A Work Project, presented as part of the requirements for the Award of a Masters Degree in Finance from the Nova – School of Business and Economics and a Professional Master in Finance from the São Paulo School of Economics.

TIME-VARYING BENEFITS OF CROSS-ASSET AND CROSS-REGION PORTFOLIO DIVERSIFICATION

Moritz Gorny
(Student-ID: 29369/C338914)

A Project carried out on the Double Degree NOVA SBE and EESP-FGV under the supervision of:

Professor Melissa Prado (Nova SBE, Lisbon, Portugal)
Professor Joelson Sampaio Oliveira (Sao Paulo, Brazil)

11 September 2017

Abstract

The thesis uses return data on equities, bonds, commodities and real estate for the U.S., Europe, Asia and Latin America to examine diversification potentials. The analysis focuses on benefits of cross-asset and cross-region diversification as well as the impact of financial distress on those strategies and portfolio performances. It concludes that diversification benefits vary over time and decrease in bear markets due to higher correlation. Investment grade bonds and gold have shown the highest diversification benefits for equity investors during financial distress. Assets from emerging markets seem to be less sensitive to global market drops and show more constant performances.

Keywords

Diversification, Cross-Asset, Cross-Country, Correlation

Table of content

1 Introduction

The theoretical model of portfolio diversification in the financial markets was first developed by Harry Markowitz (1952) providing explanation and normative rules for the diversification of risky assets. According to the *Modern Portfolio Theory (MPT),* the correlation among security returns is the crucial determinant for the degree to which diversification can reduce portfolio risk. Today, international financial markets are strongly connected and show high dependences, reducing diversification benefits. In order to exploit remaining diversification potentials more effectively, this thesis aims to explore diversification strategies over time. Several studies have been conducted to study international diversification and correlations between global stock markets. While Rezayat and Yavas (2006) and Driessen and Laeven (2007) have analyzed diversification within international equity markets, Liu (2016) examined the benefits of corporate bond diversification. However, little has been written about diversification from several asset classes, including stocks, bonds, commodities and real estate, and how regional cross-asset diversification benefits in comparison to cross-regional diversification of single asset classes.

This study takes the viewpoint of an equity investor and analyses the benefits of regional cross-asset and cross-regional single-asset diversification. Firstly, asset correlations among equities, real estate, bonds and commodities as well as U.S., European, Asian and Latin American equity markets will be computed over the 18-year period from 2000 to 2017 to examine diversification benefits and time-varying correlation. Subsequently, the study examines performances and diversification benefits of portfolios, constructed based on cross-asset or cross-region diversification. As will be presented later in this thesis, investors are concerned about returns in relation to risk. Thus, the Sharpe ratio is used as performance indicator to compare portfolios over time. Finally, asset weights of the optimal portfolio are analyzed to find the most powerful diversifier. The results of the study are relevant for investment management decisions and for purposes of maximizing diversification benefits in international portfolios.

2 Literature Review

2.1 Markowitz modern portfolio theory

Markowitz's modern portfolio theory represents one of the most important theoretical approaches in terms of portfolio construction. The theory describes the impact of the number of securities on the portfolio's diversification.[1] The term 'diversification' refers to the relationship between correlations and portfolio risk. Markowitz showed that an allocation of investments among various financial instruments, industries and other categories, reduces the overall portfolio risk substantially. Finally, diversification leads to a maximization of expected returns and minimization of risk by investing in assets that show low correlations.

However, Markowitz argues that not all risk can be eliminated by diversification. Investors are confronted with two kinds of risk: systematic and unsystematic risk. Only the unsystematic risk, also called diversifiable risk, can be reduced or eliminated as a consequence of diversification. In contrast to this, systematic risk cannot be eliminated or diminished by diversification as it is caused by external factors such as recessions, high interest rates or inflation. These drivers systematically affect the whole economy. It needs to be considered that, in practice, a well-diversified portfolio can reduce risks, but not eliminate all risks, as there are simp-

[1] Mangram, M. (2013).

