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Abstract

We investigate the diversification benefits and optimal portfolio allocation across different US asset classes. Our results from applying the principal component analysis (PCA) show that although there is an increasing trend in market integration, five major financial markets (equities, bonds, currencies, commodities, and real estate) appear to be weakly and at most moderately integrated. Applying the mean-variance portfolio simulations and out-of-sample analysis to evaluate the benefits of diversification, we find that adding new asset classes such as oil, precious metals, currency, and real estate into a traditional portfolio of stocks and bonds significantly improves its risk-adjusted performance. Diversification benefit is low during contagion periods defined as a period when correlation of residuals from PC regression is significantly different from zero. Nonetheless, an additional gain from diversification is greater during contagion periods than normal periods. Bonds provide the best hedge during contagion periods whereas stocks perform the best during normal periods.

Keywords: US asset classes, portfolio allocation, market integration, contagion, principal component analysis.
JEL classifications: G11, G12

1. Introduction

Diversification benefits might not be achieved when they are needed most during times of crisis or financial turbulences. Past studies have suggested that greater cross-market financial linkages as well as stock market contagion during crisis periods lead to the reduction of both national and international diversification benefits (Forbes and Rigobon, 2002; Chan-Lau et al., 2004; Bekaert et al., 2005; Lee et al., 2007; Diamandis, 2009; Markwat et al., 2009). Furthermore, Roll (2013) suggests the importance of diversifying across asset classes by opening his paper with two facts. First, even diversified portfolios such as the S&P500 index are quite volatile. The volatility of well-diversified portfolio of an asset class is much higher than the volatility of its constituents. Second, well-diversified portfolios within an asset class are highly correlated; nonetheless, well-diversified portfolios of different asset classes are less correlated. The first fact implies there is a unique systematic factor that limits diversification within an asset class and the second fact implies each asset class is mainly driven by its own unique factor. Our article shows, based on a newly developed measure of financial market integration, that investors can still obtain diversification benefits through a comprehensive and efficient combination of different asset classes. More importantly, the additional gain from diversification is higher during the contagion periods than during non-contagion periods.

High volatility and widespread contagion over the recent crises of the 1990s and 2000s have led investors to consider alternative investment opportunities as a hedge to diversify away the increasing risk in stock markets. Modern portfolio theory teaches that investors can improve the risk-adjusted return performance of their portfolios by allocating resources to imperfectly correlated assets. Real estate, bonds, commodities, and currencies thus emerge naturally as desirable asset classes eligible for portfolio diversification. Some studies, including among others, Fugazza and Nicodano (2009), Arouri and Nguyen (2010) and Daskalaki and Skiadopoulos (2011) show that these assets offer returns of lower correlations with stocks. Intuitively, the underlying factors that drive these alternative asset class returns may be distinct from those that move stock prices. Moreover, when risk aversion increases, particularly in times of market falling and vulnerability, most investors try to preserve their funds by investing in precious metals, bonds and real estate, viewed as the refugee or safe haven assets (Baur and Lucey, 2010; Baur and McDermott, 2010; Chan et al., 2011). For instance, Baur and Lucey (2010) show that gold serves as a safe haven for stocks in the US, the UK, and Germany especially after extreme negative shocks affecting stock markets. Gold is also a hedge for stocks in the US and the UK. Chan et al. (2011) find strong evidence of a flight to quality from stocks to bonds during the crisis regime.

Several studies have questioned the contribution of different asset classes to portfolio management (Cheung and Miu, 2010; Hammoudeh et al., 2010; Arouri et al., 2011; Daskalaki and Skiadopoulos, 2011; Su, 2011). They mainly report evidence to support the advantages of extending the set of assets held by investors to bonds, currencies, commodities, precious metals and real estate since their presence improves the Sharpe ratio of traditional portfolios of stocks. Another interesting finding is the regime-dependent behavior of the relationships across asset markets. Chan et al. (2011) suggest that stronger linkages observed over different asset markets (stocks, commodities, and real estate) in the crisis regime diminish portfolio diversification benefits. In an earlier attempt, Cheung and Miu (2010) document that the diversification benefits of commodities futures tend to concentrate only in a bullish commodity environment. This finding leads them to conclude that the low or negative static correlations do not imply that commodity futures will be a good cushion to stabilize the portfolio return when stock markets experience signs of instability and enter into bearish periods.

Although previous studies allow a better understanding of various asset class linkages and their associated diversification potential, they have had two major limitations. First, most of them treat these issues using the bilateral correlation approach. As noted by Carrieri et al. (2007) and Christoffersen et al. (2012), correlations are informative for building portfolio allocation strategies, but do not provide a complete and accurate measure of overall market integration. When using the correlation with a single factor (asset), one cannot fully account for the structure of risk. Simple correlations are not a good measure since they simplify the factor structure. One would need to incorporate the full covariance matrix, which is a very difficult task. Therefore, R-squares can help achieve this goal. Carrieri et al. (2007) and Pukthuanthong and Roll (2009) agree that there are multiple factors that should be used to measure integration. Carrieri et al. (2007) consider cross-listed securities as they are the assets that help with spanning. Similarly, Pukthuanthong and Roll (2009) argue that one cannot explain integration simply based on one factor, thereby the R-squares from a regression on a number of factors obtained from the principal component analysis in their case explain the spanned portion. Since the diversification benefits are related to the potential to increase spanning, the R-squares that measure integration will be inversely related to diversification benefits. Christoffersen et al. (2012) develop a new measure of diversification benefits, a dynamic copula model, by extending traditional correlation-based approaches to account for higher order moments and asymmetric dependences. Overall, there are many market integration approaches and thus it is impossible to apply all of them. We build on Pukthuanthong and Roll (2009)'s R-squares as it is intuitively efficient and simple to implement in our context.

Specifically, Pukthuanthong and Roll (2009) emphasize the inappropriateness of correlation as a proper measure of integration. Indeed, two highly integrated asset classes (markets) may have a low correlation. Recall that two assets are perfectly integrated if their returns are driven by the same common risk factors and there is no dependence of residual asset-specific return components. Thus, if returns on the two asset classes are affected by the same common factors but do not have the same sensitivities to all of them, the two asset classes are highly integrated but only weakly correlated. Inversely, independently of their correlation level, two asset classes are only weakly integrated when their returns are largely attributable to asset-class specific risks, and not driven by common factors. In this case, diversification within weakly integrated asset classes will reduce portfolio risk and improve its performance.

Additionally, Roll (2013) theoretically demonstrates that when combining a single asset with an existing portfolio or when evaluating the diversification benefit from combining two portfolios, the simple correlation is misleading in a multi-factor world. He thus suggests portfolios can be re-weighted so that risk profiles mimic one another. A mimicking portfolio has the same risk profile as the portfolio or asset being mimicked and the same sensitivities to the true underlying high frequency macro perception shocks that comprise the factor risk drivers. Under the engineered mimicking risk profile, the residual volatility that is not explained by the factors is the only thing that matters for diversification. In the limit, there is no residual volatility and thus no benefit of diversifying. Traditionally, diversification is believed to be most effective when assets or portfolios have low or negative correlation. Our study shows the R-square of the indexes on the portfolios, not correlation, is a better measure of potential diversification benefits; high R-square, low benefits. This finding should have significant implications for portfolio management and asset allocation. Furthermore, our results suggest the degree of integration varies over time consistent with Bekaert and Harvey, 1995; Pukthuanthong and Roll, 2009 and investors rebalance their portfolio with respect to expected asset class comovements consistent with Piplack and Straetmans, 2009.

Second, the existing works on the links among different asset classes only examine small subsets of assets and focuses mainly on principal pairs of asset classes: real estate and stocks (Liu et al., 1990), bonds and stocks (Baur, 2010), oil and stocks (Arouri and Nguyen, 2010), precious metals and stocks (Choi and Hammoudeh, 2010), currencies and stocks (Cumperayot et al., 2006), and currencies and gold (Pukthuanthong and Roll, 2011). Our sample includes several asset classes including stocks, bonds, currencies, real estate and commodities. It is also more refined as we include, for each asset class, all assets that have available data and are widely traded. That is, our sample is composed of 27 commodities, 20 currencies, stock indexes of 10 industries, 5 series of corporate and government bonds, and REIT. Moreover, while returns on different asset classes may be influenced by the same fundamental variables, none of previous studies has simultaneously analyzed their joint behavior and more importantly the common factors that drive the markets in which they are traded.[1] Proper asset allocations can only be made within a model accommodating the joint distribution of returns on different asset classes as well as their integration dynamics.

Thus, our study contributes to the extant literature in three main aspects. First, it provides

[1] Lin and Lin (2011) find for example that stock and real estate prices are commonly driven by economic growth and interest rates.

thorough analyses of diversification benefits for a set of different tradable asset classes within the United States, unlike the existing studies that focus only on some subsets of asset classes as discussed above. Although Chan et al. (2011) have examined the linkages between returns over several asset classes in the United States (stocks, treasury bonds, gold, oil and real estate), they focus on one or two assets within each class and their Markov-switching approach only allows to model the joint behavior of asset class returns, but not their integration dynamics over time. Such a framework does not favor any conclusive assessment about diversification benefits as well as their evolution over the short- and long-run. Second, we introduce a new way of measuring asset-class market integration based on principal component analysis (PCA) and examine the relative potential of diversification benefits across asset classes. Our measure of integration, initially developed by Pukthuanthong and Roll (2009) from the explanatory power of a multifactor asset pricing model applied to national stock markets, is advantageous in that it reflects the sensitivities of each asset class to common economic fundamentals. If the proportion of an asset class return explained by common factors is low, the considered asset class is weakly integrated with other asset classes and its return is rather determined by the asset-class specific effects; thus diversification is beneficial. In contrast, if that proportion is high, the influences of common factors on the asset class returns are large and expected gains for diversification are small. Finally, we take advantage of our PC analysis to study contagion across asset classes and investigate its effects on gains from diversification. Of course, any statements on contagion are contingent on the correct specification of common factors. In our approach, these common factors are directly inferred from the PC analysis. Contagion is simply defined by the correlation of the residuals from the PC regressions. Thus, in contrast to previous works on contagion, our approach avoids disagreement on the definitions of the fundamentals as well as the mechanism that links fundamentals to asset returns, and properly tests for contagion and how it affects diversification.

Our empirical results offer many interesting insights about the diversifying potential of different asset classes. The integration analysis shows that all of the asset classes we considered have been integrated with the others at various degrees over time. They display an increasing integration with other classes during the 2008 to 2010 period (bearish market phase), compared to the 2004-2007 period (bullish market phase). Although the general trend of integration is increasing, on average our assets remain only weakly and at most moderately integrated within each particular class and with the other classes. These findings thus suggest rooms for obtaining substantial diversification benefits, during both bear and bull market periods despite a tendency of their reduction over the recent periods. Our results are, to a large extent, consistent with those of Chan et al. (2011) revealing a decrease in diversification benefits during crisis times, but we show that not all asset classes are alike. For example, we find that all types of bonds are less integrated with other classes over time except during the 2008 to 2010 period. Among the commodities, only gold experiences a decrease in integration with other classes over the same period. In addition, REIT integration with bond, commodity and currency is quite low and only increases slightly during the 2008-2010 period.

With respect to the mean-variance analysis for different portfolios built from different combinations of five asset classes, we find consistent results with the integration analysis. Among all 31 portfolios, the portfolio with all asset classes, composed of 23.4% of bonds, 34.3% of currencies, 21.8% of stocks, 10.3% of commodities, and 10.2% of real estate yields the highest Sharpe ratio. The second (third) highest Sharpe ratio portfolio is composed of 46.53% currency, 28.41% stocks, 12.96% commodities, and 12.10% real estate (25.61% bond, 31.49% currency, 29.76% stocks, and 13.14% real estate). In addition to applying the Sharpe ratio as a standard measure of diversification benefits, we apply Generalized Sharpe ratio and the Sharpe ratio that applies Value-at-Risk (VaR) as a measure of risk to take into account higher moments and non-normal distribution of returns. Interestingly, our findings using these modified measures are consistent with those obtained by applying the standard Sharpe ratio. We further examine asset allocation during contagion periods vs. non-contagion periods where a contagion period is defined as a period with correlation of residuals from the PC regressions being significantly different from zero. Although diversification benefit is lower during contagion periods, an additional gain from diversification is higher during contagion periods than during normal periods. Moreover, among portfolios with different combinations of four assets, portfolios with no bonds perform the worst during contagion periods whereas portfolios without stock perform the worst during non-contagion periods.

2. Data

We collect the data of the US assets from different classes. Narrowly focusing only on the US data allows us to provide a comprehensive analysis of integration across different asset classes and thus to have a clean experiment of studying asset class diversification. Moreover, our choice of only US assets is motivated by the large home bias phenomenon in the US as documented by several previous works on international portfolio diversification (Lewis, 1999; Chan et al., 2005). Accordingly, our study may underestimate the true diversification benefit at international level. Our daily data of assets in the US come from a variety of sources as described below.

2.1 US Stock Selection

We download US stock indexes across 10 industries from the Center for Research in Security Prices (CRSP). They include Health Care, Consumer Discretionary, Energy, Finance, Industrials, Telecom, Materials, Consumer Staples, Information Technology, and Utilities. The data cover the sample period from September 1989 to December 2010.

2.2 Currencies

The series of spot exchange rates per USD from DataStream consist of the following currencies: Australia, Canada, China, Denmark, Germany spliced with the Euro, Hong Kong, India, Japan, Mexico, New Zealand, Norway, Singapore, South Korea, South Africa, Sri Lanka, Sweden, Switzerland, Taiwan, Thailand, and U.K. The data cover the period January 1971 to December 2010.

2.3 Bonds

We collect data on BAA and AAA corporate bond index returns, and Barclays US Aggregate bond index returns from DataStream, and 5-year and 30-year government bond yields from Bloomberg. The sample of returns covers the period January 1989 to December 2010.

2.4 Commodities

We cover 27 different commodity futures. Our data on Brent Crude Oil are from Intercontinental Exchange (ICE), Live Cattle, Feeder Cattle, and Lean Hogs are from Chicago Mercantile Exchange (CME), Corn, Soybean, Soybean Meal, Soybean Oil, and Wheat are from Chicago Board of Trade (CBOT), WTI Crude Oil is from New York Mercantile Exchange (NYMEX), Gold and Silver are from New York Commodities Exchange (COMEX), and Cotton, Coffee, Cocoa, and Sugar are from New York Board of Trade (NYBOT). We also include Goldman Sachs commodity index (GSCI). The commodities sample covers the period January 1989 to December 2010 (with the minimum number of commodities being 10 at any point in time).[2]

2.5 Real Estate

We include value-weighted of real estate investment trust (REIT) index. The REIT sample covers the period January 1980 to December 2010. We also apply S&P/Case-Shiller index and the results remain intact.[3]

Table 1 presents descriptive statistics of the daily returns on our assets including mean, median, maximum, minimum, standard deviation, skewness, kurtosis, number of observations, and the starting date of our data. Our data ends in December 2010. We see a significant variation in sample mean returns across different assets. Real estate, equity, bonds, and commodities yield predominantly positive returns, while various currencies yield positive, zero or negative average returns over the sample period. Only equity exhibits significant and consistent positive average returns especially for information technology, health care, energy, and consumer staples that yield daily return of 4 to 5%. Fourteen out of sixteen commodities have positive return; WTI crude oil, Brent crude oil, and silver yield higher positive returns than the others. Three out of nineteen currencies have negative returns.

[2] We have also split the universe of commodities in half into a liquid and illiquid set based on open interest and trading volume and get consistent results using only the most liquid commodity contracts. We also get similar results if we weight the commodities by their open interest in the portfolios.

[3] Case and Shiller index is only available on a monthly basis. To apply it to our data, we convert daily returns of all asset classes into monthly returns. Due to limited space, we do not report the results here but they are available upon request.

*** Insert Table 1 about here ***

More striking are the differences in volatilities (standard devisions) across the assets. Not surprisingly, commodities (1.00-2.48%), equities (1.00-1.89%), and real estate (1.53%) have much higher volatilities than bonds (0.26-0.82%) and currencies (0.24-0.88%). Even among the commodities, there is substantial cross-sectional variation in volatilities. One issue is thus how to compare across instruments or how to combine various instruments into a diversified portfolio when they have vastly different volatilities. For example, the volatility of Brent crude oil futures is almost 9 times larger than that of Barclays US aggregate and 5-year Treasury notes. We discuss below how we deal with this issue empirically.

3. Market integration analysis

3.1 Principal component (PC) analysis

We examine the extent to which asset classes are integrated within the US by extending the integration measure developed by Pukthuanthong and Roll (2009). Specifically, these authors consider levels of world integration across a broad sample of developed, emerging, and frontier countries by regressing daily country index returns on their ten global factors or principle components (PCs). These factors are estimated by out-of-sample PCs on the covariance matrix in the previous calendar year computed with the returns from 17 major countries, the "pre-1974 cohort" described in their paper. Their 10 PCs explain approximately 70% of stock return variation. In their analysis, the R-square from the regression provides a measure of the world market integration.

We consider the US asset classes and construct PCs using daily returns of all classes from September 1989 to December 2010 when all assets have data available. For classes that have number of assets fewer than ten such as bonds, we make sure that the number of PCs we extract explain at least 70% of the variation of asset returns. With this approach, the adjusted R-square measures the proportion of an index's return that is explained by common factors. Below, we discuss the intuition behind this approach and in particular show why correlation, typically used to infer portfolio diversification benefits, is not a good indicator of market integration and diverfication gain evolutions.

3.2 Correlation versus market integration and benefits from diversfication

To measure the integration between two asset classes, A and B, we assume that returns are determined by *p* common factors as follows

$$R(i,t) = a(i) + \sum_{j=1}^{p} \beta(i,j)\ f(j,t) + e(i,t) \quad ; \quad i = A, B \tag{1}$$

where *R(i,t)* is the return of asset *i*'s index at time *t*, the β's are sensitivity coefficients and the *f*'s are common factors at time *t*.

We claim that these two asset classes are completely integrated when *e(A,t)=e(B,t)=0* for all *t*. In that case, their returns are completely driven by the same underlying factors and there are no residual asset-specific return compenents independent across the assets. We can prove that the correlation of *R(A,t)* and *R(B,t)* is less than +1 provided that the following condition is not met: $\beta(A, j) = k\ \beta(B, j)$ with $j = 1,2,..., p$ for some positive constant *k*. If all "betas" are exactly proportional across the two assets, the correlation is +1; otherwise it is not. This condition is proved by simply applying the Cauchy inequality. In practice, the betas can be different for the two assets for several reasons. The simplest reason is that, for example, bond is directly driven by interest rate whereas stock is more likely driven by expected growth of economic variables. Commodities on the other hand are well known for hedging inflation and real estate market tends to co-move with stock market. Although each asset class might be subject to the same economic factors, the magnitude of each factor's impact on each asset class is different.

