0.033597
Dow Jones U.S. Insurance Index Fund (IAK)	0.061116

The above results again indicate that the liquidity of domestic exchange-traded funds do not always contribute to tracking errors. The exchange-traded funds with the most liquid underlying assets in the sample were affected, but two of the most illiquid exchange-traded funds were unaffected. The issue of these two funds being immune to illiquidity spikes because they are extremely liquid is not relevant in this tracking error test. All of the more liquid funds were affected by the liquidity variable. It is possible, however, the two illiquid funds may be so illiquid that no investors attempt to participate in arbitrage and control their tracking error. The Dow Jones U.S. Aerospace & Defense (ITA) has a liquidity level almost identical to the Dow Jones Selected Index (DVY) though, so the idea that the Dow Jones U.S. Aerospace & Defense (ITA) fund is extremely illiquid is improbable. The Dow Jones U.S. Insurance Index Fund (IAK) may be immune to liquidity shocks, but it still leaves a portion of the sample that inexplicably and statistically unaffected by liquidity. The regression results again suggest that a weaker relationship between liquidity and tracking error exists, rather than the arbitrage methodology proposed one. The regression results do not submit evidence to examine the proposed relationship between the least liquid funds having the largest tracking errors.

Average performance difference tracking error was computed and compared to the average liquidity levels to examine the relationship between less liquid funds and larger tracking errors. The ranked performance difference tracking error is as follows:

Table 6: Average Performance Difference Tracking Error of Funds in Sample (Smallest to Largest)

Exchange-Traded Funds	Tracking Error
S&P 500 (IVV)*	0.000105
Dow Jones U.S. Insurance Index Fund (IAK)	0.000427
Dow Jones U.S. Pharmaceuticals Index Fund (IHE)*	0.000432
Dow Jones U.S. Aerospace & Defense (ITA)	0.000462
Dow Jones Selected Dividend Index (DVY)*	0.001505

*=liquidity was statistically significant

The observation above questions if large tracking errors can be contributed less liquid funds. The Dow Jones Selected Dividend Index (DVY) again has the largest tracking error and is not the most illiquid fund. The Dow Jones Insurance Index Fund (IAK) has a relatively small tracking error yet is the most illiquid fund. The evidence that the most illiquid fund had one of the smallest tracking errors in the sample, and the fund with the largest tracking error is relatively liquid, further enhances the suggestion that the relationship between tracking error and liquidity is weaker than arbitrage methodology and financial literature suggests.

In sum, (i) liquidity does not statistically affect all domestic exchange-traded fund's tracking errors, regardless of measure. Both tracking error tests produced results where liquidity unaccountably did not statistically affect tracking error. The Dow Jones Selected Dividend Index (DVY) was not statistically affected by liquidity in the mathematical tracking error test yet had similar liquidity levels to the statistically

liquidity-affected Dow Jones U.S. Aerospace & Defense (ITA) fund. Thus, the issue of the former fund being immune to illiquidity spikes is discredited. The two funds experienced a similar situation in the performance difference tracking error test except the roles were reversed. The Dow Jones Selected Dividend Index (DVY) was statistically affected by the liquidity variable, but the Dow Jones U.S. Aerospace & Defense (ITA) was not. The same intuition as to why the latter fund should not be immune to illiquidity spikes applies here as well. Also, (ii) the funds with the largest tracking errors were not the most illiquid of the sample. The Dow Jones U.S. Insurance Index Fund (IAK) from the mathematical tracking error test had an extensive tracking error and was the most illiquid, but the Dow Jones Selected Dividend Index (DVY) in the same test had a similar tracking error but was relatively liquid. The Dow Jones Selected Dividend Index (DVY) appeared as the fund with the largest tracking error again in the performance difference tracking error test, but it still remained a relatively liquid fund. The two observations that a portion of the sample was inexplicably and statistically unaffected by liquidity in both tests, and the most illiquid funds not possessing the largest tracking errors in both tests, suggest that the relationship between liquidity and tracking error is weaker than the arbitrage methodology and financial literature suggest.