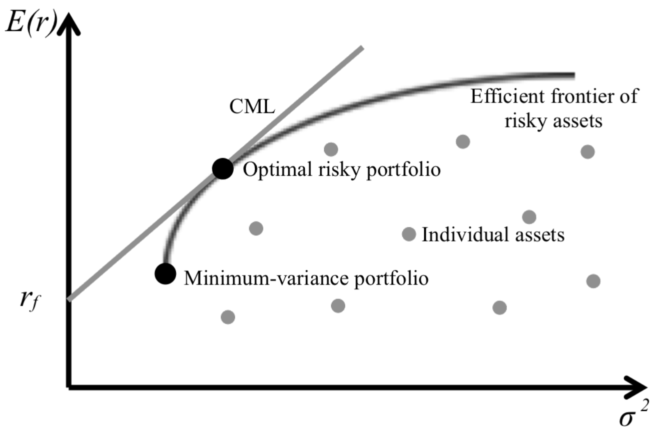
[2] Markowitz, H. M. (1952).

ly too many variables. Additionally, systematic risk always remains and affects all companies and markets at the same time.[2]

The modern portfolio theory provides guidance for the construction and selection of investment portfolios based on the maximization of expected returns and the minimization of the underlying risk. The theory provides a method to evaluate portfolios based on the expected return and variance of assets contained in the portfolio. The theory assumes risk-averse investors, meaning that a portfolio with smaller variance and higher expected returns is preferably chosen.[3]

The efficient frontier presents a key concept of the modern portfolio theory. It indicates the best constellation of securities within a given investment portfolio. Different portfolio weights change the portfolio performance values for the expected return ($E(r_p)$) and its standard deviation (σ^2) as a measure of risk. The attainable set describes all possible combinations of $E(r_p)$ and σ^2. The combinations with a minimum σ^2 for a given $E(r_p)$ or higher and a maximum $E(r_p)$ for a given σ^2 or lower represent the so-called efficient frontier and is visualized as a curve on a graph.[4] Investors seek to choose portfolios with the $E(r_p)$ - σ^2 combination located on the efficient frontier. To find the optimal risky portfolio on the efficient frontier, Sharpe, W.F. (1966) has drawn a line from the risk-free asset being tangent to the efficient frontier. This line, known as the capital market line (CML), has the steep-

Figure 1: The Efficient Frontier



[2] Markowitz, H. M. (1952).
[3] Fabozzi, F., Gupta, F. Markowitz, H. (2002).
[4] Mangram, M. (2013).

est slope and determines the tangency point with the efficient frontier. The tangency point is the portfolio's best combination of risky assets and known as the optimal risky portfolio.

2.2 International stock market diversification

Longin and Solnik (1995) studied the correlation between seven major international stock markets over the period 1960-1990, using monthly excess return data. They revealed that international correlations vary over time depending on national dividend yields and interest rates. Furthermore, international correlations increase during periods of high market volatility. Later, Longin and Solnik (2001) further elaborated on this topic and argued that correlations are not only related to market volatilities but to the overall market trend. It was further corrected that equity market correlations rise in bear markets and not in bull markets. This provides evidence for increased correlations within equity markets during times of financial crisis. Ramchand and Susmel (1998) have confirmed these findings while examining the relation between time and state varying variance and dependences between the U.S. and major foreign equity markets. During periods of high U.S. volatility, correlations between foreign markets and the U.S. market increase. This implies that, particularly in times of financial distress, portfolio diversification needs to be based on other alternatives apart from major equity markets.

Gilmore and McManus (2002) examined correlations and diversification potentials between international equity markets and revealed reduced benefits from international diversification due to global markets becoming more integrated and showing increased correlations. When diversifying within international equity markets, investors can find more promising diversification potentials in the emerging markets such as Asia or Latin America. Kearney and Poti (2006) analyzed correlation dynamics in European stock markets over the period from 1993 to 2002 by the usage of daily data on the five largest European stock market indices. Due to high correlations diversification across European stock indices only brings little benefit. The close connection between different markets, caused by the Euro-zone, has taken away stock index diversification potentials and favored rather cross-industry strategies.

2.3 Portfolio diversification with bond markets

Bond and stock prices have mostly shown a negative correlation in the past. For this reason, Emons (2015) encourages investors seeking diversification to include both assets into a single portfolio. Rising interest rates should be positive for a moderate inflation, stable economic growth, companies' future earnings, and hence supportive for stock prices. In opposite to stocks, bond prices decrease with rising interest rates.