We therefore make the same statement as in Pukthuanthong and Roll (2009) that perfect integration when assets are completely and exclusively driven by the same global factors does not imply perfect correlation. If there are multiple factors driving returns in each asset, the same analogous condition obtains unless all the betas in one asset are proportional to the betas in its companion asset; that is, the simple correlation of asset returns is strictly less than +1. In our empirical investigation, we extract different factors that explain at least 70% of return variation of studying assets. All in all, we think that the correlation between broad asset indexes is not a very good measure of integration as well as not a very good indicator of the benefits of diversification. As an example, consider class A and class B that are perfectly integrated according to our R-square metric but whose broad market indexes are imperfectly correlated (because the indexes factor exposures are *not* proportional). Provided that there are sufficient numbers of individual assets within the two classes and that portfolios can be constructed freely, meaning that short positions are possible if necessary, a portfolio can be structured from class B's individual assets to have factor exposures that exactly match the broad market index from class A. If such a structured portfolio is well-diversified, it will be highly correlated with class A's market index. Indeed, if perfect diversification could be achieved, the correlation would also be perfect. It follows that there is *no* benefit whatsoever from diversifying between these two asset classes even though their market indexes exhibit imperfect correlation. There might, however, be a pure arbitrage if the mean returns differ between class A's market index and class B's structured portfolio.

In reality, of course, market indexes do not have R-squares of 1.0 on global asset factors. There is some remaining asset-specific volatility even when the indexes are very well-diversified. So, there is <u>some</u> benefit from diversifying away asset-specific risk, but this benefit declines as the R-square increases. Consequently, the multi-factor R-square is also a *better* indicator of diversification benefits across asset classes than the simple correlation between asset class index returns used by the majority of works focusing on diversification benefits. Roll (2013) demonstrates that simple correlation is one-dimensional and fails to properly measure the potential benefits of diversification.

3.3 Ex-ante volatility estimate

Table 1 shows that volatility varies dramatically across our asset classes. We follow Moskowitz et al. (2012) and scale the returns by their volatilities in order to make meaningful comparisons across assets. We estimate each asset's ex-ante volatility σ_t at each point in time using an extremely simple model: the exponentially-weighted lagged squared daily returns. Specifically, the ex-ante annualized variance σ_t^2 for each asset is calculated as follows:

$$\sigma_t^2 = 261 \cdot \sum_{i=0}^{\infty} (1-\delta)\delta^i (r_{t-1-i} - \bar{r}_t)^2 \qquad (2)$$

where the factor 261 scales the variance to be annual, the weights $(1-\delta)\delta^i$ add up to 1, and $\bar{r}_t$ is the exponentially weighted average return computed similarly. The parameter δ is chosen so that the center of mass of the weights is $\sum_{i=0}^{\infty}(1-\delta)\delta^i$ where $i = \frac{\delta}{1-\delta}$ = 60 days. The volatility model is the same for all assets at all times. While all of the results in the paper are robust to more sophisticated volatility models, we choose this model due to its simplicity and lack of look-ahead bias in the volatility estimate. To ensure no look-ahead bias contaminates our results, we use the volatility estimates at time *t*-1 applied to time *t* returns throughout the analysis.

3.4 Asset class integration

Table 2 presents the adjusted R-squares from regressing the returns of each asset on ten PCs constructed from other asset classes. The adjusted R-squares of commodity returns on the PCs constructed from other assets together is 12.07% while the adjusted R-squares of commodities on PCs constructed independently from bonds, currencies, stocks, real estate, and GSCI index are 1.53%, 14.44%, 3.50%, 1.64%, and 38.56%, respectively, suggesting that commodities are most integrated with GSCI index, then currencies, stocks, real estate, and bonds, respectively. Bonds are most integrated with stocks and least integrated with GSCI index. Nonetheless, the degrees of bond integration with other asset classes are close to zero and do not vary much as the adjusted R-squares of bond returns on PCs of different asset returns range from 0.13% to 1.39%. Currencies are most integrated with commodities and least integrated with bonds. Stocks are most integrated with real estate with adjusted R-squares of 42.37% but negatively integrated with GSCI index with an integration of -0.01%. Real estate is most integrated with stocks with adjusted R-squares of 45.82% and least integrated with commodities with adjusted R-squares of 1.3%. Since real estate has become securitized, risk in the real estate market has tied more closely to overall equity market and thus a portfolio of real estate and stocks provides small diversification benefit. Among all assets, real estate is highly integrated with other classes with adjusted R-squares of 32.62% mainly due to their integration with stocks while bonds are least integrated with others with adjusted R-squares of 2.32%. With a portfolio of two assets, commodities and bond, GSCI index and stocks, bonds and GSCI index, and currencies and bonds yield lowest risk as the asset in each pair is least integrated to its counterpart. The results of mean-variance analysis in Section 4 show that, among the 10 optimized mean-variance portfolios of various 2 assets combinations, a portfolio of bond and commodities has lowest standard deviation.

*** Insert Table 2 about here ***

3.5 Integration of each asset in particular class

Next, we study integration of assets in each class with other asset classes. Most commodies are highly integrated with GSCI index except for feeder cattle and lean hogs. All commodities are least integrated with real estate and bonds with adjusted R-squares less than 1%. Among all commodities, gold and silver are the most integrated with other classes with adjusted R-squares of 9.13% to 9.90%, which is expected as gold and silver are regarded as safe-haven assets and thus widely invested. On the other hand, lean hogs, live cattle, feeder cattle, and coffee are least integrated with other classes with adjusted R-squares less than 1%.

Different grade bonds have different degrees of integration. 5-year Treasury notes and corporate bonds including BAA and AAA grades are mostly integrated with stocks. Most bonds are least integrated with GSCI and real estate. Aggregate corporate bond index is mostly integrated currencies but least integrated with real estate. A portfolio of bonds and GSCI index or that of bonds and commodities diversifies risk well. Among bonds, Barclay aggregate bond index is least integrated with other classes together with adjusted R-squares of 3.5% while BAA bonds are most integrated with other classes with adjusted R-squares of 6.74%. The diversified nature of the Barclay aggregate bond index (i.e., mixed set of Treasury securities, Government agency bonds, mortgage-backed bonds, corporate bonds, and foreign bonds traded in the US) may lower its exposures to common risk factors with other asset classes.

For stocks, all ten sectors are mostly integrated with real estate with adjusted R-squares ranging from 15.71% for healthcare to 52.99% for finance sector and least integrated with GSCI index. Seven out of ten stock sectors are negatively integrated with GSCI index with absolute value of adjusted R-squares of 0% to 0.02%. As some commodities such as gold tend to have more value during recession periods or when stock markets do not perform well, commodities have lowest integration with stocks of all industries. A portfolio of stocks and commodities should provide the highest diversification benefit. Among the 10 sectors of equity, energy is mostly integrated with other assets altogether with adjusted R-squares of 14.34% while comsumer staples are least integrated with adjusted R-squares of 1.81%. Energy prices depend on many factors, some of which might be an underlying factor of other asset classes. Moreover, energy, whatever the type, has both direct and indirect interactions with the other economic sectors. In contrast, consumer surplus sector consists of goods and services whose demand does not change considerably through time; as such, this sector has modest integration with other asset classes. Stocks of this industry are commonly viewed by investors as non-cyclical or defensive securities that generate profit regardless of economic fluctuations.

Interestingly, all currencies are mostly integrated with commodities except for Japanese Yen and Euro, which are mostly integrated with stocks. Surprisingly, Japanese Yen has low integration with other assets ranging from 0.03% to 0.51%; although, Yen is well known as one of the most liquid currencies and it is traded considerably by carry traders. Besides, Japan is also one of the largest exporters in the world. Australian Dollar, Canadian Dollar, and New Zealand Dollar have the highest integration with commodities with adjusted R-squares of 10.44%, 9.51%, and 8.11%, respectively. These three countries are indeed the largest commodities exporters, especially to China. Sri Lanka Rupee is negatively integrated with most assets, but we are hesitant to draw any conclusion because its trading volume is low. Half of all currencies is least integrated with bonds and another half is least integrated with real estate. Hong Kong Dollar (HKD) is negatively related to bonds and stocks suggesting a portfolio of HKD, bonds, and stocks might have low standard devation. With all of other asset classes, Australian Dollar, Canadian Dollar and New Zealand Dollar are mostly integrated with other asset classes (adjusted R-squares of 9.56%, 9.14% and 7.63% respectively), whereas Hong Kong Dollar, Chinese Yuan, Sri Lankan Rupees, Thai Baht, Taiwanese Dollar, and South Korean Won are least integrated (adjusted R-squares less than 1%).

3.6 Integration of commodities with other asset classes

Figure 1 plots integration of commodities with other classes across time. Table 2 shows that gold and silver are mostly integrated with other classes whereas lean hog is least integrated. Table 3 shows there is a distinguishing trend of integration of all commodities with other classes altogether. All commodities have an increasing integration with other classes except for gold that is less integrated with other assets during the period 2008-2010, compared to 2004-2007. Gold integration with other classes reduced by 5% whereas GSCI, soybean oil, and Brent crude oil have an increase in adjusted R-squares of 34%, 29%, and 26% during the same period. It is not surprising as GSCI is mainly composed of crude oil (You and

Daigler, 2010), which is one of the most traded commodities in the world today.

As well, we show integration of commodities with each asset class. Commodities are not highly integrated with bonds with adjusted R-squares between 0.07% and 1.64%. However, most commodities have increasing trend in integration with bonds except for gold and silver that are less integrated during 2008-2010. Commodities are mostly integrated with currencies, and gold and silver have the highest integration during both 1989-1999 and 2000-2010 periods. The less integration of gold with other asset classes during 2008-2010 compared to 2004-2007 may be attributed to its less integration with currencies. During this time period, adjusted R-squares of gold returns to currency PCs decreases by 12.97% while other commodities are more integrated with currencies especially Brent crude oil, GSCI, and soybean oil, which have an increase in integration of about 26% for the first two and about 22% for soybean oil.

Gold, silver, WTI crude oil and Brent crude oil are less integrated with stocks during 1994-1998 compared to 1989-1993. WTI and Brent crude oils have an increasing integration with stocks from 2004 whereas gold and silver are also less integrated with stocks and real estate during 2008-2010 compared to 2004-2007.

*** Insert Table 3 about here ***

*** Insert Figure 1 about here ***

Next, Table 4 shows a time-trend regression of adjusted R-squares of individual assets on each asset and all asset classes altogether. Although gold appears to be less integrated with other assets during the last three years of the sample period, it displays significant and increasing integration over time with t-stat of 4.86. In addition, Brent crude oil, WTI crude oil, silver, and soybean oil are significantly increasingly integrated with other classes. What contributes to such a significant increase in integration of these assets?

We investigate further by performing integration of commodities returns on each class. We find that 8 out of 16 commodities are more integrated with currency and stocks over time. 6 commodities have increasingly positively integrated with real estate. The degree of integration with stocks is most astonishing for Brent crude oil and WTI crude oil (t-stat of 7.4 and 8.4, respectively). Corn, soybean oil, and gold are also increasingly integrated with stocks with t-stat of 3.5. With real estate, Brent crude oil and WTI crude oil are increasingly integrated. Although gold appears to be increasingly integrated with other classes, it is significantly integrated only with currency and stocks but not with bonds and real estate.

*** Insert Table 4 about here ***

3.7 Integration of bonds with other classes

In contrast to commodities, we find all types of bonds in our sample are less integrated with other classes over time except during 2008-2010 compared to 2004-2007 when bonds, especially 30-year T-bond and BAA bonds, become more integrated with an increase in adjusted R-squares of 13%. We investigate bond integration with individual classes (Table 5). With commodities, bonds are less integrated except during 2008-2010 compared to 2004-2007 when there is sharp increase in integration of bonds with commodities. The same pattern is found for the bond integration with real estate. The increasing integration of bonds with currencies is more distinguished. With stocks, there is a sharp decrease of bond integration during 1999-2003 compared to 1994-1998. A decrease in integration is about 15% to 18% for 30-year T-bond, BAA and AAA bonds. After 2003 integration of bonds with stocks has been slowly increasing and has a significant incline in integration during 2008-2010. Taken together, bond has an increasing integration with currencies and stocks from 2004 to 2010 and with commodities and REITs only from 2008. In absolute term, bonds have highest degree of integration with stocks but are less integrated over time, which suggests that investors tend to invest in bonds and stocks with respect to different market phases. During the bull market of 1999-2003, bonds are highly disintegrated with stocks but during the bear period, they are highly integrated, consistent with the evidence shown by market integration literature such as Pukthuanthong and Roll (2009) that adjusted R-squares are higher during bear markets than bull markets.

*** Insert Table 5 about here ***

*** Insert Figure 2 about here ***

Although sub-period analysis shows an increasing integration of bonds with other classes, the time trend analysis in Table 6 shows they are less integrated with other classes over time, especially AAA bonds and aggreage bond index. What contributes to disintegration? Interestingly, bonds are increasingly integrated with currency over time but decreasingly integrated with stocks and REITs. They have an insignificant time trend integration with commodities. With stocks, all bonds are decreasingly integrated over time but with REITs, only corporate bonds are.

*** Insert Table 6 about here ***

3.8 Integration of currencies with other classes

While currencies of most developed countries except for Japanese Yen are increasingly integrated with other asset classes, currencies of emerging countries such as Chinese Yuan, Hong Kong Dollar, Indian Rupee, South Korean Won, Mexican Peso, Sri Lankan Rupee and Thai Baht are not. Australian Dollar, Canadian Dollar, New Zealand Dollar, and Singapore Dollar have the most dramatic increase in integration with other classes with an increase in adjusted R-squares of 20% to 21% during 2008-2010 compared to 2004-2007 (Table 7). Trading volume of these currencies is also high during the past few years (Bank of International Settlement, 2011). We find that such a sharp increase integration is mostly attributed to an increase in integration with commodities. With bonds, most currencies have an increasing trend of integration; although, it is not dramatic as much as integration with commodities. Some currencies such as Danish Krone and Swiss Franc are less integrated with bonds. Astonishingly, Japanese Yen has been disintegrated with bonds from 1989 to 2003, but then had a jump of 8% in adjusted R-squares during 2004-2007 compared to 1999-2003 and another jump of 8% during 2008-2010 compared to 2004-2007. Most currencies have a sharp increase in integration with stocks except for Swiss Franc that has a decrease in adjusted R-square of 4% and 2% during 2004-2007 and 2008-2010 compared to the previous three years, respectively. Compared to other asset classes, currency is least integrated with real estate and shows least change in integration. Similar to other classes, currency integration with real estate increases during 2008-2010 compared to 2004-2007. Japanese Yen and Singapore Dollar have the highest increase in adjusted R-squares of 5%-6% during 2008-2010.

*** Insert Table 7 about here ***

*** Insert Figure 3 about here ***

Table 8 shows adjusted R-squares regression on time trend. Consistent with sub-period analysis, most currencies are increasingly integrated with other classes over time. Although Japanese Yen has the most increasing integration with bond (with t-stat of 5.4) and moderate increasing integration with stocks and real estate, it is not increasingly integrated over time with all asset classes due particularly to its disintegration with commodities. Albeit insignificant, Chinese Yuan has a negative time trend in market integration with other asset classes. This is not surprising as Yuan is controlled by the Chinese government and thus its currency value is independent of other currencies' movement.

Korean Won and Thai Baht are among a few currencies that have *no* significant pattern of integration with any asset. Taiwanese Dollar is only integrated with bonds. Danish Krone, Swiss Franc, and British pound are increasingly integrated only with commodities. Mexican Peso is only integrated with stocks. Swedish Krone and Indian Rupee are increasingly integrated with commodity and REITs. Singarpore Dollar is integrated with commodities, bonds, and real estate. Norwegian Krone and South African Rand are integrated with commodities, stocks, and real estate. Canadian Dollar and Australian Dollar are increasingly integrated with *all* classes over time.

*** Insert Table 8 about here ***

3.9 Integration of stocks with other classes

Table 9 shows a steep increase in integration of stocks with other classes during 2008-2010. Overall, consumer discretionary, finance, industrials, materials and information technology have highest increase in integration of about 43% to 47%. Energy, utilities, and health care have least increase in integration of 20%. *All* stock industry sectors have an increasing trend of integration. Noticeably, energy has a sharp increase in adjusted R-squares from 8.37% during 1999-2003 to 16.22% during 2004-2007. Although its integration with commodities increases during 2008-2010, such increase is only 7%. Materials show a sharpest increase with commodities during 2008-2010 with a jump in adjusted R-squares of 17%. With bonds, all industrial sectors are more integrated from 2004 to 2010. They are disintegrated with bonds during 1994-1998 compared to 1989-1993, however. Stocks are also highly integrated with currencies. Materials have been increasingly integrated with currencies from 2004 to 2010 with an increase of about 11% and 15% in adjusted R-squares in both two sub-periods, respectively. Amazingly, stocks are mostly integrated with real estate. Finance sector is mostly integrated with real estate during 2008-2010 with adjusted R-squares of 76%. Overall, all industrial sectors show an increasing integration with real estate during 2004 to 2010. Health care, consumer discretionary, finance, industrials, and consume staples are less integrated during 1994-1998 compared to 1989-1993.

*** Insert Table 9 about here ***

*** Insert Figure 4 about here ***

Table 10 shows that stocks of all industrial sectors are increasingly integrated with other asset classes over time especially for energy and materials with the highest t-stat of 8.2 and 6.7, respectively. Such an increasing integration is explained by an increasing integration of stocks with commodities, currencies, and real estate, not with bonds over time. The integration of most industrial sectors with bonds do not significantly increase over time except for the information technology. Effectively, finance, telecom, and utitlies show a disintegration with bonds. That is, when bond market is doing well, finance, telecom, and utilities perform the opposite.

*** Insert Table 10 about here ***

3.10 Integration of real estate with other classes

Figure 5 and Table 11 illustrate a clear increasing pattern of real estate integration with other classes especially stocks. Real estate integration with other classes increased from 5.83% during 1989-1999 to about 40% during 2000-2010. Its highest integration was achieved during 2008-2010 with adjusted R-squares of 69.95%, which is largely attributed to real estate integration with stocks of 74.08% over the same period. The securitization of real estate induces its co-movement with stocks; therefore, real estate might not provide diversification benefits for equity portfolios. The figure shows that real estate integration with bonds, commodities, and currencies is very low.

*** Insert Figure 5 about here ***

*** Insert Table 11 about here ***

4. Mean-variance analysis

We present the descriptive statistics of maximized Sharpe ratio optimization portfolios for 31 portfolios as combinations of five asset classes. The Sharpe ratio is a standard measure of portfolio performance when returns of the underlying assets have normal distribution and when investors only care about the mean and the variance of their investment. The extant literature shows that various financial assets have non-normal return distributions (e.g., Agarwal and Naik, 2004; Malkiel and Saha, 2005) and also that investors care for higher moment of returns (Golec and Tamarkin, 1998; Harvey and Siddique, 2000). When return distributions are non-normal, the conclusion from the Sharpe ratio can be misleading. Researchers have developed various measures of risk to take the departure from normality into account. Of course, this paper would be unacceptably lengthy if every newly developed performance measures were thoroughly examined. Therefore, we selected two modified versions of Sharpe ratio that seem promising and appropriate for our performance measurement problem: the generalized Sharpe ratio (henceforth, GSR) developed by Zakamouline and Koekebakker (2009) and the Sharpe ratio using the adjusted value-at-risk (henceforth, VaR-adj SR) as the risk measure (Dowd, 2000; Favre and Galeano, 2002). The GSR is motivated by the investor's preferences to higher moments of distribution when facing the optimal capital allocation problem within expected utility theory framework. On the other hand, the VaR is commonly recognized by practitioners as an understandable measure of downside risk that greatly matters for investors' investments and can be used for non-normally distributed assets. Following Favre and Galeano (2002), we adjust the standard VaR so that it takes the skewness and kurtosis into account.