Joint-factor Tracking Error Regressions

A recent strand of asset pricing literature questions the robustness of illiquidity when market volatility is combined to create a joint factor. The joint factor was created because

market volatility and illiquidity are positively correlated (Bandi 2008). In their findings, Bandi, Moise, and Russell prove volatility to be more robust than illiquidity in the effects of mispricing. Thus, it can be argued that the exchange-traded funds that appear to be unaffected by liquidity in the previous regressions are because volatility has driven out the effects. To examine if the relationship between tracking error and liquidity appears to be weak as this paper previously suggests, a regression of an illiquidity and volatility variable on mathematical and performance difference tracking error will be utilized.

The first regression using mathematical tracking error gives the following results:

Table 7: Liquidity and Volatility Joint-Factor Mathematical Tracking Error Regressions

	ITA	IVV	IHE	IAK	DVY
Beta1	-0.024432*	-0.005072	-0.005954	0.051489**	0.026060
Beta2	4.023469**	2.569652**	5.285905**	6.966539**	-1.831046
R-squared	0.7683	0.5625	0.7361	0.5706	0.0079

Beta1 = Illiquidity (t) coefficients
Beta2 =Volatility (t) coefficients
*=Significant at the 95% confidence level
**=Significant at the 99% confidence level

Compare these results to the mathematical tracking error regression using only the liquidity variable.

Table 2: Mathematical Tracking Error-Liquidity Regression Results

	ITA	IVV	IHE	IAK	DVY
Beta1	0.044451**	0.144752	0.226330**	0.095600**	0.014001
R-squared	0.1366	0.0561	0.3491	0.5085	0.0055

Beta1 = Illiquidity (t) coefficients
*=Significant at the 95% confidence level
**=Significant at the 99% confidence level

All of the exchange-traded funds in the joint-factor regression were statistically unaffected by volatility unless liquidity statistically affected them first in the single liquidity factor regression. The exception appears to be the S&P 500 (IVV) fund, however, when expanded to a 90% confidence interval in the single liquidity factor regression the S&P 500 (IVV) fund is actually statistically affected by liquidity. The relationship between liquidity and tracking error is simply weaker than the other domestic funds in the sample. The Dow Jones Selected Dividend Index (DVY) was not statistically affected by liquidity in the single liquidity factor regression though and is statistically unaffected by volatility in the joint-factor regression. Volatility does not appear to be driving out liquidity unless liquidity statistically affected the fund in the first regressions. Implementing innovations in joint-factor pricing seems to further support the suggestion that liquidity and tracking error have a weaker relationship than the arbitrage methodology and financial literature suggest.

The second regression utilizes performance difference tracking error. The results may be seen below:

Table 8: Liquidity and Volatility Joint-Factor Performance Difference Tracking Error Regressions

	ITA	IVV	IHE	IAK	DVY
Beta1	0.004747	0.019253**	-0.013653	-0.001635	0.054249**
Beta2	-0.362086*	0.053850	0.835238**	0.216033	-3.690377**
R-squared	0.0947	0.2422	0.3601	0.0198	0.3538

Beta1 = Illiquidity (t) coefficients
Beta2 =Volatility (t) coefficients
*=Significant at the 95% confidence level
**=Significant at the 99% confidence level

Compare these results to the performance difference tracking error regression using only the liquidity variable.