Coaker (2006) examined the volatility of correlation and its implications for asset allocation decisions by analyzing the changing correlation of 15 asset classes from 1970 to 2004. According to the analysis, investment grade corporate bonds have provided high diversification benefits for equity investors. Whenever U.S. equity markets declined, investment grade bonds earned positive returns, with a 35-year correlation of 0.23. High yield bond markets have shown a correlation coefficient of 0.50 and thus correlate more to U.S. equity markets than corporate bond markets. Reilly and Wright (2001) even revealed a stronger correlation between high yield bonds and U.S. equity markets than between high yield and investment grade bond markets. This can be explained by the very significant equity component included in the composition of high yield bonds. Liu (2016) analyzed equity investor's portfolio gains through corporate bond diversification and found that international diversified equity portfolios can significantly benefit and achieve Sharpe ratio gains. Furthermore, diversification by bonds caused equity portfolios to reduce large risk, particularly during the financial crisis in 2008.

2.4 Portfolio diversification with commodities and REIT

Coaker (2006) analyzed the correlation between the U.S. equity market and commodity markets and found great diversification benefits. Equity and commodity markets showed a 35-year correlation of 0.01 with negative values in 17 out of 35 years from 1970 to 2004. Büyükşahin et al. used a different methodology to examine the correlation between the same assets. Although no correlation trend was found, diversification benefits of commodities were highlighted. However, looking at the returns in 2008, diversification benefits seem to decrease during the financial crisis. Filis et al. (2011) more specifically analyzed the dynamic correlation between stock markets and oil prices. They conclude that economic crises or booms cause strong positive links between oil prices and stock markets, while non-economic oil price shocks trigger stronger negative correlations, indicating that in times of falling equity markets oil does not bring great diversification benefits for investors. In contrast to this, Hoang et al. (2015) outlined the diversification benefits of gold in stock portfolios. It has been stated that gold can maximize the equity portfolio's expected utility, especially in unstable or crisis times. Baur and Lucey (2010) came to the same conclusion and described gold as a "safe haven" during crises due to negative correlations and great diversification potential.

Also real estate represents an asset class with diversification potentials for investors. Several studies, such as Hoesli et al. (2004), outlined real estate to be an effective portfolio diversifier when both domestic and international real estate assets are considered. Conover et al. (2002) analyzed the diversification benefits from foreign real estate investments and found lower correlation of foreign real estate with U.S. stocks than U.S. stocks with foreign stocks. Foreign real estate has shown significant weight in efficient international portfolios and implies great diversification benefits. Knight et al. (2005) studied diversification benefits of real estate in a diverse asset portfolio. The Real Estate Investment Trust (REIT) tends to be far more correlated with the stock market. In particular, when other asset markets are falling, real estate shows a high correlation and limited diversification protection.

3 Data

The data used for following analysis consists of equity, real estate, corporate investment grade and high yield bond indices for the continents North America, Europe, Asia and Latin America, as well as commodity data, including energy commodities, precious metals, agricultural commodities, gold and oil. The world indices for the respective asset classes are used as comparables. To compute annual excess returns 3-Month U.S. Treasury Bills have been downloaded. The data set begins in the year of 2000 or at the inception of the particular index, ranging until May 2017. The data was collected from Bloomberg Markets. Non-trading days were excluded from the data sample and returns have been adjusted for capital changes. Transaction costs are not included.

3.1 Stock markets

The stock indices presented below are used as proxy for the respective region's large-cap equity markets and comprise a broad range of the region's major stock listed companies. World and emerging markets indices are used for comparisons.

Table 1: Descriptive statistics of annual average returns for major regional equity indices over the total period from January 01, 2000 to May 31, 2017.

Index	Mean	Standard Deviation	Sharpe Ratio
S&P U.S. 500	2.94%	19.51%	0.10
Euro Stoxx 50	-1.75%	23.94%	-0.12
MSCI Asia Pacific	3.51%	20.29%	0.12
S&P Latin America 40	5.94%	30.79%	0.16
MSCI World	1.70%	16.40%	0.04
MSCI Emerging Markets	7.86%	27.40%	0.25

Moreover, following country stock indices have been used to analyze cross-country stock market correlation.

Table 2: Descriptive statistics of annual average returns for country equity indices over the total period from January 01, 2000 to May 31, 2017.