Overall, the results under these two modified versions of Sharpe ratios are consistent with those using the standard Sharpe ratio; as such, we only describe the results of Sharpe ratios (henceforth, SR). Figure 6 shows mean-variance frontiers of the portfolios with all assets and five other portfolios without one asset class. Table 12 shows the weight, mean and standard deviation of returns of portfolios that maximized SR, GSR, and VaR-adj SR based on the portfolios shown in Table 12. For instance, portfolio 7 that is made of 63% (79% and 74%) in stocks, 13% (13% and 14%) in commodities, and 24% (8% and 12%) in real estate has a maximized Sharpe ratio (maximized GSR and maximized VaR-adj SR) among different weights of stocks, commodities, and real estate with a mean return of 0.49% (0.56% and 0.56%) and standard deviation of 3.55% (3.55% and 3.51%). Among all 31 portfolios, the portfolio with *all* classes has the highest average Sharpe ratio of 0.17 and it is composed of 23.43% in bond, 34.31% in currency, 21.77% in stocks, 10.33% in commodities, and 10.16% in real estate. With four different assets, the portfolio without bond has the highest mean Sharpe ratio of 0.17 whereas the portfolio without stocks has the lowest standard deviation of monthly return, 1.23% but also the lowest Sharpe ratio of 0.14. With 3 assets, a portfolio with 44% in currency, 42% in stocks, and 15% in commodities yields the highest mean Sharpe ratio of 0.16. Portfolios of currency-stocks-real estate, bonds-stocks-real estate and stocks-commodities-real estate also have high Sharpe ratio of around 0.16, marginally lower than that of currency, stocks, and commodities. Notably, the maximized Sharpe ratio portfolio consisting of bond, currency, and commodity has 846% short position in bond, 331% long in currency and 614% long in commodities. With short-sales constraint (portfolio#15), investors can achieve the same level of Shape ratio by investing nothing in bond, 28% in currency and 72% in commodities, which is the same combination as Portfolio #22.

Among the portfolios of two assets, the portfolio of 73% stocks and 27% real estate yields the highest mean Sharpe ratio of 0.16. The portfolio of bond and currency has very high proportion of both assets in absolute value due to their negative monthly return; such proportion yields Sharpe ratio of -0.01 (Portfolio #17). With short-sales restriction, investors can maximize Sharpe ratio by allocating all of their wealth into bonds, which have higher returns and lower risk than currencies. With one asset, stocks deliver the highest mean Sharpe ratio of 0.15 while bonds and currencies have the lowest, -0.02.

In the earlier section, we suggest a portfolio of commodities and bonds which, based on this analysis, has the lowest standard deviation of 2.05% among the maximized Sharpe ratio portfolios that are composed of 2 assets. Notably, a maximized VaR-adj portfolio with bond and currency has the lowest standard deviation of 1.65%. We also suggest the currencies and bonds portfolio. With the maximum Sharpe ratio optimization, we obtain some abnormal proportions of both assets, whereas with minimized variance portfolio optimization shown in the Appendix, the standard deviation of currencies and bonds is even lower than that of commodities and bonds portfolios (i.e., a standard deviation of 0.69% and a Sharpe ratio of -0.03). Finally, we suggest portfolios of GSCI index and stocks, and bonds and GSCI index. We do not apply GSCI in our analysis because GSCI is heavily weighted by crude oil. In unreported result of applying GSCI index, the portfolio of GSCI and stocks have the highest Sharpe ratio (0.18) among all 2-asset portfolios shown in Table 12 and also the highest standard deviation (4.84%). With the minimized variance portfolio of GSCI and stocks, the variance is 3.99% and Sharpe ratio is 14.61%. The maximized portfolio of GSCI and bond yields a Sharpe ratio of only 0.10. The minimum variance portfolio of these two assets yields the lowest standard deviation (0.70%) among all 2-asset portfolios shown in Table 12 but has a negative Sharpe ratio of 0.02.

Overall, the portfolio that has the highest Sharpe ratio (0.17) is the portfolio of five assets with over 30% weight in currency. Investors can achieve marginally a lower Sharpe ratio (0.17) by investing in four assets with 47% weight in currency and zero percent in bond, Portfolios of 3 assets composed of stocks-commodities-real estate, currency-stocks-commodities, currency-stocks-real estate, bond-stocks-real estate and of 2 assets including stocks and real estate have the Sharpe ratio of 0.16. By investing only in stocks, investors can generate a Sharpe ratio of 0.15. Taken together, the results under the mean-variance analysis consistently support those under the PCA approach. We also perform the same optimization to minimize variance of the portfolios, not to maximize Sharpe ratio. The results remain intact with the PCA in the earlier section. With the same number of assets, the portfolios with more weight on stocks have the highest Sharpe ratio while those with more weight on bonds have the lowest Sharpe ratio. For minimum variance portfolio optimization, the five-asset portfolio with 66% weight on bonds has the lowest standard deviation but also a low Sharpe ratio of 0.07. Among the four-asset portfolios, the one without stocks has the lowest standard deviation whereas the one without bonds has the highest Sharpe ratio of 0.10. Among the three-asset portfolios, bond-currency-real estate portfolio has the lowest standard deviation and the marginal Sharpe ratio of 0.04, while the stock-commodity-real estate portfolio has the highest Sharpe ratio of 0.13. Among the minimized variance portfolios with different asset class combinations, the ones that have the highest Sharpe ratio contain stocks and real estate; on the other hand, the portfolios that have the lowest Sharpe ratio ratio (0.05 for 4 assets of bond, stocks, commodities, and real estate, 0.002 for 3 assets of bonds, currency, and commodities, -0.03 of 2 assets of bonds and currency, and -0.02 for an asset of bonds) all have most weight on bonds. The results are reported in the Appendix.

Insert Table 12 and Figure 6 about here

5. Contagion and diversification benefit

How large is the diversification benefit during high contagion periods? Can investors gain from diversifying their portfolios during these periods compared to the normal ones? This section attempts to answer these intriguing questions. To define a contagion period, we follow Bekaert et al. (2005) to define contagion as an excess correlation or correlation over and above economic fundamentals. They particularly define contagion from the correlation of model residuals and apply various versions of CAPM as factor models. Based on our PCs, the economic fundamentals are principle components extracted from all asset classes. We then correlate the residuals of our monthly PC regressions across different asset portfolio combinations shown in Table 12. We derive the time series of residuals of each asset against the other asset classes and define a contagion period as a period when average correlation of residuals from PC regression across pairs of assets is significantly different from zero. For example, the residual of currency is estimated from the PC regression where a dependent variable refers to currency returns and independent variables are PCs constructed from stocks, commodities, bonds, and real estate. Similarly for stocks, the residual is from the PC regression where a dependent variable is equity return and independent variables are PCs constructed from currency, commodities, bonds, and real estate. We then estimate correlation on a monthly basis across assets. In each month, we compute the average correlation across each pair of assets. Consider, for example, the portfolio #2 that is made up of currency, stocks, commodities, and real estate. The average correlation of month *t* is the average of correlations of residuals between currency and stocks, currency and commodities, currency and real estate, stock and commodities, stock and real estate, and commodities and real estate. Then we define a contagion month as the month that has a correlation significantly different from zero.[4] For another example, portfolio #25, contagion is defined from the correlation between stocks and real estate. With the same optimal weight of all 31 maximized Sharpe ratio portfolios, we compute monthly returns and Sharpe ratios of these portfolios during contagion vs. non-contagion periods.

Table 13 shows the mean and standard deviation of maximized Sharpe ratio portfolios during contagion vs. non-contagion periods. For instance, the mean and standard deviation of returns of portfolio #7 composed of 79% (74%) in stocks, 13% (14%) in commodities, and 8% (12%) in real estate that has maximum GSR (VaR-adj SR) among portfolios comprised of stocks, commodities, and real estate are 0.30% and 7.38% (0.28% and 6.85%) during contagion period and 0.78% and 0.27% (0.83% and 0.17%) during non-contagion period, respectively. Overall, the results show that mean returns and standard deviations are higher during contagion than non-contagion periods. Among portfolios that have maximized Sharpe ratios, the exceptions are portfolios #6, #7, #22, #24, #27 and #28 that have lower returns and portfolio #28 that has a lower standard deviation in contagion periods. The number of exceptions is higher for GSR and VaR-adj SR portfolios. For maximized GSR portfolios, 9 of them have lower returns and 1 of them has a lower standard deviation, while for maximized VaR-adj SR portfolios, 11 of them have lower returns and 3 of them have lower standard deviations during contagion periods.

*** Insert Table 13 here ***

Although most of the returns during contagion periods are higher than those during non-contagion periods, they do not compensate for high volatility and thereby the Sharpe ratios of these portfolios during contagion periods are lower. Table 14 presents SR, GSR, and VaR-adj SR of portfolios shown in Tables 12 and 13 and the p-value of the statistic test that examines the difference in Sharpe ratios between contagion and non-contagion periods. The test of difference in the Sharpe ratios was firstly proposed by Jobson and Korkie (1981) and then revised by Memmel (2003). Nonetheless, their test does not work well when returns have heavy tails and stylized time-series characteristics. Ledoit and Wolf (2008) consider these issues and propose a test of the difference in Sharpe ratios based on a Studentized time-series bootstrap. We thus perform this test to compare performance measures. For the five-asset portfolios, the difference in SRs is marginally significant at the 10% level. For four-asset combinations, the SRs in non-contagion periods are significantly higher than those in contagion periods. The difference is less significant for the GSR. The difference in GSR and VaR-adj SR for portfolios #5 and #6 composed of bonds-currencies-commodities-real estate and bonds-currencies-stocks-commodities respectively is not significant at conventional levels. For the three-asset portfolios, only the portfolio #15 has insignificant

[4] When we define a contagion period as a period when correlation is above the median, the results remain intact. The results are available upon request.

difference in all three versions of Sharpe ratios whereas for two-asset portfolios, all portfolios have higher SRs in non-contagion periods. For one-asset portfolios, bonds and currencies do not have any significant difference in SRs during two periods. In aggregate, diversification benefit is higher during non-contagion periods, supporting the evidence shown by the extant literature that diversification gain is lower during high comovement periods.

*** Insert Table 14 here ***

Figure 7A shows the mean-variance frontiers of the portfolios of all asset classes and portfolios of different combinations of four assets based on the weight from Table 12. It is worth noting that portfolio frontiers of these asset combinations during non-contagion periods are above those during contagion periods, thereby suggesting that diversification benefit is lower during contagion periods. Specifically, Figure 7B shows the portfolio frontiers of these asset combinations under non-contagion periods. Consistent with Figure 7A, the portfolio frontier of all assets is on the top of other frontiers, suggesting that investors benefit most from diversifying into all asset classes. A portfolio frontier without stocks is in the bottom whereas the frontiers with no bond, no real estate, no commodities and no currencies, respectively are on the top. The results imply that during normal or non-contagion periods, stocks yield highest returns with the same risk whereas bonds yield lowest returns. The results are consistent with the evidence shown in Table 12. With four asset classes, a portfolio without bonds has the highest mean Sharpe ratio whereas a portfolio without stocks has the lowest mean. Figure 7C focuses on portfolio frontiers during contagion periods. A portfolio frontier of all asset classes is still on the top. The frontier of portfolio without bond is in the bottom suggesting that investors should hold bonds in order to diversify the risk during contagion times. Portfolio frontiers with no currencies and real estate are top two frontiers. The lower ones are the portfolios with no commodities and no stocks. The results thus far support a common belief that bond is a safe asset during down periods and currencies perform worst among all assets during contagion times. Interestingly, there is a larger gap between each frontier during contagion period than non-contagion period. The results typically provide evidence to suggest a larger discrepancy of risk-adjusted returns between portfolios with five assets and those with four assets during contagion period than non-contagion period. Table 15 shows a comparison of Shape ratios between portfolios with different number of assets. For example, we compare the Sharpe ratio of portfolio #7 with the average Sharpe ratio of portfolios #2 and #3, #16 vs. the average of #4 and #6, or #18 vs. the average of #12, #13 and #16. The results show there is a larger gap between the portfolio frontier of five vs. four, four vs. three, three vs. two, and two vs. one asset during contagion periods than non-contagion periods. The results are not perfect. For instance, compared portfolio #8 to portfolios # 2 and 5, 10 vs, 2 and 4, 11 vs. 3 and 5, and 17 vs. 14, 15, and 16, the additional gain from diversification is higher during non-contagion periods. In fact, during contagion periods, portfolio #8 (10) has lower Sharpe ratio than portfolios 2 and 5 (2 and 4) suggesting these portfolios have diversification loss.

*** Insert Table 15 and Figures 7 (a) to (c) here ***

For the same number of asset classes, the Shape ratio of portfolios during contagion period is significantly lower but the additional gain measured by an increase in the Sharpe ratio from adding one asset class to a portfolio during contagion period is ***higher***. For instance, investors benefit more from holding four asset classes rather than three asset classes during contagion periods compared to the normal periods. As well, they gain more from diversification during contagion periods if they hold 3 asset classes rather than 2 asset classes, or 2 asset classes rather than 1 asset class. Taken together, our results show that, although stocks have higher returns, they also have high risks while bonds have low returns but also low risks. Stocks and real estate on average have higher returns and are mutually integrated, whereas bonds and currencies have lower returns and are highly integrated. Our results from applying our PCs to evaluate portfolio performance during contagion periods suggest that the Sharpe ratios for portfolios with the same number of assets are higher during non-contagion periods than contagion periods. However, there is always a room for diversification across asset classes as the additional gain of diversification strategies is higher during contagion than non-contagion periods.

6. Conclusion

Recurrent financial crises have prompted investors to seek for new assets with high diversifying potential. This study provides a comprehensive evidence of diversification benefits among a broad set of five different asset classes in the US (bonds, stocks, commodities, currencies and real estate). Roll (2013) theoretically proves that correlation is not a good measure of diversification benefits but R-squares developed by Pukthuanthong and Roll (2009) is. We then base our analysis on R-squares which enable us to explore not only the level of, but also the variations in diversification benefits of investing across multiple asset classes over time.

We find that all of the asset classes we consider have different and time-varying degree of integration with the others. Our time-trend analysis indicates an increasing integration of each class with the others during the 2008 to 2010 crisis period, compared to the 2004-2007 bullish period. On average, our selected assets are only weakly and at most moderately integrated within each particular class and with the other classes, thus providing diversification benefits when they appear in a diversified portfolio that includes different asset classes. Regarding the decrease of diversification benefits during crisis times as reported in previous studies (e.g., Chan et al., 2011), our results reveal that not all asset classes are alike. In particular, gold offers higher diversification benefits during the 2008-2010 as its integration with other asset classes has decreased by 5% over the same period. The maximized portfolio optimization within the mean-variance framework shows consistent results with the integration analysis as the portfolio with all classes consistently outperforms the other five portfolios that have four assets in terms of maximized risk-return trade-off. Furthermore, we examine the extent of diversification benefits during contagion periods based on correlation of residuals from PC regression analysis. Our results reveal that diversification benefit during contagion periods is lower; nonetheless, an additional gain from diversification benefit is higher. The results remain intact regardless of the performance measure used.

All in all, our findings comfort the view that diversification across asset classes is superior and suggest a relevant strategy in both tranquil and crisis times, especially when home bias still exists in the US markets (French and Porteba, 1991; Chan et al., 2005). Future research should explain why some assets help diversify the most during high contagion period vs. low contagion period. Is it because they have low comovement with other asset classes? Do they have common factors with other assets and what do those factors represent? Second, it is important to consider investability of each asset and transaction costs. Future research should attempt to apply the idea of this study to other investable assets and examine how the results change.

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Table 1: Descriptive statistics

This table presents summary statistics of the daily returns commodities, bonds, stocks, currencies, and real estate we employ in this study. The starting date is listed in the last column and the ending date is December 2010. All indices are value-weighted.

	Mean(%)	Median(%)	Max(%)	Min(%)	Std. dev(%)	Skewness	Kurtosis	Observations	Starting date
					Commodities				
Brent crude oil	0.03	0.06	13.15	-42.72	2.32	(1.38)	27.98	5,401	1/1/1989
Live cattle	0.00	0.00	9.12	-9.24	1.00	(0.35)	12.39	5,401	1/1/1989
Feeder cattle	0.00	0.00	5.44	-8.92	0.85	(0.38)	8.30	5,401	1/1/1989
Lean hogs	-0.01	0.00	29.18	-26.37	2.02	0.73	32.67	5,401	1/1/1989
Corn	0.01	0.00	9.80	-21.65	1.62	(0.17)	11.84	5,401	1/1/1989
Soybean	0.00	0.00	7.54	-14.08	1.49	(0.61)	8.57	5,401	1/1/1989
Soybean meal	0.00	0.00	8.88	-25.40	1.65	(1.10)	17.63	5,401	1/1/1989
Soybean oil	0.01	0.00	8.72	-7.24	1.49	0.12	5.20	5,401	1/1/1989
Wheat	0.01	0.00	12.93	-15.93	1.80	0.08	7.36	5,401	1/1/1989
WTI crude oil	0.03	0.05	16.41	-40.05	2.48	(0.94)	20.10	5,401	1/1/1989
Gold	0.02	0.00	8.89	-7.73	1.00	(0.06)	11.11	5,401	1/1/1989
Silver	0.03	0.06	12.36	-14.79	1.74	(0.61)	10.25	5,401	1/1/1989
Cotton	0.02	0.00	16.71	-10.30	1.72	0.18	7.66	5,401	1/1/1989
Coffee	0.00	0.00	23.77	-15.03	2.44	0.32	10.05	5,401	1/1/1989
Cocoa	0.01	0.00	12.56	-12.51	2.00	0.04	6.04	5,401	1/1/1989
Sugar	-0.01	0.00	13.21	-48.55	2.38	(2.15)	40.63	5,401	1/1/1989
GSCI	0.02	0.03	560.54	-561.61	78.09	(0.00)	39.27	5,567	1/5/1971
					Bonds				
5yr Treasury note	0.01	0.01	1.95	-1.92	0.28	(0.42)	6.36	5,401	1/1/1989
30yr Treasury Bond	0.01	0.03	3.98	-3.88	0.61	(0.27)	5.06	5,401	1/1/1989
BAA Bond	-0.02	0.00	6.15	-7.02	0.82	0.08	8.35	5,349	1/1/1989
AAA Bond	-0.01	0.00	5.04	-3.67	0.66	0.33	6.11	5,349	1/1/1989
BARCLAYS US AGGREGATE	0.00	0.00	1.36	-1.76	0.26	(0.17)	5.21	5,385	1/1/1989
					Stocks				
Health Care	0.04	0.04	12.43	-8.77	1.23	0.02	8.78	5,329	9/12/1989
Consumer Discretionary	0.03	0.04	13.10	-9.61	1.34	0.19	9.98	5,329	9/12/1989
Energy	0.04	0.03	18.48	-15.54	1.52	0.07	15.71	5,329	9/12/1989
Finance	0.03	0.03	18.77	-17.01	1.89	0.44	19.18	5,329	9/12/1989
Industrials	0.03	0.03	9.98	-8.80	1.26	(0.10)	8.97	5,329	9/12/1989
Telecom	0.01	0.00	13.80	-9.81	1.41	0.25	10.25	5,329	9/12/1989
Materials	0.03	0.01	13.28	-12.13	1.43	0.02	10.66	5,329	9/12/1989