Table 5: Performance Difference Tracking Error-Liquidity Regression Results

	ITA	IVV	IHE	IAK	DVY
Beta1	-0.001452	0.022393**	0.023051*	-0.000267	0.029944**
R-squared	0.0026	0.2078	0.0981	0.0012	0.2542

Beta1 = Illiquidity (t) coefficients
*=Significant at the 95% confidence level
**=Significant at the 99% confidence level

Notice that most the exchange-traded funds were not statistically affected by volatility unless they were statistically affected by liquidity in the single liquidity factor regression. The Dow Jones U.S. Aerospace & Defense (ITA), however, is statistically affected by

volatility and was never statistically affected by liquidity. It can be argued that volatility pushed out liquidity so that is was never statistically affected by liquidity in the single liquidity factor regression, but its R-Squared in the joint-factor regression is 9.47%. It is a relatively weak R-Squared, where volatility accounts for 9.47% of tracking error movement. A more robust volatility factor would be required to render the fund invulnerable to the liquidity variable. It appears to be the case that the fund was never statistically affected by liquidity in the single liquidity factor regression. The innovative joint-factor tests from both tracking errors provide further support to the proposal that the relationship between liquidity and tracking error appears to be weaker than the arbitrage methodology suggests.

To summarize, volatility seems to only appear when liquidity was present in the fund's first single liquidity factor regression. The two cases when it didn't, the S&P 500 (IVV) fund in the mathematical tracking error regression and the Dow Jones U.S. Aerospace & Defense (ITA) in the performance difference tracking error regression, cannot be valid arguments. The S&P 500 (IVV) is affected by liquidity when expanded to a 90% confidence interval, and the weakness of Dow Jones U.S. Aerospace & Defense's (ITA) R-Squared seems to discredit the idea that volatility pushed out the presence of liquidity in the single factor regression. The fund was simply subject to volatility similar to any asset. Funds that were statistically unaffected by liquidity in the single liquidity factor regression remained statistically unaffected by liquidity and volatility in the joint-factor regression. The empirical evidence from these joint-factor regressions seems to further enhance the suggestion that the relationship between tracking error and liquidity is

weaker than the arbitrage methodology and financial literature suggest.

V. Conclusion

The relationship between liquidity and tracking error is not as established as the arbitrage methodology and financial literature proposes. When examining the relationship between tracking error and liquidity, the results of the study indicate that some domestic exchange-traded funds' tracking errors, regardless of measure, are not statistically affected by liquidity. A fund in both tracking error regressions was inexplicably unaffected by liquidity.

Using innovations in joint-factor pricing to account for volatility in the presence of liquidity, further supported the idea that liquidity does not significantly affect all tracking errors. Volatility was only present when liquidity affected the fund's tracking error in the first single liquidity factor regression.

The results of the study also suggest that larger tracking errors were not attributed to the most illiquid funds. The fund with the largest tracking error in both measures was relatively liquid. Some funds were illiquid and had relatively large tracking errors, but the inconsistency in the relationship between illiquid funds and large tracking errors suggests that is weaker than the arbitrage methodology and financial literature claim.

This paper does not aim to disprove the efficiency of arbitrage in domestic funds or claim that previous financial literature is false. The purpose of this study is to examine the strength of the relationship between liquidity and exchange-traded fund tracking error. The evidence it finds simply contributes to the increasing amount of exchange-traded fund research to gain a better understanding of them.