Index	Mean	Standard Deviation	Sharpe Ratio
U.S. - S&P 500	2.94%	19.51%	0.10
Germany - DAX	3.64%	24.20%	0.11
Japan - NIKKEI	0.22%	24.13%	-0.03
Brazil - IBOVESPA	7.91%	28.53%	0.24
China - SSE	4.82%	25.15%	0.15
Russia - MICEX	15.67%	33.31%	0.44

3.2 Bond markets

The bond indices presented below are representative for the respective region's corporate bond markets. All indices were taken from the Bank of America Merril Lynch (BofAML) bond index family. All indices have been constructed based on the BofAML construction criteria and track the performance of corporate debt publicly issued by corporate issuers in the U.S., major domestic and eurobond markets. Investment Grade Corporate Indices include qualified securities with investment grade rating. High Yield Corporate indices consist only of securities rated below investment grade.[5]

Table 3: Descriptive statistics of annual average returns for regional corporate bond indices over the total period from January 01, 2000 to May 31, 2017.

Index	Mean	Standard Deviation	Sharpe Ratio
U.S. Investment Grade	6.18%	4.96%	1.04
U.S. High Yield	7.23%	4.78%	1.30
Euro Investment Grade	4.95%	2.50%	1.57
Euro High Yield	5.42%	6.42%	0.68
Asian Investment Grade	7.22%	3.80%	1.63
Asian High Yield	8.87%	5.83%	1.34
Latin America Bonds	4.07%	5.87%	0.52
Global Investment Grade	5.42%	5.21%	0.84
Global High Yield	7.31%	5.01%	1.25
Emerging Markets	7.35%	3.71%	1.70

[5] http://www.mlindex.ml.com/gispublic/bin/getDoc.asp?source=generalmethodology&fn=BAML%20Bond%20Index%20Guide%20May_23_2016.pdf, collected 2017-07-01.

3.3 Real estate

This thesis considers the performance and contribution of the real estate asset class either via Real Estate Investment Trusts (REIT) or Real Estate indices. A REIT is an exchange-traded security that invests in real estate through property or mortgages and maintains high dividend payout ratios. Regional REIT indices include several securities, classified in the equity REIT industry, across different markets. Real Estate indices include stocks of the major companies classified in the Real Estate sector. The following securities are used as proxies for the respective region's real estate market.

Table 4: Descriptive statistics of annual average returns for regional real estate indices over the total period from January 01, 2000 to May 31, 2017.

Index	Mean	Standard Deviation	Sharpe Ratio
MSCI U.S. REIT	1.84%	28.72%	0.03
Euronext Europe REIT	3.03%	19.71%	0.10
MSCI Asia Pacific REIT	3.37%	14.72%	0.16
Solactive Latin America REIT	-2.70%	9.73%	-0.38
MSCI World Real Estate	3.25%	17.33%	0.13
MSCI Emerging Markets Real Estate	-0.27%	24.55%	-0.05

3.4 Commodities

To represent the commodity asset class the Bloomberg Commodity Index (BCOM) has been selected as proxy. The BCOM has been launched in 1998 and is a highly liquid and diversified benchmark for the global commodity market. The index is divided into six subgroups including energy, grains, industrial metals, precious metals, softs and livestock. On an absolute basis, crude oil has the largest weight, followed by gold, natural gas, copper and corn.[6] Besides the BCOM, following indices have been retrieved and will be used to analyze correlations between single commodity groups.

[6] https://www.bloombergindices.com/bloomberg-commodity-index-family/, collected 2017-07-01.

Table 5: Descriptive statistics of annual average returns for commodity indices over the total period from January 01, 2000 to May 31, 2017.

Index	Mean	Standard Deviation	Sharpe Ratio
BCOM	-0.58%	16.65%	-0.10
LBMA Gold Price	8.78%	18.01%	0.43
WTI Crude Oil Future	3.87%	38.39%	0.07
London Metal Exchange	4.61%	23.31%	0.15
Bloomberg Agriculture	-2.06%	18.74%	-0.16

4 Research Questions

First, the thesis computes annual correlations between different asset classes and between several geographic regions over an 18-year time horizon from 2000-2017. The stability of correlation coefficients and the potential of cross-asset and geographic cross-region diversification will be analyzed and compared over time.