	Mean(%)	Median(%)	Max(%)	Min(%)	Std. dev(%)	Skewness	Kurtosis	Observations	Starting date
Information Technology	0.05	0.07	17.44	-9.52	1.81	0.34	8.20	5,329	9/12/1989
Consumer Staples	0.04	0.04	9.24	-8.88	1.00	0.01	10.85	5,329	9/12/1989
Utilities	0.02	0.04	13.52	-8.60	1.12	0.24	15.45	5,329	9/12/1989
					Currencies				
Canadian Dollar	0.00	0.00	3.81	-5.07	0.39	(0.21)	16.28	9,747	1/5/1971
Japanese Yen	-0.01	0.00	6.26	-9.50	0.65	(0.74)	13.20	9,733	1/5/1971
Chinese Yuan	0.01	0.00	23.80	-2.43	0.34	46.68	3,233.45	7,154	1/6/1981
Danish Krone	0.00	0.00	8.13	-7.81	0.66	0.07	13.54	9,737	1/5/1971
Hong Kong Dollar	0.01	0.00	6.53	-4.11	0.24	4.76	184.54	7,245	1/6/1981
Indian Rupee	0.02	0.00	12.81	-5.43	0.47	3.13	94.24	9,225	1/3/1973
South Korean Won	0.00	0.00	13.65	-19.76	0.73	(1.37)	160.36	7,097	4/14/1981
Mexican Peso	0.00	0.00	7.20	-9.16	0.44	(0.46)	78.39	9,712	1/5/1971
Norwegian Kroner	0.00	0.00	6.82	-6.44	0.66	0.22	11.31	9,737	1/5/1971
Swedish Kronor	0.00	0.00	9.80	-5.40	0.66	0.60	18.54	9,737	1/5/1971
South Africa Rand	0.02	0.00	19.74	-9.78	0.88	1.55	44.90	9,687	1/5/1971
Singapore Dollar	-0.01	0.00	2.76	-4.14	0.34	(0.65)	16.44	7,243	1/6/1981
Sri Lankan Rupees	0.03	0.00	62.90	-17.94	0.84	48.62	3,695.31	8,740	1/3/1973
Swiss Franc	-0.02	0.00	5.83	-4.98	0.73	(0.05)	6.68	9,739	1/5/1971
Taiwanese Dollar	0.00	0.00	4.08	-3.42	0.30	0.89	42.02	6,103	10/4/1983
Thai Baht	0.00	0.00	20.77	-7.41	0.59	6.36	248.48	7,120	1/6/1981
Australian Dollar	0.00	0.00	19.25	-6.67	0.69	3.94	97.19	9,729	1/5/1971
New Zealand Dollar	0.00	0.00	16.28	-9.30	0.72	2.14	48.87	9,718	1/5/1971
British Pound	0.00	-0.01	4.97	-4.59	0.60	0.17	7.78	9,739	1/5/1971
Value-weighted world exchange index	0.00	0.00	2.95	-4.08	0.42	(0.18)	6.91	9,211	1/5/1971
					Real Estate				
REIT	0.04	0.05	16.29	-20.60	1.53	(0.20)	33.40	5,369	1/3/1980
					Value-weighted (VW) Index				
Commodity Index	0.01	0.02	5.50	-5.95	0.79	-0.25	8.09	5401	1/3/1989
Bond Index	0.00	0.00	1.71	-1.51	0.15	-0.01	12.33	5333	1/3/1989
Stock Index	0.03	0.05	11.98	-9.20	1.11	0.03	14.14	5329	9/12/1989
Currency index	0.00	0.00	1.94	-2.91	0.32	-0.19	8.13	5578	10/4/1983

Table 2: Returns integration across asset classes

This table shows R-squares (in%) from regressing returns of the assets shown in the first column on principle components constructed from various asset classes. The *R*-square is constructed based on the Pukthuanthong and Roll (2009) principal component approach. The sample period is from the date each asset has data available until December 2010. * denotes R-squares from commodities returns on PCs constructed from all assets except commodities and GSCI index.

Dependent variables	Independent variables						
	PCs constructed from						
	All asset classes except itself	Bonds	Currencies	Stocks	VW REIT index	Commodities	GSCI index
Commodities VW index	12.07*	1.53	14.44	3.50	1.64		38.56
GSCI index	8.54*	0.92	8.57	0.02	1.30	52.86	
Bonds VW index	2.32		0.44	1.39	1.14	0.52	0.13
Currencies VW index	9.75	1.15		2.22	1.18	12.55	6.06
Stocks VW index	7.41	6.00	3.84		42.37	2.29	-0.01
Real estate							
Value-weighted REIT	32.62	3.41	3.88	45.82		1.87	1.30
Commodities							
Brent crude oil	5.89	0.55	4.95	1.56	0.72		67.88
Live cattle	0.68	0.33	0.45	0.65	0.49		1.86
Feeder cattle	0.74	0.23	0.56	0.68	0.55		0.56
Lean hogs	0.21	0.01	0.02	0.26	-0.02		0.49
Corn	3.80	0.82	3.63	1.44	0.40		8.44
Soybean	4.05	0.59	4.00	1.73	0.51		8.24
Soybean meal	4.05	0.28	2.10	0.91	0.21		4.57
Soybean oil	5.26	0.96	5.12	2.28	0.84		9.01
Wheat	3.20	0.70	3.81	1.37	0.49		6.94
WTI crude oil	6.00	0.72	4.68	1.49	0.46		69.54
Gold	9.13	0.70	14.30	0.68	0.03		8.09
Silver	9.90	0.19	13.97	0.65	0.14		7.65
Cotton	2.11	0.73	2.42	1.17	0.72		3.34
Coffee	0.93	0.64	1.49	0.72	0.34		1.41
Cocoa	2.60	0.08	4.64	0.65	0.29		1.58
Sugar	1.30	0.09	1.33	0.67	0.16		2.18

Dependent variables	Independent variables						
	PCs constructed from						
	All asset classes except itself	Bonds	Currencies	Stocks	VW REIT index	Commodities	GSCI index
Bonds							
5yr Treasury note	5.47		1.85	2.92	1.42	1.72	0.79
30yr Treasury Bond	5.93		1.60	2.13	1.30	2.55	1.86
BAA Bond	6.74		1.62	3.32	2.56	1.90	1.46
AAA Bond	4.75		1.19	1.89	1.24	1.34	0.95
BARCLAYS US AGGREGATE	3.50		1.46	1.31	0.44	1.29	0.85
Stocks							
Health Care	2.01	1.65	1.12		15.71	0.42	-0.02
Consumer Discretionary	5.00	5.75	2.31		38.03	0.73	-0.02
Energy	14.34	3.66	5.36		20.60	10.87	-0.02
Finance	6.95	3.70	3.04		52.99	1.04	-0.01
Industrials	5.37	5.90	3.29		37.92	1.25	0.00
Telecom	3.36	3.11	1.45		17.89	0.73	-0.01
Materials	8.68	5.91	5.63		32.04	4.72	-0.01
Consumer Staples	1.81	2.07	1.23		17.38	0.57	0.01
Information Technology	2.58	4.42	0.98		17.43	0.60	-0.01
Utilities	3.89	2.06	2.66		18.36	1.49	0.00
Currencies							
Canadian Dollar	9.14	2.06		3.95	1.65	9.51	5.22
Japanese Yen	1.98	1.26		1.51	0.68	1.19	0.03
Chinese Yuan	0.42	0.36		0.13	0.05	0.48	-0.01
Danish Krone	2.38	0.50		0.05	0.18	3.70	0.91
Hong Kong Dollar	0.04	-0.07		-0.03	0.01	0.20	0.02
Indian Rupee	1.42	0.36		0.95	0.41	1.50	0.49
South Korean Won	0.91	0.57		0.63	0.22	0.75	0.71
Mexican Peso	1.44	0.37		0.84	0.14	0.85	0.62
Norwegian Kroner	5.06	0.57		1.04	0.78	7.07	2.56
Swedish Kronor	5.38	0.69		1.76	1.49	5.82	2.20
South Africa Rand	5.42	1.06		3.29	1.39	4.87	1.48

Dependent variables	Independent variables						
	PCs constructed from						
	All asset classes except itself	Bonds	Currencies	Stocks	VW REIT index	Commodities	GSCI index
Singapore Dollar	3.33	0.32		1.63	0.68	3.62	1.52
Sri Lankan Rupees	-0.09	0.00		0.01	-0.01	-0.07	-0.01
Swiss Franc	1.17	0.82		0.64	0.00	2.45	0.55
Taiwanese Dollar	0.59	0.28		0.22	0.18	0.85	0.42
Thai Baht	0.24	0.02		0.19	0.02	0.21	0.12
Australian Dollar	9.56	1.51		3.47	1.19	10.44	3.53
Euro	6.49	1.25		3.18	0.56	2.18	1.13
New Zealand Dollar	7.63	1.48		2.91	1.56	8.11	2.28
British Pound	3.40	0.16		0.42	0.57	4.67	1.40
Value-weighted world exchange index	4.74	0.49		0.46	0.31	6.90	2.19

Table 3: Integration of commodities with other asset classes across time

This table shows adjusted R-squares (in %) of regressing commodity returns on PCs constructed from other asset classes. The *R*-square is constructed based on the Pukthuanthong and Roll (2009) principal component approach. The sample period is from the date each asset has data available until December 2010.

	Bond, currency, stock, and real estate PCs						
	1989-1999	2000-2010	1989-1993	1994-1998	1999-2003	2004-2007	2008-2010
Brent crude oil	4.30	11.60	15.84	2.25	4.33	15.90	41.70
Live cattle	0.02	1.57	0.63	0.28	0.00	-0.24	8.94
Feeder cattle	-0.20	1.52	2.26	-0.25	-0.41	0.68	8.44
Lean hogs	-0.02	0.30	-0.90	-0.12	0.38	-0.51	0.08
Corn	1.11	6.51	1.68	1.08	0.14	1.44	20.51
Soybean	1.00	6.69	2.05	0.99	0.52	1.88	21.46
Soybean meal	1.16	3.37	1.63	1.19	0.15	0.70	10.07
Soybean oil	0.42	9.91	0.30	0.20	0.45	3.28	32.00
Wheat	0.64	5.66	-0.24	0.64	0.36	0.91	15.71
WTI crude oil	4.52	10.47	15.13	2.61	4.36	17.20	37.15
Gold	4.49	14.26	8.37	8.78	12.29	27.06	22.34
Silver	2.09	16.67	1.94	2.77	6.87	18.23	33.46
Cotton	0.18	3.70	3.38	-0.21	0.31	1.42	14.28
Coffee	0.17	3.16	-0.32	0.69	-0.06	1.46	15.16
Cocoa	0.82	4.86	0.48	0.84	0.48	1.64	20.40
Sugar	0.23	2.74	1.53	-0.23	-0.20	2.24	9.22
GSCI	4.17	19.84	9.05	3.73	2.86	13.64	47.63
Commodities VW index	5.34	14.65	19.76	2.41	4.69	20.74	50.01
	Bond PCs						
Brent crude oil	0.50	1.83	2.74	-0.13	0.92	0.78	7.66
Live cattle	0.30	0.54	0.80	0.06	-0.14	-0.02	2.41
Feeder cattle	0.01	0.60	0.36	-0.33	0.31	0.47	3.98
Lean hogs	0.03	0.65	0.34	0.06	0.83	0.22	1.69
Corn	0.09	1.44	2.77	-0.35	-0.01	2.05	2.94
Soybean	0.17	1.02	1.58	-0.11	-0.17	0.50	2.96
Soybean meal	0.30	0.48	1.56	-0.13	-0.11	0.41	0.72
Soybean oil	0.16	1.84	1.25	-0.12	0.48	0.18	6.79
Wheat	-0.03	1.64	0.21	-0.22	0.42	1.53	3.42
Crude oil	0.68	2.84	3.60	-0.02	1.09	0.71	10.54
Gold	0.36	0.95	5.17	0.82	1.04	2.29	1.54
Silver	0.10	0.18	2.46	0.45	0.49	1.87	0.76
Cotton	-0.15	1.43	-0.26	-0.27	1.83	0.16	2.43
Coffee	0.36	1.16	1.85	0.02	0.87	1.88	3.57
Cocoa	-0.03	0.22	0.12	-0.35	0.24	-0.20	0.70
Sugar	-0.06	0.07	-0.05	0.19	-0.39	0.28	0.81
GSCI	0.49	2.77	6.06	-0.17	1.29	1.93	6.60
Commodities VW index	0.68	2.31	4.57	-0.11	0.57	0.99	9.64
	Currencies PCs						
Brent crude oil	0.30	10.31	-0.26	0.47	1.09	3.42	29.82
Live cattle	0.57	0.98	-0.68	0.42	-0.01	0.17	7.26
Feeder cattle	0.22	0.82	0.13	0.32	0.57	0.03	5.87
Lean hogs	-0.16	-0.05	4.57	-0.33	-0.11	0.03	0.07
Corn	1.16	6.04	-0.27	1.44	0.15	1.40	17.29
Soybean	0.42	6.31	0.25	0.72	1.31	3.10	17.06
Soybean meal	0.75	2.91	0.90	1.62	0.87	2.17	8.31
Soybean oil	0.19	8.98	-0.26	0.19	0.56	3.94	26.06

	Currencies PCs						
	1989-1999	2000-2010	1989-1993	1994-1998	1999-2003	2004-2007	2008-2010
Wheat	0.81	5.82	-1.24	1.34	-0.16	1.05	15.07
WTI crude oil	0.55	9.85	0.47	0.64	1.05	2.24	27.94
Gold	4.74	19.31	4.25	9.32	13.52	32.48	19.51
Silver	2.38	21.19	1.71	2.79	7.00	24.34	29.44
Cotton	-0.19	4.03	-1.04	-0.44	0.37	0.78	13.04
Coffee	-0.22	3.51	0.42	-0.13	-0.29	3.53	12.92
Cocoa	1.34	6.81	1.38	1.02	0.52	5.14	18.49
Sugar	0.44	1.98	0.77	0.58	-0.37	0.46	7.77
GSCI	2.62	21.67	1.42	2.91	2.16	12.91	39.10
Commodities VW index	1.53	14.24	0.39	1.72	1.60	4.42	36.54
	Stock PCs						
Brent crude oil	4.18	4.83	11.37	4.74	0.90	4.89	21.92
Live cattle	0.00	1.25	1.55	0.21	-0.43	0.18	6.54
Feeder cattle	-0.18	1.37	0.05	-0.21	-0.14	0.22	7.59
Lean hogs	0.01	0.83	-0.28	-0.38	1.01	-0.19	0.00
Corn	0.09	2.61	0.14	0.40	0.83	1.67	8.32
Soybean	-0.10	3.58	-0.02	0.00	0.53	1.68	10.44
Soybean meal	0.21	1.88	-0.18	0.00	0.63	1.32	5.63
Soybean oil	-0.28	5.08	-0.30	-0.14	0.39	1.37	15.17
Wheat	0.27	2.27	0.12	0.36	0.44	0.23	6.47
WTI crude oil	4.41	4.01	13.36	4.87	1.72	5.89	16.46
Gold	3.26	1.25	8.43	3.98	2.25	9.12	2.46
Silver	1.36	2.24	3.59	2.36	0.75	8.98	5.37
Cotton	-0.06	2.00	-0.06	-0.11	-0.08	0.31	6.63
Coffee	0.45	1.63	-0.11	1.04	0.18	0.69	6.09
Cocoa	0.31	1.17	0.72	0.22	-0.25	1.06	5.96
Sugar	0.24	1.20	-0.15	0.14	-0.02	0.34	3.86
GSCI	1.30	7.81	4.96	2.16	0.76	6.93	18.71
Commodities VW index	-0.16	0.02	17.19	-0.06	-0.41	0.73	-1.00
	REIT						
Brent crude oil	0.14	1.72	2.34	0.15	0.27	0.69	7.31
Live cattle	-0.01	0.85	0.46	-0.08	-0.08	0.01	4.10
Feeder cattle	-0.03	0.99	0.39	-0.08	-0.07	0.10	4.57
Lean hogs	-0.04	-0.04	-0.04	-0.05	-0.08	-0.04	-0.12
Corn	-0.01	0.59	-0.08	-0.02	-0.05	0.05	1.19
Soybean	0.03	0.76	-0.02	-0.02	0.32	-0.10	1.81
Soybean meal	0.05	0.28	0.25	-0.08	0.23	-0.06	0.43
Soybean oil	-0.04	1.48	-0.07	-0.07	0.31	-0.10	3.64
Wheat	0.05	0.69	0.33	-0.08	0.19	-0.10	1.48
WTI crude oil	0.28	1.19	3.31	0.03	0.17	0.31	4.55
Gold	0.42	-0.01	1.91	0.11	0.27	0.20	-0.06
Silver	-0.03	0.23	0.13	-0.06	-0.02	0.40	0.26
Cotton	-0.03	1.10	0.13	-0.06	0.03	-0.10	3.47
Coffee	-0.03	0.86	-0.05	-0.06	0.19	0.19	3.15
Cocoa	-0.04	0.54	-0.04	-0.08	-0.08	-0.07	1.79
Sugar	-0.03	0.26	-0.08	-0.06	-0.08	0.03	0.78
GSCI	-0.03	2.50	0.48	0.06	-0.03	-0.08	4.96
Commodities VW index	0.36	2.08	3.50	-0.02	0.21	0.26	7.01

Table 4: Evolving integration of commodities with other asset classes

This table shows the coefficient of time trend from adjusted R-squares regression. The R-square is constructed based on the Pukthuanthong and Roll (2009) principal component approach. The sample period is from the date each asset has data available until December 2010.

	PCs of other assets		Commodity PCs		Bond PCs		Currency PCs		Stock PCs		REIT	
	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat
Commodities												
Brent crude oil	0.0026	7.01			0.0004	1.66	0.0010	2.51	0.0028	7.42	0.0008	5.81
Live cattle	0.0004	0.99			-0.0004	-1.76	0.0000	-0.03	-0.0002	-0.37	0.0002	2.02
Feeder cattle	0.0005	1.21			0.0004	1.57	0.0003	0.63	-0.0001	-0.18	0.0001	0.60
Lean hogs	0.0006	1.38			-0.0002	-0.55	0.0002	0.53	0.0009	2.34	-0.0001	-0.50
Corn	0.0008	1.76			0.0000	0.11	0.0004	1.00	0.0014	3.46	0.0001	1.62
Soybean	0.0004	0.90			0.0002	0.86	0.0005	1.22	0.0006	1.70	0.0001	0.97
Soybean meal	-0.0006	-1.30			0.0003	1.04	0.0000	-0.05	0.0002	0.49	0.0000	0.32
Soybean oil	0.0016	3.70			0.0002	0.93	0.0012	2.93	0.0012	3.18	0.0003	2.60
Wheat	0.0006	1.53			0.0003	1.04	0.0007	1.61	0.0001	0.17	0.0002	2.21
WTI crude oil	0.0024	6.50			0.0006	2.40	0.0015	3.75	0.0030	8.44	0.0009	6.08
Gold	0.0018	4.86			0.0001	0.23	0.0016	4.06	0.0014	3.56	0.0001	1.01
Silver	0.0018	4.78			0.0003	1.20	0.0018	4.39	0.0009	2.49	0.0002	1.79
Cotton	0.0000	0.08			0.0002	0.81	0.0008	1.88	0.0005	1.27	0.0001	1.07
Coffee	0.0003	0.71			0.0004	1.69	0.0008	2.01	0.0004	1.08	0.0003	3.14
Cocoa	0.0005	1.01			-0.0001	-0.28	0.0008	1.86	0.0003	0.68	0.0000	-0.15
Sugar	0.0000	0.05			0.0000	-0.13	-0.0004	-1.04	0.0005	1.35	0.0001	0.75
Commodities VW index	0.0028	7.55			0.0004	1.59	0.0015	3.74	0.0034	6.43	0.0007	4.93
GSCI	0.0021	4.95			0.0007	2.97	0.0018	4.38	0.0020	5.45	0.0005	4.02

Table 5: Integration of bonds with other asset classes across time

This table shows adjusted R-squares (in %) of regressing commodity returns on PCs constructed from other asset classes. The R-square is constructed based on the Pukthuanthong and Roll (2009) principal component approach. The sample period is from the date each asset has data available until December 2010.