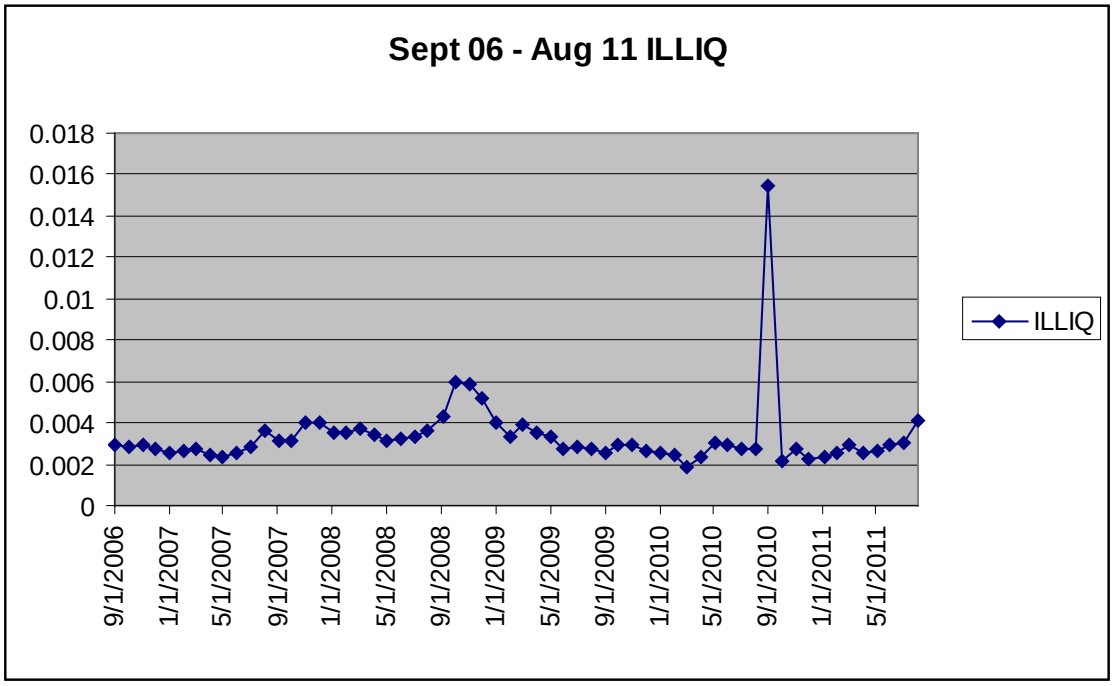
Appendix A

Effectiveness of Liquidity and Volatility Variables

This Appendix provides a discussion of the effectiveness of the liquidity and volatility variables used in the study. The following graphs are of market liquidity and market volatility using the respective measures found in this paper.

Amihud's measure of illiquidity is a reasonable measure as it corresponds to market illiquidity shocks. The following graph is of the S&P500's liquidity levels using Amihud's measure. Note that all significant illiquidity shocks rise above the 0.04 threshold.