	PCs constructed from other asset classes						
	1989-1999	2000-2010	1989-1993	1994-1998	1999-2003	2004-2007	2008-2010
	Commodity, currency, stock, and real estate PCs						
5yr Treasury note	1.98	8.74	11.20	7.18	7.97	6.87	12.91
30yr Treasury Bond	3.18	8.90	20.66	9.59	5.98	4.72	16.96
BAA Bond	4.42	8.92	3.88	9.57	4.29	3.38	16.82
AAA Bond	4.52	6.21	5.72	9.99	4.35	3.92	11.66
BARCLAYS US AGGREGATE	3.48	5.51	16.98	9.71	5.32	5.78	9.56
Bond VW Index	2.11	3.08	15.76	1.84	0.90	1.06	8.14
	Commodity PCs						
5yr Treasury note	2.76	1.82	3.21	2.92	1.78	0.00	8.11
30yr Treasury Bond	4.75	2.76	7.53	2.90	1.36	-0.05	11.15
BAA Bond	2.32	2.56	4.06	2.54	0.69	0.11	7.73
AAA Bond	2.29	1.70	3.39	2.74	0.95	0.43	6.87
BARCLAYS US AGGREGATE	3.39	1.07	4.41	2.82	1.35	0.38	5.29
Bond VW Index	0.60	1.12	3.38	-0.13	0.24	0.99	2.77
	Currency PCs						
5yr Treasury note	0.12	5.18	3.43	0.64	2.97	13.36	18.34
30yr Treasury Bond	0.93	4.71	4.09	2.05	1.51	10.01	20.08
BAA Bond	2.05	3.91	2.90	2.92	1.55	7.31	14.29
AAA Bond	2.03	3.52	4.51	3.01	2.13	6.94	12.15
BARCLAYS US AGGREGATE	0.64	5.24	4.73	1.58	2.35	11.00	16.93
Bond VW Index	1.27	1.10	-0.72	2.13	0.68	1.10	4.34
	Stock PCs						
5yr Treasury note	8.67	10.71	7.22	15.33	6.96	8.74	15.26
30yr Treasury Bond	13.62	8.95	16.76	19.67	4.52	6.54	15.55
BAA Bond	12.06	7.86	8.98	18.93	2.45	5.11	15.18
AAA Bond	12.68	5.81	11.17	19.19	2.82	4.60	10.26
BARCLAYS US AGGREGATE	13.56	6.05	13.20	21.17	3.54	5.45	10.11
Bond VW Index	0.79	1.79	6.35	1.77	1.09	1.37	5.58
	REIT PCs						
5yr Treasury note	1.88	3.89	2.05	1.80	3.53	0.17	7.06
30yr Treasury Bond	3.46	3.68	6.20	2.39	1.72	-0.10	7.72
BAA Bond	3.30	4.44	4.78	3.36	0.73	-0.10	8.08
AAA Bond	4.12	2.75	6.49	3.96	0.70	-0.10	5.76
BARCLAYS US AGGREGATE	3.82	2.16	4.72	3.53	1.65	-0.04	4.94
Bond VW Index	-0.03	1.76	0.94	1.47	0.50	-0.05	3.77

Table 6: Evolving integration of bonds with other asset classes

This table shows the coefficient of time trend from adjusted R-squares regression. The R-square is constructed based on the Pukthuanthong and Roll (2009) principal component approach. The sample period is from the date each asset has data available until December 2010.

	PCs of other assets		Commodity PCs		Bond PCs		Currency PCs		Stock PCs		REIT	
	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat
Bonds												
5yr Treasury note	-0.0004	-0.99	0.0000	0.03			0.0023	5.32	-0.0009	-2.14	0.0000	0.08
30yr Treasury Bond	-0.0008	-1.77	0.0003	0.61			0.0020	4.58	-0.0013	-3.20	0.0000	-0.22
BAA Bond	-0.0008	-1.71	0.0000	-0.01			0.0013	2.98	-0.0013	-3.02	-0.0008	-3.12
AAA Bond	-0.0009	-2.04	-0.0002	-0.55			0.0015	3.42	-0.0013	-3.04	-0.0008	-3.07
BARCLAYS US AGGREGATE	-0.0012	-2.64	0.0000	0.05			0.0020	4.52	-0.0016	-3.88	-0.0003	-1.72
Bond VW index	0.0006	1.25	-0.0001	-0.25			0.0006	1.50	-0.0001	-0.20	0.0001	0.96

Table 7: Integration of currency returns with other asset classes across time

This table shows adjusted R-squares (in %) of regressing currency returns on PCs constructed from other asset classes. The R-square is constructed based on the Pukthuanthong and Roll (2009) principal component approach. The sample period is from the date each asset has data available until December 2010.

	PCs constructed from other asset classes						
	1989-1999	2000-2010	1989-1993	1994-1998	1999-2003	2004-2007	2008-2010
	Commodity, bond, stock, and real estate PCs						
Canadian Dollar	0.47	13.39	-0.38	0.39	0.99	6.94	27.83
Japanese Yen	0.42	4.79	0.32	1.20	1.14	2.57	15.70
Chinese Yuan	-0.25	0.84	-0.53	-0.36	-0.50	-0.47	2.33
Danish Krone	0.70	6.04	2.51	0.72	3.22	8.01	21.92
Hong Kong Dollar	0.04	0.08	0.03	0.06	-0.35	-0.07	3.00
Indian Rupee	0.45	4.76	2.25	-0.34	0.65	3.47	9.56
South Korean Won	-0.10	2.66	0.90	-0.22	1.04	3.68	4.23
Mexican Peso	1.50	5.19	-0.08	2.94	0.27	7.10	8.00
Norwegian Krone	0.48	11.30	2.40	0.70	2.27	10.28	27.55
Swedish Kronor	0.11	12.05	0.63	0.18	0.56	8.65	28.58
South Africa Rand	0.37	8.65	0.17	0.64	-0.19	10.15	26.59
Singapore Dollar	1.55	8.96	3.60	2.88	0.99	7.97	23.88
Sri Lankan Rupees	-0.18	-0.01	0.65	-0.14	-0.28	0.49	-0.56
Swiss Franc	0.55	3.11	1.48	0.50	4.96	6.52	10.82
Taiwanese Dollar	-0.02	1.39	0.83	0.05	0.11	3.03	6.16
Thai Baht	0.07	1.16	0.28	0.04	0.77	1.07	3.73
Australian Dollar	1.34	14.92	0.38	1.71	1.07	10.86	31.80
New Zealand Dollar	1.25	11.36	-0.25	2.86	1.00	6.97	27.81
British Pound	0.47	8.20	1.81	-0.32	2.94	8.55	21.15
Value-weighted exchange index	0.80	9.96	1.86	1.04	2.69	9.54	26.02
Currency VW index	1.63	14.29	1.69	1.89	2.36	13.43	32.69
	Commodity PCs						
Canadian Dollar	0.41	15.38	0.66	0.41	3.04	10.13	30.53
Japanese Yen	0.82	3.52	1.12	2.56	2.14	4.39	9.64
Chinese Yuan	-0.11	0.93	0.21	-0.33	0.43	-0.39	2.20
Danish Krone	0.55	9.55	2.54	1.70	2.27	14.52	24.69
Hong Kong Dollar	0.30	0.21	1.12	-0.36	-0.25	0.14	2.04
Indian Rupee	0.46	4.62	3.29	-0.38	1.07	2.35	8.77
South Korean Won	-0.30	2.71	-0.43	-0.57	0.90	3.11	6.09
Mexican Peso	0.62	4.96	-0.16	1.57	0.71	5.43	6.99
Norwegian Krone	0.85	15.94	3.16	1.71	3.83	13.96	32.49
Swedish Kronor	0.09	13.67	1.46	0.41	2.93	13.29	28.59

	1989-1999	2000-2010	1989-1993	1994-1998	1999-2003	2004-2007	2008-2010
				Commodity PCs			
South Africa Rand	0.19	8.76	0.18	0.11	0.58	13.13	24.55
Singapore Dollar	1.33	10.65	5.21	2.08	1.09	11.79	21.89
Sri Lankan Rupees	-0.21	-0.15	-0.70	-0.33	-0.26	-0.58	-0.80
Swiss Franc	0.33	6.68	1.32	1.01	2.69	11.71	14.15
Taiwanese Dollar	0.02	2.28	0.46	0.29	0.13	1.44	7.53
Thai Baht	-0.09	1.76	0.33	-0.12	0.13	1.49	3.67
Australian Dollar	1.38	17.34	0.49	2.07	3.60	18.21	33.16
New Zealand Dollar	1.10	12.88	-0.33	2.15	2.30	10.36	28.08
British Pound	0.82	10.83	1.82	0.04	1.96	13.65	22.26
Value-weighted exchange index	1.09	15.38	2.45	2.59	4.99	16.89	31.11
Currency VW index	2.20	18.97	3.67	2.17	5.74	20.57	35.65
				Bond PCs			
Canadian Dollar	0.13	3.59	1.15	-0.20	0.72	1.44	8.71
Japanese Yen	1.92	7.39	2.86	2.79	0.05	8.34	16.67
Chinese Yuan	0.07	0.66	-0.38	0.22	0.04	-0.11	2.69
Danish Krone	1.45	2.24	4.12	1.94	2.98	6.70	1.63
Hong Kong Dollar	-0.17	-0.15	-0.34	-0.19	-0.05	0.15	-0.55
Indian Rupee	-0.12	1.30	-0.36	-0.31	-0.14	0.46	2.47
South Korean Won	-0.13	2.23	0.68	-0.15	0.19	0.64	4.10
Mexican Peso	0.01	3.09	0.61	-0.04	0.17	2.52	4.81
Norwegian Krone	1.56	1.30	4.55	0.97	2.23	2.85	4.80
Swedish Kronor	0.72	1.72	2.91	0.22	1.37	4.56	6.37
South Africa Rand	0.69	1.86	2.54	0.17	1.44	3.14	6.50
Singapore Dollar	0.54	0.87	1.38	0.62	0.09	2.04	3.42
Sri Lankan Rupees	-0.20	0.01	1.19	-0.26	0.46	0.37	-0.03
Swiss Franc	1.25	4.17	3.06	2.47	2.72	7.89	2.04
Taiwanese Dollar	0.06	0.60	0.08	0.01	-0.24	0.06	3.04
Thai Baht	0.03	0.10	-0.02	-0.13	-0.17	0.03	0.59
Australian Dollar	0.30	3.53	0.02	0.16	0.08	4.75	7.91
New Zealand Dollar	0.53	2.97	0.62	0.32	-0.09	4.95	6.61
British Pound	1.08	0.83	3.07	0.81	1.35	5.31	2.48
Value-weighted exchange index	2.37	2.37	5.18	2.98	1.59	5.55	3.07
Currency VW index	1.73	2.55	7.34	1.64	1.50	4.61	5.88
				Stock PCs			
Canadian Dollar	0.46	6.05	-0.09	1.02	-0.08	3.99	13.78
Japanese Yen	0.70	3.91	0.04	1.40	1.02	1.60	10.42

	PCs constructed from other asset classes						
	1989-1999	2000-2010	1989-1993	1994-1998	1999-2003	2004-2007	2008-2010
	Stock PCs						
Danish Krone	0.42	0.43	1.43	1.75	4.22	2.45	5.91
Chinese Yuan	-0.22	0.29	-0.06	-0.52	-0.05	0.63	1.47
Hong Kong Dollar	-0.04	-0.10	-0.15	0.74	-0.58	0.87	0.40
Indian Rupee	-0.33	3.07	-0.55	-0.49	0.78	0.53	7.27
South Korean Won	0.28	1.52	-0.14	0.52	1.67	0.42	2.72
Mexican Peso	1.12	2.33	-0.69	2.30	-0.28	2.45	3.78
Norwegian Krone	0.10	3.13	0.96	0.81	2.04	1.72	12.43
Swedish Kronor	-0.06	4.38	0.00	0.27	0.71	1.02	15.26
South Africa Rand	0.56	4.71	0.10	1.21	-0.10	4.40	14.82
Singapore Dollar	0.20	3.88	1.03	1.04	0.98	2.52	10.52
Sri Lankan Rupees	0.34	-0.23	1.39	0.47	-0.50	-0.67	-0.36
Swiss Franc	1.31	0.31	1.09	2.60	5.80	1.83	0.14
Taiwanese Dollar	-0.11	0.66	-0.37	0.28	-0.21	0.06	3.62
Thai Baht	0.45	0.27	-0.11	1.77	0.88	-0.04	2.85
Australian Dollar	0.01	6.39	0.51	1.15	0.45	3.87	15.39
New Zealand Dollar	-0.18	5.39	0.15	0.09	0.34	4.49	13.71
British Pound	0.14	1.79	0.69	0.70	2.93	1.15	7.36
Value-weighted exchange index	0.38	1.53	0.27	1.08	2.89	2.53	7.52
Currency VW index	0.45	4.33	-0.42	1.48	1.54	3.31	13.44
	REIT						
Canadian Dollar	0.62	1.84	-0.06	1.70	0.07	0.15	3.17
Japanese Yen	0.09	2.46	0.03	0.70	0.06	0.03	5.65
Chinese Yuan	0.10	0.29	0.36	-0.07	-0.06	-0.01	0.73
Danish Krone	0.36	0.50	0.01	1.93	0.90	0.36	1.55
Hong Kong Dollar	-0.02	-0.04	0.04	-0.03	0.21	0.19	-0.06
Indian Rupee	-0.02	1.06	-0.07	-0.07	0.16	-0.01	1.55
South Korean Won	-0.04	0.58	0.07	-0.08	0.24	0.20	0.58
Mexican Peso	0.02	0.61	-0.03	0.01	-0.06	0.67	0.53
Norwegian Krone	0.01	1.63	0.00	0.36	0.08	0.51	3.08
Swedish Kronor	0.00	3.00	-0.08	0.01	-0.08	0.37	5.70
South Africa Rand	0.28	2.47	-0.08	0.49	0.48	3.14	4.23
Singapore Dollar	-0.04	2.04	0.16	-0.06	-0.01	1.37	4.02
Sri Lankan Rupees	0.02	-0.04	-0.09	0.06	-0.06	-0.04	-0.07
Swiss Franc	1.42	-0.01	0.23	3.21	1.67	-0.04	-0.14
Taiwanese Dollar	0.01	0.43	-0.07	0.01	-0.04	0.18	0.93
Thai Baht	-0.04	0.13	0.02	-0.08	-0.05	0.16	0.28

	PCs constructed from other asset classes						
	1989-1999	2000-2010	1989-1993	1994-1998	1999-2003	2004-2007	2008-2010
	REIT						
New Zealand Dollar	-0.03	2.98	-0.02	0.03	0.28	2.15	4.74
Australian Dollar	-0.04	2.15	0.01	-0.08	0.37	1.42	3.08
British Pound	0.11	1.53	-0.07	0.80	0.26	0.14	3.24
Value-weighted exchange index	0.14	0.59	-0.06	0.90	0.33	0.18	1.35
Currency VW index	0.23	2.15	-0.03	0.45	-0.08	1.21	3.54

Table 8: Evolving integration of currencies with other asset classes

This table shows the coefficient of time trend from adjusted R-squares regression. The R-square is constructed based on the Pukthuanthong and Roll (2009) principal component approach. The sample period is from the date each asset has data available until December 2010.

	PCs of other assets		Commodity PCs		Bond PCs		Currency PCs		Stock PCs		REIT	
	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat
Currencies												
Canadian Dollar	0.0017	3.87	0.0014	3.64	0.0006	2.53			0.0014	3.28	0.0004	3.58
Japanese Yen	0.0005	1.12	0.0003	0.74	0.0014	5.40			0.0008	1.99	0.0002	2.07
Chinese Yuan	-0.0003	-0.65	-0.0003	-0.66	-0.0004	-1.54			0.0002	0.54	0.0000	-0.15
Danish Krone	0.0017	4.24	0.0016	4.00	-0.0002	-0.84			0.0000	0.09	0.0001	1.18
Hong Kong Dollar	0.0000	0.05	0.0001	0.14	0.0001	0.40			0.0002	0.46	0.0000	0.36
Indian Rupee	0.0007	1.72	0.0012	2.76	0.0003	1.10			0.0004	1.00	0.0002	2.01
South Korean Won	0.0001	0.14	0.0007	1.76	0.0002	0.75			0.0000	0.08	0.0001	0.65
Mexican Peso	0.0004	1.13	0.0005	1.30	0.0004	1.47			0.0009	2.30	0.0000	0.18
Norwegian Krone	0.0016	3.74	0.0013	3.20	-0.0001	-0.41			0.0010	2.43	0.0004	2.65
Singapore Dollar	0.0017	4.00	0.0016	4.12	0.0004	1.71			0.0007	1.83	0.0005	4.35
South Africa Rand	0.0013	3.32	0.0015	4.05	0.0004	1.39			0.0015	3.93	0.0004	3.45
Singapore Dollar	0.0013	3.23	0.0015	3.55	0.0005	2.00			0.0005	1.14	0.0003	2.63
Sri Lankan Rupees	0.0002	0.43	0.0003	0.72	0.0002	0.69			-0.0009	-2.11	0.0001	1.60
Swiss Franc	0.0014	3.76	0.0014	3.65	0.0000	-0.03			-0.0004	-1.09	0.0000	0.06
Taiwanese Dollar	0.0005	1.15	0.0006	1.51	0.0005	2.30			0.0001	0.31	0.0001	1.46
Thai Baht	0.0001	0.21	0.0003	0.78	0.0001	0.26			0.0002	0.42	0.0000	0.27
Australian Dollar	0.0018	4.44	0.0019	5.11	0.0007	2.76			0.0018	4.39	0.0004	3.46
New Zealand Dollar	0.0011	2.90	0.0008	2.18	0.0003	1.23			0.0011	2.72	0.0004	3.47
British Pound	0.0010	2.54	0.0016	3.80	0.0000	0.07			0.0002	0.59	0.0001	0.56
Value-weighted exchange index	0.0016	3.69	0.0017	3.95	-0.0001	-0.35			0.0007	1.67	0.0002	1.59
Currency VW index	0.0021	5.49	0.0021	3.46	0.0001	-1.32			0.0012	2.92	0.0002	8.98

Table 9: Integration of stocks with other asset classes across time

This table shows adjusted R-squares (in %) of regressing stock returns of ten industries on PCs constructed from other asset classes. The R-square is constructed based on the Pukthuanthong and Roll (2009) principal component approach. The sample period is from the date each asset has data available until December 2010.

	PCs constructed from other asset classes						
	1989-1999	2000-2010	1989-1993	1994-1998	1999-2003	2004-2007	2008-2010
	Commodity, bond, currency, and real estate PCs						
Health Care	0.51	5.56	5.86	0.13	1.10	1.66	32.73
Consumer Discretionary	1.29	10.13	9.27	0.16	2.98	1.24	47.24
Energy	2.77	23.55	0.10	5.58	8.37	16.22	45.64
Finance	1.29	13.80	8.67	1.22	1.93	0.40	46.54
Industrials	1.10	10.81	10.49	0.60	2.90	0.58	47.43
Telecom	0.92	7.45	7.31	1.12	2.43	2.08	36.03
Materials	1.29	14.54	11.81	0.84	2.05	4.17	48.76
Consumer Staples	1.07	4.98	9.79	0.22	1.61	1.60	34.00
Information Technology	-0.10	5.48	3.24	0.76	1.53	0.60	43.11
Utilities	1.62	7.22	4.39	1.80	1.14	3.08	33.76
Stocks VW index	0.90	14.94	8.96	1.18	3.65	1.76	51.36
	Commodity PCs						
Health Care	1.24	2.33	3.54	0.22	-0.11	1.88	7.20
Consumer Discretionary	1.87	2.86	7.47	-0.45	0.71	1.57	10.04
Energy	1.17	18.33	0.11	2.85	7.74	21.56	28.49
Finance	1.49	2.70	6.18	0.59	0.00	0.18	7.82
Industrials	1.78	4.00	7.74	0.01	0.85	1.00	13.81
Telecom	2.02	2.45	6.45	0.47	1.14	1.15	9.70
Materials	0.42	9.29	3.18	-0.08	0.29	5.65	23.26
Consumer Staples	2.62	1.88	7.96	0.18	1.32	2.15	6.90
Information Technology	0.12	1.94	3.49	0.23	0.84	0.81	13.20
Utilities	0.68	2.84	3.60	-0.02	1.09	0.71	10.54
Stocks VW index	0.68	2.31	4.57	-0.11	0.57	0.99	9.64
	Bond PCs						
Health Care	0.77	3.56	6.73	3.56	0.68	5.25	7.73
Consumer Discretionary	1.37	8.68	10.26	4.13	5.60	8.64	13.80
Energy	0.14	6.64	1.70	1.26	1.39	3.26	14.99
Finance	0.85	6.49	10.91	4.87	2.85	7.46	9.64
Industrials	1.09	9.54	8.94	4.25	5.82	8.23	14.92
Telecom	0.19	5.87	12.33	3.13	5.23	6.05	7.97
Materials	1.52	8.47	6.68	2.40	3.99	9.00	14.26
Consumer Staples	0.82	3.73	14.64	2.65	-0.06	6.12	10.30
Information Technology	0.46	7.79	3.97	1.45	6.92	6.42	13.80

	1989-1999	2000-2010	1989-1993	1994-1998	1999-2003	2004-2007	2008-2010
	PCs constructed from other asset classes						
Utilities	0.51	3.60	19.53	4.33	0.71	5.12	11.13
Stocks VW index	1.00	9.97	13.28	4.43	6.27	9.30	14.94
	Currency PCs						
Health Care	0.29	2.40	1.40	0.66	0.80	3.83	16.69
Consumer Discretionary	1.25	4.88	0.60	1.94	3.45	5.55	21.93
Energy	1.70	9.46	0.71	2.27	-0.02	5.72	22.87
Finance	1.82	5.46	0.95	2.70	2.71	4.17	15.47
Industrials	1.38	6.62	1.78	2.64	2.85	5.44	25.06
Telecom	0.37	3.07	1.01	0.73	1.35	3.79	15.43
Materials	0.99	10.10	-0.34	2.15	0.88	11.34	25.99
Consumer Staples	0.12	3.59	0.42	0.56	1.07	2.76	18.24
Information Technology	1.01	2.42	1.48	0.95	1.99	4.29	21.46
Utilities	0.25	4.47	0.95	0.39	0.26	3.48	18.54
Stocks VW index	1.17	7.62	0.85	1.96	2.76	7.21	24.73
	REITs						
Health Care	11.03	23.46	10.72	17.39	10.85	25.51	41.29
Consumer Discretionary	21.72	45.99	23.74	28.64	22.92	42.19	67.54
Energy	5.91	25.41	2.89	8.03	9.31	13.15	37.61
Finance	22.49	61.64	23.33	28.78	21.98	51.93	75.47
Industrials	24.12	44.46	23.28	29.86	24.33	35.65	65.16
Telecom	8.23	22.22	11.40	8.81	11.58	21.49	42.37
Materials	17.29	37.04	18.38	20.95	19.25	33.22	51.21
Consumer Staples	12.84	25.00	18.35	13.42	6.84	30.73	45.22
Information Technology	11.38	22.30	13.76	13.61	13.07	24.46	57.96
Utilities	7.46	21.01	11.25	5.39	11.56	33.52	33.19
Stocks VW index	22.74	51.14	23.02	27.57	29.22	45.89	67.19

Table 10: Evolving integration of stocks with other asset classes

This table shows the coefficient of time trend from adjusted R-squares regression. The R-square is constructed based on the Pukthuanthong and Roll (2009) principal component approach. The sample period is from the date each asset has data available until December 2010.

	PCs of other assets		Commodity PCs		Bond PCs		Currency PCs		Stock PCs		REIT	
	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat
Stocks												
Health Care	0.0016	3.97	0.0009	2.50	0.0000	0.06	0.0010	4.13			0.0016	6.40
Consumer Discretionary	0.0022	5.11	0.0011	2.74	0.0002	0.53	0.0009	3.52			0.0024	9.35
Energy	0.0031	8.23	0.0023	5.82	0.0005	1.79	0.0018	7.11			0.0015	6.45
Finance	0.0027	5.81	0.0010	2.39	-0.0010	-3.29	0.0009	3.18			0.0029	10.45
Industrials	0.0025	5.56	0.0013	3.36	-0.0003	-0.92	0.0009	3.36			0.0020	7.63
Telecom	0.0016	3.35	0.0009	2.36	-0.0007	-2.44	0.0005	2.15			0.0014	5.95
Materials	0.0030	6.71	0.0021	4.90	0.0004	1.27	0.0015	5.55			0.0017	6.60
Consumer Staples	0.0019	4.39	0.0010	2.60	-0.0003	-1.03	0.0010	3.70			0.0020	8.16
Information Technology	0.0018	3.98	0.0008	2.01	0.0009	3.35	0.0013	5.33			0.0024	9.61
Utilities	0.0019	4.01	0.0009	2.21	-0.0006	-1.92	0.0009	3.38			0.0017	7.20
Stock VW index	0.0025	5.23	0.0014	5.40	-0.0004	0.27	0.0011	4.14			0.0024	2.14

Table 11: Integration of real estate returns with other asset classes across time

This table shows adjusted R-squares (in %) of regressing value-weighted REIT returns on PCs constructed from other asset classes. The *R*-square is constructed based on the Pukthuanthong and Roll (2009) principal component approach. The sample period is from the date each asset has data available until December 2010.

	1989-1999	2000-2010	1989-1993	1994-1998	1999-2003	2004-2007	2008-2010
				Commodity, bond, currency, and stock PCs			
Real estate	5.83	40.07	13.59	9.66	21.88	18.61	69.95
				Commodity PCs			
Real estate	0.02	3.20	1.81	-0.19	0.57	0.12	7.12
				Bond PCs			
Real estate	1.45	4.84	8.13	2.93	2.30	5.45	8.43
				Currency PCs			
Real estate	0.90	6.00	1.95	2.62	0.53	3.74	11.74
				Stock PCs			
Real estate	23.40	54.73	23.97	29.99	29.78	49.82	74.08

	PCs of other assets		Commodity PCs		Bond PCs		Currency PCs		Stock PCs		REIT	
	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat	Time trend	t-stat
VWREIT	0.0028	7.92	0.0009	2.31	0.0000	-0.06	0.0011	2.56	0.0027	7.87		

Table 12: Maximized Sharpe ratio optimization portfolios based on out-of-sample weighting

This table presents summary statistics of maximized Sharpe ratios optimization portfolios based on out-of-sample portfolio weights. We present the standard, generalized, and VaR-adjusted Sharpe ratios in percentage. Optimal portfolio weights are calculated at the start of each calendar year, based on the previous five years of monthly data. Weights are maintained for the following 12 months. Sharpe ratio summary statistics are calculated based on the monthly time-series for each portfolio. The risk-free rate is the three-month T-Bill rate. The sample period is from the date each asset has data available until December 2010.

Portfolio #	Weight (%)					Monthly Returns		SR	GSR	VaR-adj SR
	Bond	Currency	Stocks	Commodities	Real estate	Mean (%)	Std Dev (%)			
					5 assets					
1	23.43	34.31	21.77	10.33	10.16	0.21	1.19	0.17		
	20.92	27.85	21.29	9.07	20.87	0.28	1.65		0.13	
	25.87	31.84	23.16	10.46	8.67	0.21	1.19			0.13
					4 assets					
2		46.53	28.41	12.96	12.10	0.27	1.55	0.17		
		49.63	32.41	13.87	4.10	0.24	1.42		0.13	
		56.59	24.24	13.77	5.40	0.20	1.18			0.07
3	47.50		31.27	7.65	13.58	0.29	1.77	0.16		
	37.69		26.19	5.78	30.33	0.37	2.34		0.09	
	50.53		37.30	6.40	5.77	0.27	1.68			0.11
4	25.61	31.49	29.76		13.14	0.26	1.52	0.16		
	27.26	28.83	24.60		19.30	0.27	1.61		0.10	
	26.16	35.60	33.94		4.31	0.23	1.36			0.07
5	28.69	32.60		15.13	23.58	0.18	1.23	0.14		
	23.42	38.50		18.01	20.08	0.16	1.11		0.09	
	21.98	26.76		15.91	35.36	0.26	1.35			0.05
6	10.14	38.78	37.86	13.22		0.25	1.49	0.16		
	9.28	42.62	33.84	14.26		0.23	1.36		0.13	
	8.32	45.41	35.15	11.12		0.23	1.37			0.08
				3 assets						
7			63.34	13.01	23.65	0.49	3.55	0.16		
			78.96	13.23	7.81	0.56	3.55		0.11	
			73.66	14.07	12.28	0.56	3.51			0.05
8		47.98		20.51	31.51	0.25	1.71	0.14		
		55.60		18.05	26.35	0.20	1.43		0.09	
		41.28		25.36	33.36	0.27	1.89			0.10
9		43.88	41.65	14.47		0.27	1.65	0.16		
		41.25	33.04	25.71		0.25	1.54		0.12	
		51.93	51.73	-3.66		0.30	1.92			0.05
10		44.37	39.48		16.15	0.34	2.01	0.16		
		42.84	43.14		14.02	0.35	2.07		0.12	
		33.97	47.87		18.16	0.40	2.43			0.11
11	53.06			14.60	32.34	0.24	1.77	0.13		
	44.44			13.10	42.46	0.31	2.28		0.10	
	62.07			13.03	24.90	0.19	1.37			0.07
12	33.33		55.47	11.20		0.36	2.28	0.15		
	40.23		64.65	4.88		0.38	2.49		0.09	
	29.34		63.20	7.46		0.40	2.55			0.10
13	47.66		36.73		15.61	0.32	1.99	0.16		
	43.68		34.53		21.79	0.35	2.17		0.10	
	49.79		41.02		9.19	0.31	1.89			0.11
14	35.95	26.53			37.52	0.24	1.81	0.13		
	30.88	27.62			41.51	0.27	2.02		0.09	

Portfolio #	Weight (%) Bond	Currency	Stocks	Commodities	Real estate	Monthly Returns Mean (%)	Std Dev (%)	SR	GSR	VaR-adj SR
	39.21	20.95			39.85	0.26	1.94			0.11
15	-845.50	331.33		614.17		1.28	21.30	0.06		
	-892.16	384.75		607.42		1.26	20.98		0.04	
	-987.52	392.42		695.10		1.45	24.11			0.03
16	28.29	2.93	68.78			0.41	2.69	0.15		
	35.05	2.37	62.59			0.38	2.44		0.09	
	21.44	2.96	75.60			0.45	2.97			0.10
					2 assets					
17	111033	-110933				11.00	1607.10	-0.01		
	134404	-112836				9.93	1673.69		0.01	
	122941	-113041				10.63	1653.85			0.00
18	30.24		69.76			0.42	2.74	0.15		
	23.81		76.19			0.46	3.00		0.10	
	29.05		70.95			0.43	2.79			0.12
19	40.00			60.00		0.12	2.05	0.11		
	39.84			60.16		0.12	2.05		0.08	
	31.96			68.04		0.14	2.33			0.07
20	55.83				44.17	0.29	2.22	0.13		
	45.72				54.28	0.36	2.77		0.08	
	66.77				33.23	0.22	1.65			0.10
21		40.36	59.64			0.35	2.23	0.15		
		45.25	54.75			0.32	2.04		0.10	
		38.80	61.20			0.36	2.30			0.09
22		27.76		72.24		0.15	2.35	0.06		
		30.21		69.79		0.14	2.25		0.04	
		26.29		73.71		0.15	2.41			0.02
23		44.73			55.27	0.36	2.75	0.13		
		34.36			65.64	0.43	3.32		0.09	
		42.68			57.32	0.38	2.86			0.06
24			84.21	15.79		0.54	3.53	0.15		
			97.62	2.38		0.59	3.91		0.10	
			85.18	14.82		0.55	3.55			0.12
25			72.84		27.16	0.62	3.92	0.16		
			87.37		12.63	0.61	3.91		0.12	
			61.83		38.17	0.63	3.99			0.12
26				72.84	27.16	0.33	3.15	0.10		
				88.30	11.71	0.26	3.25		0.07	
				61.71	38.29	0.38	3.22			0.09
					1 asset					
27	100.00					-0.006	0.70	-0.02		
	100.00					-0.006	0.70		0.01	
	100.00					-0.006	0.70			0.00
28		100.00				-0.02	1.47	-0.02		
		100.00				-0.02	1.47		0.01	
		100.00				-0.02	1.47			0.00
29			100.00			0.60	3.99	0.15		
			100.00			0.60	3.99		0.10	
			100.00			0.60	3.99			0.11
30				100.00		0.21	3.48	0.06		
				100.00		0.21	3.48		0.05	
				100.00		0.21	3.48			0.03
31					100.00	0.67	5.28	0.12		
					100.00	0.67	5.28		0.08	

Portfolio #	Weight (%) Bond	Currency	Stocks	Commodities	Real estate	Monthly Returns Mean (%)	Std Dev (%)	SR	GSR	VaR-adj SR
					100.00	0.67	5.28			0.05
				With short-sales constraint						
15		27.76		72.24		0.15	2.35	0.06		
		30.21		69.79		0.14	2.25		0.04	
		26.29		73.71		0.15	2.41			0.02
17	100.00					-0.006	0.70	-0.02		
	100.00					-0.006	0.70		-0.01	
	100.00					-0.006	0.70			-0.0004

Table 13: Mean and standard deviation during contagion vs. non-contagion periods

This table presents monthly return and standard deviation of returns of the portfolios (in %) that maximize Sharpe Ratio, Generalized Sharpe Ratio (GSR), and VaR-adjusted Sharpe Ratio (VaR-adj SR) according to Table 12. The mean and standard deviation in each row are for three portfolios, each of which is composed of different weight of assets and maximize different Sharpe Ratios. Contagion period is defined as a month that correlation of residuals from PC regression is significantly different from zero. The sample period is from the date each asset has data available until December 2010.

	Contagion periods						Non-contagion periods					
	SR		GSR		VaR-adj SR		SR		GSR		VaR-adj SR	
Portfolio #	Mean return	Stdev of return	Mean return	Stdev of return	Mean return	Stdev of return	Mean return	Stdev of return	Mean return	Stdev of return	Mean return	Stdev of return
						5 assets						
1	0.25	1.26	0.34	2.18	0.31	1.29	0.18	1.10	0.23	1.07	0.12	1.13
						4 assets						
2	0.28	2.96	0.26	3.55	0.34	2.70	0.26	0.14	0.23	0.71	0.07	0.35
3	0.32	2.60	0.38	2.40	0.33	5.54	0.27	0.95	0.36	2.09	0.22	2.89
4	0.31	1.77	0.32	1.84	0.26	1.52	0.22	1.21	0.22	1.64	0.19	1.19
5	0.22	1.30	0.21	1.54	0.41	1.18	0.14	1.19	0.12	0.72	0.12	2.43
6	0.20	1.46	0.24	1.40	0.27	1.35	0.30	1.46	0.21	1.35	0.17	1.32
						3 assets						
7	0.26	5.96	0.30	7.38	0.28	6.85	0.71	1.17	0.78	0.27	0.83	0.17
8	0.25	2.04	0.28	2.10	0.29	2.26	0.24	1.34	0.12	0.76	0.25	1.52
9	0.36	4.01	0.27	4.57	0.30	3.75	0.19	0.74	0.22	1.51	0.28	0.09
10	0.40	3.07	0.49	2.48	0.31	2.60	0.27	0.94	0.21	1.63	0.50	2.29
11	0.31	3.25	0.36	3.96	0.38	3.41	0.17	0.28	0.27	0.62	0.00	0.70
12	0.41	5.47	0.32	5.50	0.33	4.13	0.30	0.89	0.42	0.52	0.48	0.98
13	0.45	3.96	0.35	4.14	0.55	3.45	0.20	0.01	0.37	0.21	0.07	0.32
14	0.26	2.52	0.26	2.83	0.24	2.74	0.23	1.13	0.27	1.21	0.29	1.13
15	1.51	36.34	1.72	32.69	1.61	41.53	1.05	6.44	0.79	9.63	1.35	6.59
16	0.50	4.30	0.57	5.18	0.45	4.43	0.32	1.09	0.17	0.32	0.47	1.52
						2 assets						
17	NA											
18	0.47	5.76	0.45	4.78	0.36	4.41	0.37	0.29	0.45	1.20	0.51	1.19
19	0.14	2.22	0.13	2.30	0.11	2.34	0.11	1.85	0.12	1.75	0.18	2.39
20	0.38	4.57	0.31	4.51	0.37	4.78	0.21	0.12	0.41	1.08	0.06	1.44
21	0.39	4.67	0.47	5.39	0.42	5.28	0.30	0.20	0.17	1.38	0.29	0.71
22	0.14	2.84	0.11	3.28	0.13	2.57	0.15	1.90	0.18	1.20	0.17	2.18
23	0.44	3.88	0.50	4.14	0.41	3.07	0.28	1.66	0.37	2.49	0.35	2.63
24	0.51	7.03	0.42	7.34	0.42	8.04	0.58	0.02	0.78	0.48	0.69	0.91
25	0.85	8.76	0.92	7.66	0.82	7.87	0.38	0.94	0.31	0.16	0.43	0.12
26	0.36	3.22	0.30	3.72	0.32	2.45	0.32	3.03	0.22	2.80	0.47	4.19
						1 asset						
27	-0.01	0.85	-0.01	0.65	-0.01	0.93	0.00	0.53	0.00	0.73	0.00	0.46
28	-0.02	1.39	-0.02	1.49	-0.02	1.56	-0.01	1.54	-0.01	1.45	-0.02	1.32
29	0.80	10.48	0.65	12.50	0.64	13.08	0.41	2.59	0.57	4.52	0.59	4.98
30	0.39	12.02	0.43	12.27	0.35	11.49	0.03	4.97	-0.01	5.27	0.07	4.61
31	0.90	10.67	0.74	11.33	1.08	12.07	0.45	0.10	0.58	0.75	0.25	1.57

Table 14: Diversification benefits during contagion vs. non-contagion periods

This table presents maximized Sharpe Ratio, Generalized Sharpe Ratio (GSR), and VaR-adjusted Sharpe Ratio (VaR-adj SR) according to Table 12. The *p*-value is the statistical significance of the difference in Sharpe Ratio between contagion and non-contagion periods for the two-sided test of equal Sharpe ratios developed by Ledoitt and Wolf (2008). Contagion period is defined as a month that correlation of residuals from PC regression is significantly different from zero. The sample period is from the date each asset has data available until December 2010.