Table 9: The Effectiveness of Amihud's Measure of Illiquidity

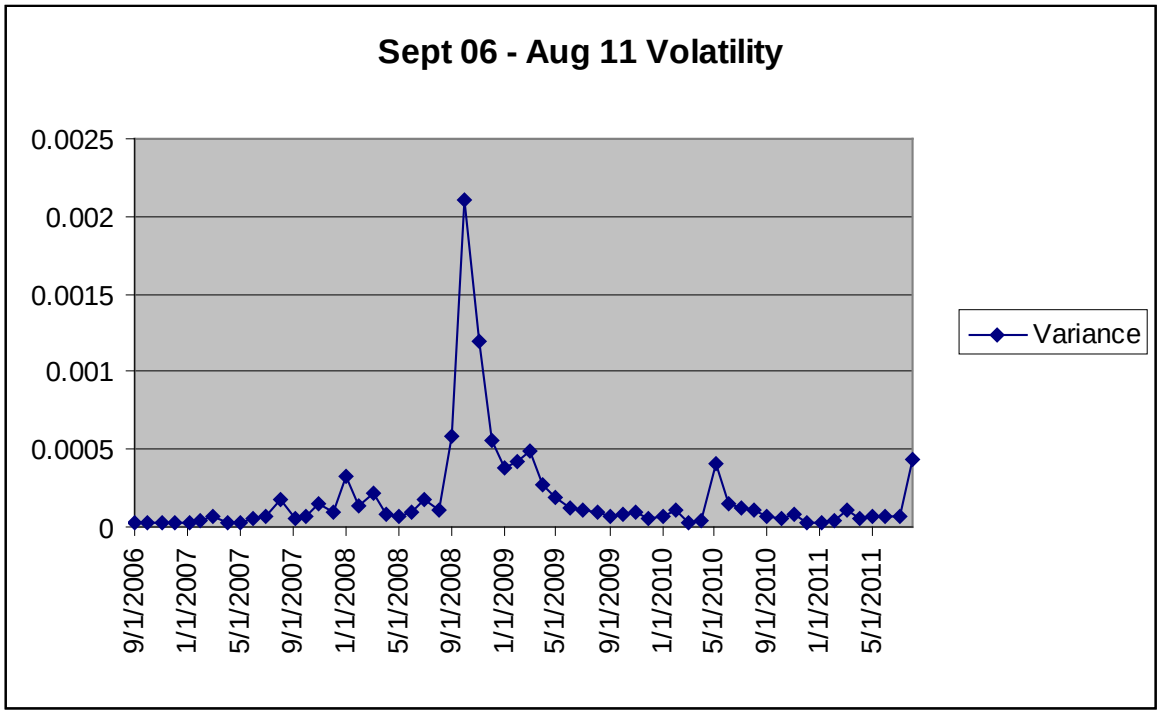


Aug 07 – Yale Economist Robert Shiller warns of further dramatic decreases in housing prices (Shiller); Panic in the Streets as Credit Markets Seize Up (Bougearel)
Nov 07 – Fed warns of Growth Scare (Torres)
Dec 07 - Recession fears continue to grow and credit markets continue to dry up (Bougearel)
Oct/Nov 08 – U.S. Recession (Baily)

Mar 09 – U.S. stock market bottoms (Badkar)
Sept 10 – Basel III proposal (Arnt); fear of market crash because of Hindenburg Omen tripped (Russolillo)
Aug 11 – U.S. credit rating downgraded on possibility of debt default (Wirz)

Realized variance estimates constructed at 5-minute intervals is a reasonable measure of market volatility as it corresponds to volatility shocks. The following graph illustrates the S&P500's volatility using realized variance estimates constructed at 5-minute intervals.

Table 10: The Effectiveness of Realized Variance Estimates Constructed at 5-Minute Intervals



Aug 07 – Panic in the Streets as Credit Markets Seize Up (Bougearel)
Jan 08 – Recession fears from 2007 continue (Bougearel)
Sept-Dec 08 – U.S. Recession (Baily)
Mar 09 – U.S. stock market bottoms (Badkar)
May 2010 – Flash Crash (Phillips)
Aug 2011 – U.S. credit rating downgraded on possibility of debt default (Wirz)

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ACADEMIC VITA

Jeffrey Cannon

EDUCATION

The Pennsylvania State University **University Park, PA**
Bachelor of Science in Finance, Minor in Economics *May 2012*
Honors: Schreyer Honors College, Beta Gamma Sigma Honors Society

EXTRA-CURRICULAR ACTIVITIES

Penn State Investment Association **University Park, PA**
Analyst, Financial Sector *Fall 2010-Present*

- Participating in an organization that provides research and analytical support for the Nittany Lion Fund, a $4 million portfolio of alumni investments managed by students
- Research and analyze equities using DCF's, public comparables, and financial ratios
- Gaining experience via attending supplemental educational sessions on topics such as the use of Bloomberg to research equities, market trends, and interpreting market news

Penn State Dance Mara(THON) **University Park, PA and Lehigh Valley, PA**
Fundraiser *2009-Present*

- Actively promoted awareness of the 46 hour philanthropic event that raises millions of dollars annually to support pediatric cancer care and research
- Raise funds through participation in "canning" events, soliciting donations in various state-wide locations

The Pennsylvania State University **Lehigh Valley, PA**
Research Assistant *May 2010 – July 2010*

- Researched and analyzed consumer discretionary equities with an Assistant Professor of Business Studies
- Recommended for financial research with the campus's premier finance professor due to strong performance and ability to learn quickly
- Valued McDonald's using DCF analysis and financial ratios; found the company to be properly valued