Portfolio	Contagion periods			Non-contagion periods			P-value for difference		
#	SR	GSR	VAR-adj SR	SR	GSR	VAR-adj SR	SR	GSR	VaR-adj SR
				5 assets					
1	0.21	0.16	0.20	0.24	0.16	0.21	0.10	0.65	0.24
				4 assets					
2	0.09	0.07	0.05	0.20	0.13	0.12	0.00	0.08	0.07
3	0.11	0.08	0.06	0.20	0.15	0.17	0.03	0.07	0.01
4	0.12	0.07	0.04	0.20	0.15	0.14	0.01	0.08	0.01
5	0.10	0.09	0.07	0.20	0.10	0.08	0.01	0.16	0.28
6	0.10	0.09	0.11	0.19	0.12	0.08	0.07	0.19	0.13
				3 assets					
7	0.04	0.03	0.03	0.28	0.21	0.17	<0.001	<0.001	0.00
8	0.12	0.09	0.11	0.17	0.10	0.10	0.07	0.18	0.24
9	0.09	0.06	0.04	0.24	0.14	0.17	0.01	0.08	0.00
10	0.13	0.10	0.11	0.19	0.12	0.11	0.05	0.17	0.23
11	0.10	0.07	0.10	0.16	0.11	0.14	0.05	0.13	0.08
12	0.07	0.04	0.05	0.23	0.15	0.15	0.00	0.00	0.01
13	0.11	0.07	0.10	0.22	0.16	0.11	0.01	0.02	0.23
14	0.10	0.07	0.04	0.16	0.10	0.12	0.05	0.15	0.07
15	0.08	0.03	0.02	0.08	0.06	0.04	0.81	0.16	0.19
16	0.12	0.09	0.07	0.18	0.11	0.13	0.05	0.18	0.06
				2 assets					
17	NA								
18	0.07	0.05	0.06	0.23	0.18	0.07	0.00	0.00	0.22
19	0.06	0.04	0.02	0.16	0.10	0.09	0.01	0.06	0.07
20	0.06	0.04	0.05	0.20	0.14	0.14	0.01	0.03	0.01
21	0.07	0.05	0.04	0.23	0.15	0.16	0.00	0.01	0.01
22	0.05	0.04	0.03	0.17	0.14	0.14	0.01	0.01	0.01
23	0.10	0.07	0.03	0.16	0.10	0.07	0.05	0.14	0.08
24	0.05	0.04	0.03	0.25	0.18	0.10	<0.001	0.01	0.05
25	0.07	0.05	0.04	0.25	0.17	0.11	<0.001	0.01	0.07
26	0.09	0.06	0.03	0.21	0.16	0.10	0.00	0.48	0.08
				1 assets					
27	-0.01	0.01	0.00	-0.03	0.08	0.03	0.20	0.08	0.14
28	-0.01	0.01	0.00	-0.03	0.07	0.05	0.22	0.08	0.06
29	0.05	0.04	0.02	0.24	0.19	0.21	<0.001	0.01	<0.002
30	0.02	0.02	0.01	0.10	0.18	0.06	0.05	0.00	0.09
31	0.06	0.04	0.05	0.18	0.13	0.13	0.01	0.01	0.06

Table 15: Changes in diversification benefits from adding one more asset

This table presents the difference in Sharpe Ratio, Generalized Sharpe Ratio (GSR), and VaR-adjusted Sharpe Ratio (VaR-adj SR) from adding one asset class into a portfolio. The p-values of the test are for the two-sided test of equal Sharpe ratios developed by Ledoitt and Wolf (2008) and reported in brackets under each corresponding difference Portfolio numbers in the first two columns are consistent with the portfolios shown in Table 12. Contagion period is defined as a month that correlation of residuals from PC regression is significantly different from zero. The sample period is from the date each asset has data available until December 2010.

Portfolio #	Compared portfolio #	Contagion			Non-contagion		
		SR	GSR	VaR-adj SR	SR	GSR	VaR-adj SR
				4 to 5 assets			
2	1	0.116	0.135	0.158	0.044	0.113	0.125
		(0.01)	(0.00)	(0.00)	(0.08)	(0.01)	(0.00)
3	1	0.096	0.128	0.142	-0.205	-0.148	-0.165
		(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
4	1	0.086	0.132	0.170	-0.001	0.053	0.056
		(0.00)	(0.00)	(0.00)	(0.51)	(0.10)	(0.12)
5	1	0.106	0.121	0.132	0.005	0.103	0.126
		(0.01)	(0.01)	(0.00)	(0.27)	(0.01)	(0.00)
6	1	0.106	0.115	0.094	0.013	0.085	0.124
		(0.01)	(0.01)	(0.02)	(0.19)	(0.01)	(0.00)
				3 to 4 assets			
7	2 and 3	0.063	0.048	0.022	-0.076	-0.075	-0.023
		(0.10)	(0.72)	(0.17)	(0.08)	(0.08)	(0.17)
8	2 and 5	-0.025	-0.007	-0.045	0.035	0.015	0.003
		(0.19)	(0.26)	(0.08)	(0.11)	(0.18)	(0.36)
9	2 and 6	0.005	0.020	0.037	-0.042	-0.015	-0.076
		(0.25)	(0.21)	(0.08)	(0.11)	(0.18)	(0.08)
10	2 and 4	-0.025	-0.026	-0.072	0.015	0.016	0.023
		(0.19)	(0.19)	(0.07)	(0.18)	(0.17)	(0.17)
11	3 and 5	0.005	0.010	-0.026	0.046	0.018	-0.023
		(0.27)	(0.24)	(0.19)	(0.08)	(0.24)	(0.17)
12	3 and 6	0.035	0.042	0.036	-0.033	-0.019	-0.029
		(0.10)	(0.11)	(0.10)	(0.11)	(0.18)	(0.16)
13	3 and 4	0.005	0.007	-0.046	-0.012	-0.016	0.044
		(0.26)	(0.25)	(0.75)	(0.20)	(0.16)	(0.08)
14	4 and 5	0.010	0.007	0.016	0.044	0.023	-0.006
		(0.25)	(0.26)	(0.16)	(0.08)	(0.17)	(0.21)
15	5 and 6	0.027	0.058	0.074	0.114	0.049	0.043
		(0.21)	(0.17)	(0.08)	(0.01)	(0.09)	(0.11)
16	4 and 6	-0.010	-0.008	0.001	0.018	0.022	-0.015
		(0.25)	(0.25)	(0.54)	(0.24)	(0.17)	(0.17)
				2 to 3 assets			
17	14, 15, 16	0.100	0.065	0.044	0.138	0.091	0.093
		(0.01)	(0.08)	(0.08)	(0.00)	(0.01)	(0.01)
18	12, 13, 16	0.035	0.017	0.019	-0.021	-0.034	0.059
		(0.14)	(0.23)	(0.18)	(0.17)	(0.11)	(0.18)
19	11, 12, 15	0.023	0.014	0.035	-0.001	0.001	0.018
		(0.10)	(0.19)	(0.10)	(0.60)	(0.52	(0.24)
20	11, 14, 15	0.033	0.017	-0.002	-0.069	-0.048	-0.038
		(0.11)	(0.24)	(0.40)	(0.07)	(0.72)	(0.07)
21	9, 10, 16	0.043	0.032	0.037	-0.028	-0.026	-0.020
		(0.11)	(0.11)	(0.08)	(0.18)	(0.18)	(0.21)
22	8, 9, 15	0.047	0.023	0.023	-0.010	-0.044	-0.037
		(0.71)	(0.17)	(0.18)	(0.24)	(0.11)	(0.08)
23	8, 10, 14	0.017	0.021	0.053	0.014	0.013	0.034

Portfolio #	Compared portfolio #	Contagion			Non-contagion		
		SR	GSR	VaR-adj SR	SR	GSR	VaR-adj SR
		(0.23)	(0.21)	(0.12)	(0.19)	(0.28)	(0.11)
24	7, 9, 12	0.017	0.007	0.019	0.002	-0.010	0.058
		(0.23)	(0.26)	(0.24)	(0.50)	(0.25)	(0.11)
25	7, 10, 13	0.023	0.011	0.037	-0.027	0.002	0.015
		(0.17)	(0.20)	(0.08)	(0.18)	(0.47)	(0.17)
26	7, 8, 11	-0.003	-0.002	0.048	-0.014	-0.020	0.040
		(0.32)	(0.49)	(0.70)	(0.18)	(0.21)	(0.18)
1 to 2 assets							
27	17 to 20	0.058	0.025	0.032	0.177	0.022	0.044
		(0.13)	(0.18)	(0.11)	(0.00)	(0.17)	(0.08)
28	17, 21-23	0.065	0.032	0.026	0.168	0.026	0.041
		(0.08)	(0.12)	(0.18)	(0.00)	(0.19)	(0.11)
29	18, 21, 24-25	0.013	0.008	0.015	-0.024	-0.044	-0.097
		(0.24)	(0.26)	(0.18)	(0.18)	(0.08)	(0.01)
30	19, 22, 24, 26	0.043	0.027	0.019	0.099	-0.030	0.050
		(0.11)	(0.18)	(0.18)	(0.01)	(0.15)	(0.08)
31	20, 23, 25-26	0.023	0.012	-0.007	0.025	0.015	-0.022
		(0.21)	(0.28)	(0.26)	(0.19)	(0.18)	(0.21)

Figure 1: Commodities integration with other asset classes

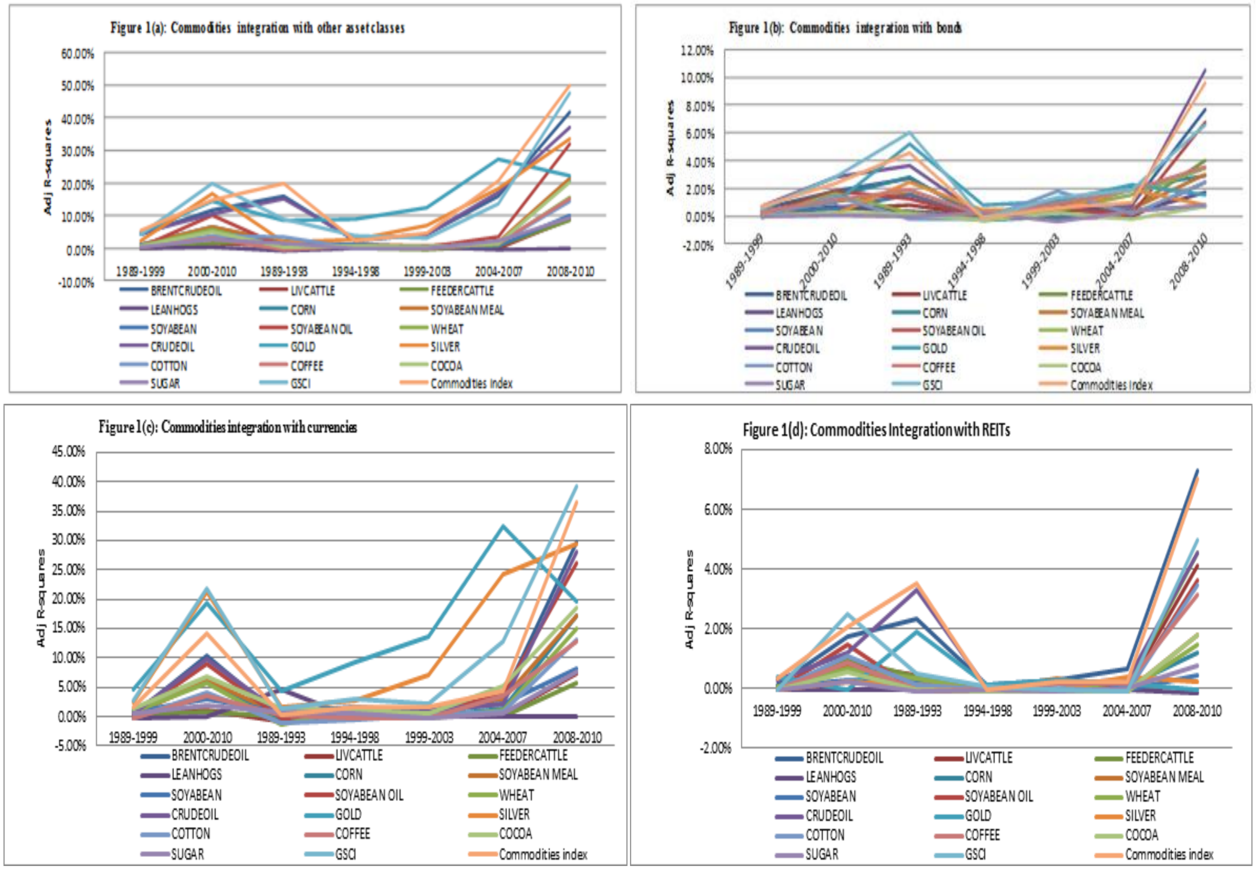


Figure 2: Bond integration with other asset classes

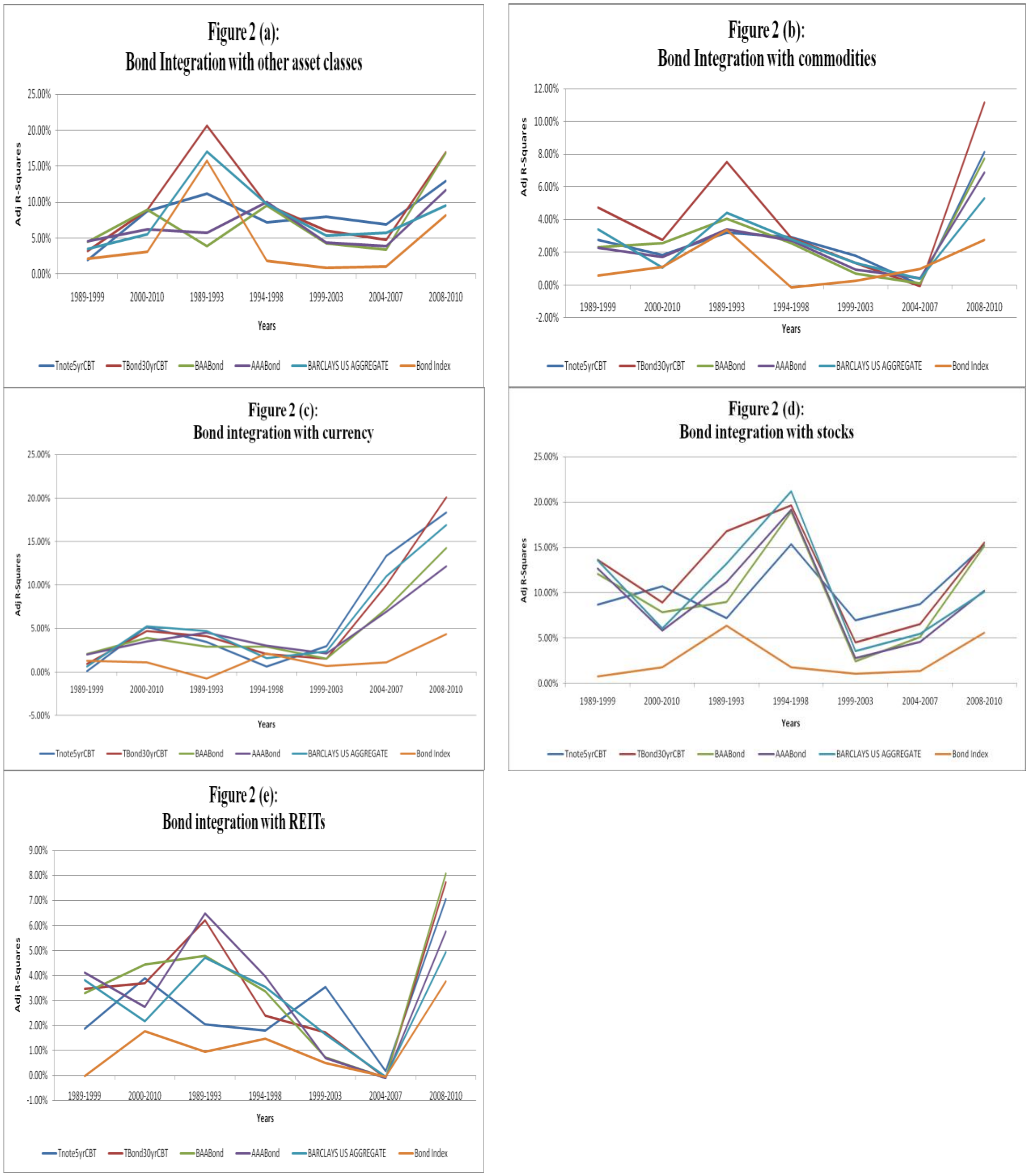
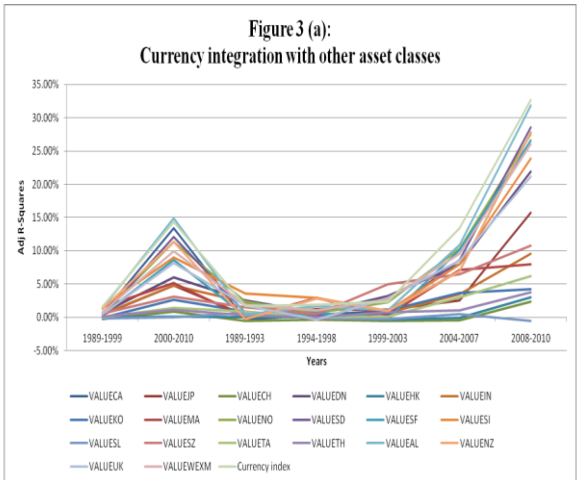
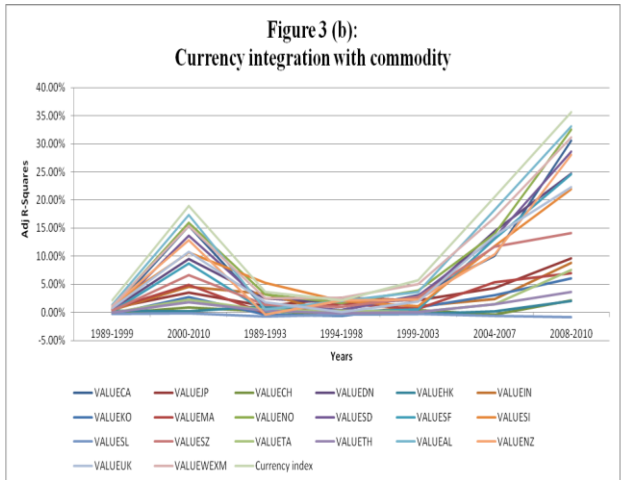
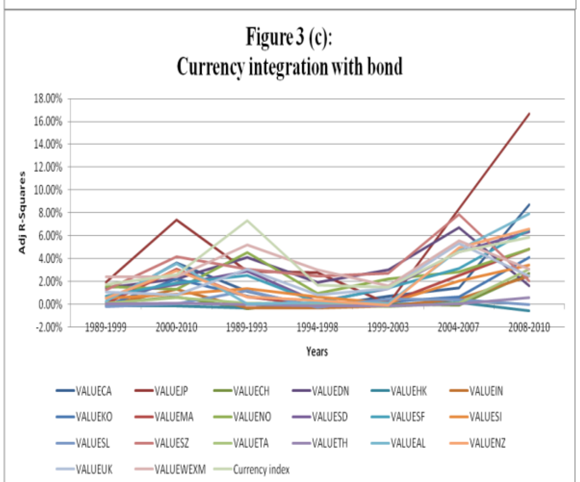
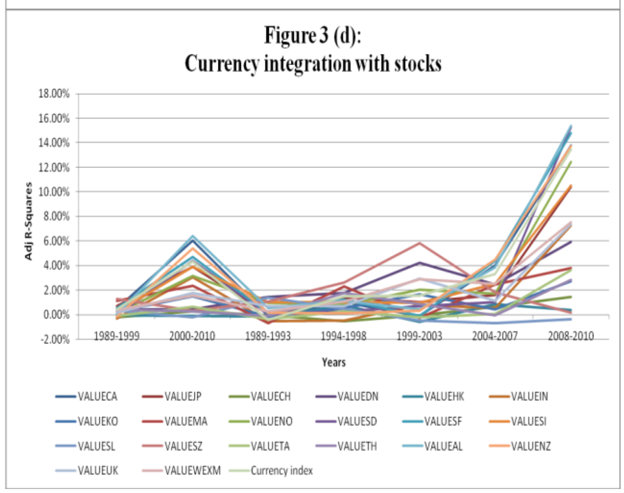


Figure 3: Currency integration with other asset classes









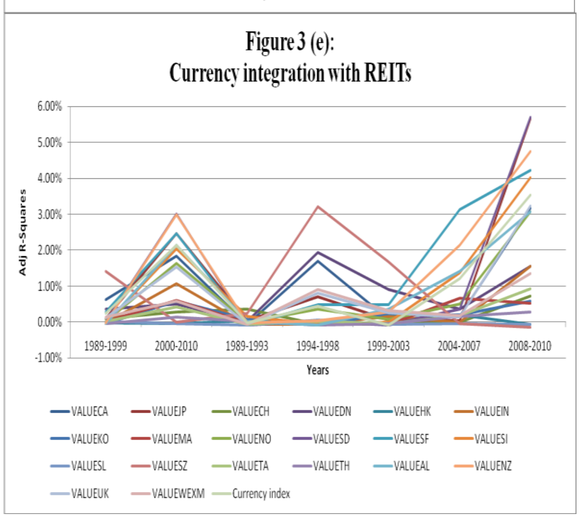


Figure 4: Stock integration with other asset classes

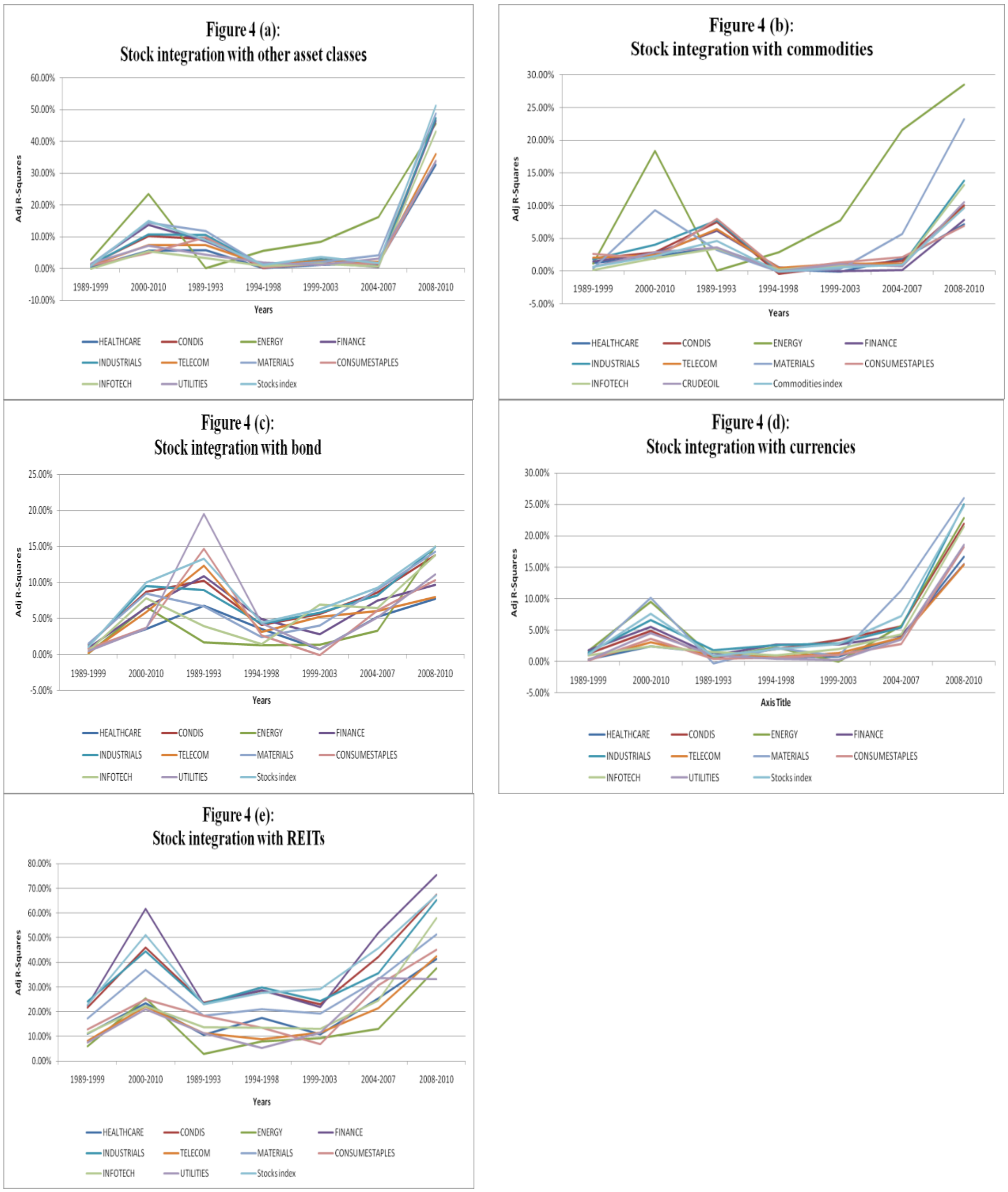


Figure 5: REITs Integration with other asset classes

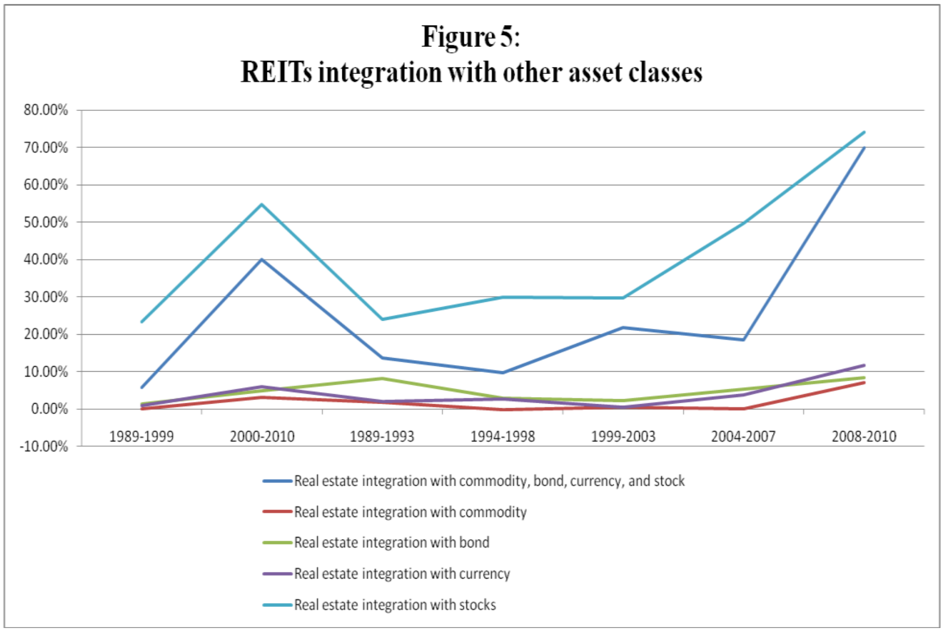


Figure 6: Mean-variance frontiers allowing short sales

This figure depicts mean-variance frontiers for maximized Sharpe ratio optimization portfolios of five different asset classes. These frontiers represent the first six portfolios shown in Table 12. The sample period is from January 1971 to December 2010.

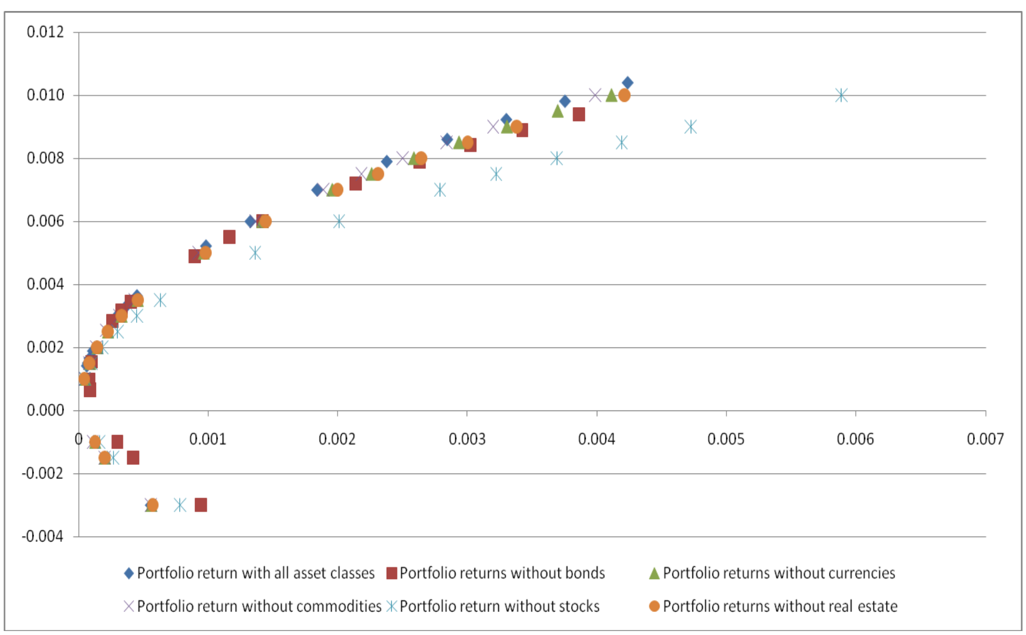
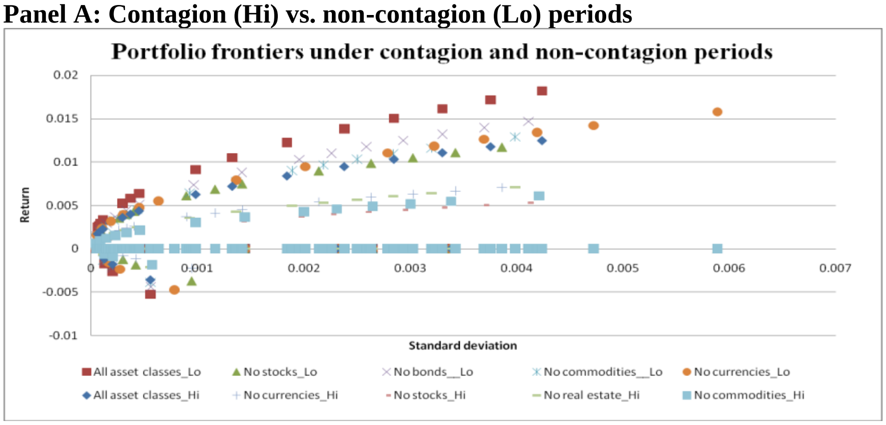


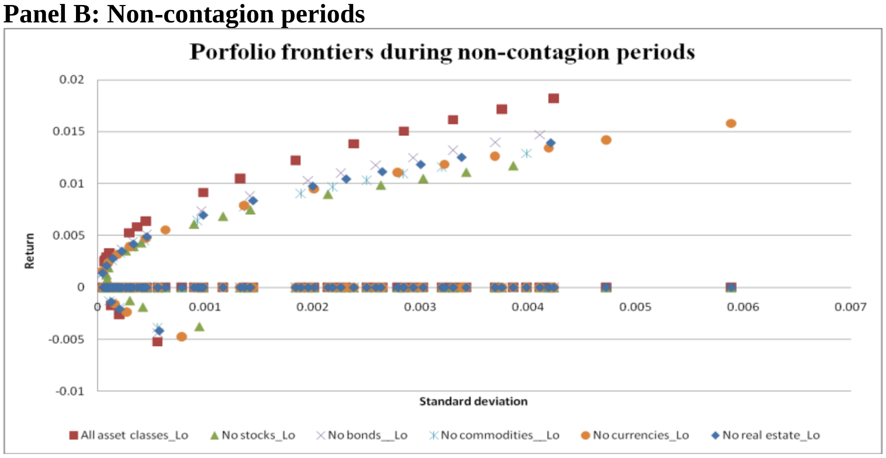
Figure 7: Mean-variance frontiers allowing short sales

This figure depicts mean-variance frontiers for maximized Sharpe ratio optimization portfolios of five different asset classes and of different combinations of four asset classes. The weight of five asset portfolio is from portfolio 1 and the weights of other portfolios are from portfolios 2 to 6 shown in Table 12. A contagion period is defined as a period when the average correlation of residuals from principle component analysis (PCA) across pairs of assets is significantly different from zero. The sample period is from January 1989 to December 2010. Panel A shows all frontiers together, Panel B shows those frontiers during non-contagion period (Lo), and Panel C shows those frontiers during contagion periods (Hi).

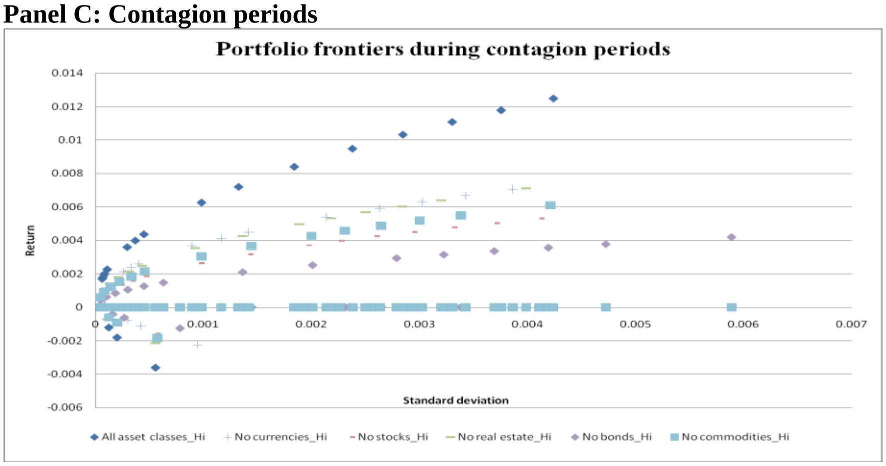
Panel A: Contagion (Hi) vs. non-contagion (Lo) periods



Panel B: Non-contagion periods



Panel C: Contagion periods



Appendix
Minimized variance optimization portfolios based on out-of-sample weighting

This table presents summary statistics of minimized variance optimization portfolios based on out-of-sample portfolio weights. Optimal portfolio weights are calculated at the start of each calendar year, based on the previous five years of monthly data. Weights are maintained for the following 12 months. Sharpe ratio summary statistics are calculated based on the monthly time-series for each portfolio. The risk-free rate is the three-month T-Bill rate. The sample period is from January 1989 to December 2010.

Port.	Weight (%)					Monthly Returns		Sharpe Ratio			
	Bond	Currency	Stocks	Comm-odities	Real estate	Mean (%)	Std Dev (%)	Mean	Median	Max	Min
						5 assets					
1	66.27	20.03	2.64	6.97	4.09	0.05	0.52	0.74	0.17	3.29	-5.23
						4 assets					
2		70.61	7.59	17.30	4.50	0.01	0.91	0.99	0.17	3.55	-2.66
3	89.28		1.90	4.79	4.04	0.04	0.59	0.53	0.06	2.94	-4.85
4	76.06	15.50	3.74		4.70	0.05	0.57	0.62	0.13	4.59	-5.39
5	67.90	19.49		7.35	5.25	0.04	0.53	0.60	0.14	3.21	-5.12
6	66.64	19.92	5.88	7.56		0.04	0.55	0.59	0.12	4.53	-5.36
						3 assets					
7			35.45	57.58	6.97	0.38	2.89	0.13	0.15	3.05	-6.36
8		72.74		19.23	8.03	0.08	0.94	0.08	0.18	3.04	-2.85
9		70.80	11.18	18.02		0.09	0.93	0.09	0.14	3.62	-2.93
10		79.95	13.43		6.62	0.11	1.12	0.09	0.15	3.47	-2.87
11	90.01			5.11	4.88	0.04	0.60	0.04	0.05	3.13	-4.79
12	89.52		5.10	5.38		0.04	0.62	0.04	0.02	3.71	-5.00
13	92.67		2.84		4.50	0.04	0.61	0.05	0.05	3.67	-5.05
14	79.22	14.35			6.43	0.04	0.59	0.04	0.10	4.56	-5.26
15	72.58	17.98		9.44		0.00	0.60	0.00	0.02	5.34	-5.16
16	82.85	10.55	6.60			0.03	0.63	0.03	0.09	5.93	-5.45
						2 assets					
17	89.55	10.45				-0.01	0.69	-0.03	0.03	7.30	-5.42
18	93.42		6.58			0.03	0.64	0.04	0.04	4.95	-5.25
19	40.00			60.00		0.12	0.98	0.11	0.13	7.65	-9.11
20	94.15				5.85	0.03	0.62	0.04	0.03	4.08	-4.99
21		80.82	19.18			0.10	1.15	0.08	0.13	3.60	-2.76
22		76.15		23.85		0.04	1.04	0.03	0.04	3.02	-3.23
23		86.09			13.91	0.08	1.21	0.06	0.08	3.10	-3.30
24			41.14	58.86		037	2.91	0.12	0.15	3.16	-5.90
25			81.23		18.77	0.62	3.90	0.15	0.28	3.09	-4.97
26				74.09	25.91	0.33	3.15	0.10	0.14	3.07	-7.06
						1 asset					
27	100					-0.01	0.70	-0.02	-0.04	6.48	-5.25
28		100				-0.02	1.47	-0.02	-0.01	6.08	-3.16
29			100			0.60	3.99	0.15	0.24	2.58	-4.01
30				100		0.21	3.48	0.06	0.10	3.74	-5.17
31					100	0.67	5.28	0.12	0.18	4.36	-6.48