Question 1: Do cross-asset and cross-region correlations show constant coefficients over the period from 2000 – 2017?

After question one has been answered in the negative, the impact of financial crises, as given in chapter 5.2, on moving cross-asset and cross-region correlations is examined.

Question 2: How are correlations between different asset classes or geographic regions affected during times of financial crisis?

The two research questions are followed by portfolio analyses. The data of several geographic asset returns is used to construct portfolios based on the lowest variance, the highest Sharpe ratio, and an equal asset weighting. The performance of these portfolios will help to compare the benefits between cross-asset and cross-region diversification. Furthermore, the diversification strategies are compared over time and the impact of financial distress examined.

Question 3: What are the benefits and differences between cross-asset and cross-region diversification over time?

After the diversification strategies and benefits have been outlined, all available assets will be used to reach a maximum degree of diversification. Portfolios are constructed on an annual basis for a period of 18 years. The weightings are compared to reveal assets with the highest diversification potential in an international context. As stated by Filis et al. (2011), portfolio diversification is especially crucial during financial crises. Hence, the contribution of these assets as diversifier will be observed also during times of falling equity markets to estimate the real impact.

Question 4: Which assets show the highest diversification benefits over time?

Finally, the findings are summarized and conclusions based on diversification potentials and the impact of financial distress can be drawn.

5 Methodology

The following part presents the methodology of how analyses are performed and the respective research questions are answered.

5.1 Return relationships and persistence over time

The first aim of this study is to investigate the existence of time-varying cross-asset and geographic cross-region correlations over time. The correlation coefficient determines existence and quantification of diversification. Unless the correlation coefficient between two assets is 1, combining these assets within one portfolio brings diversification benefits and reduces overall portfolio risk. The lower the correlation, the higher the benefits of diversification. Thus, I compute cross-asset and cross-region correlations and observe movements over time to examine the first research question.

To run the first analysis I use moving and rolling estimation windows. Zivot and Wang (2006) have outlined the common use and characteristics of rolling analysis when analyzing financial time series data. If parameters are truly constant over the entire sample, the results over the rolling window do not show significant deviations. The rolling window analysis has been also used by Coaker (2006) for the same purpose of studying correlation volatility over time. The moving window represents an alternative method, which is very commonly used for financial time-series analyses, where the estimate is computed by the aggregated correlation within the window. To strengthen the significance of the results, both 1-year rolling windows, as used by Coaker (2006), and moving window correlations are analyzed.

As described in chapter number three, a broad data set, comprising different assets and regional indices, has been downloaded for a period of 18 years from Bloomberg Markets. Afterwards, daily returns were calculated for all assets. The daily rate of return *r(t)* for each asset is defined as the percentage change in the dollar value of the asset, where *P* is the asset value in period *t*.

$$r(\mathrm{t}) = \frac{P(t) - P(t-1)}{P(t-1)} \tag{1}$$

The daily mean rate of return for each asset is calculated by taking the arithmetic average of the daily returns. Regardless of the underlying distribution of asset returns, a collection of *n* asset returns $r(1), r(2), \dots, r(t)$ has a daily mean of asset returns (m).

$$m = \frac{1}{N}\sum_{t=1}^{n} r\,(t) \tag{2}$$

The annualized mean return (M) is derived subsequently. Annualized returns are period returns scaled to a period of one year, given by the following formula, where *n* indicates the number of annual trading days.

$$M = [(1+m)^n - 1] \, * 100 \tag{3}$$

The standard deviation of the rate of return (σ) measures risk and is computed as the square root of the variance (σ^2), which in turn is defined as the expected value of the squared deviations from the expected return. The higher the volatility of returns, the higher the average value of the squared deviations. Thus, variance and standard deviation provide a measure of uncertainty of the returns and represent the second performance measure:

$$\sigma^2 = \frac{\sum_{t=1}^{n} r(\mathrm{t}) - m}{n} \tag{4}$$

In the next step, returns and standard deviations were used to compute annual correlations between different asset-classes and geographic regions within the software Eviews. The correlation expresses the simultaneous change in value of two random asset returns, where the correlation coefficient scales the assets' linear dependence to a value between -1 and +1. In case of a correlation of +1, the two assets are said to be perfectly positively correlated, meaning that the returns will exactly equal each other. The value of -1 indicates the opposite. Asset movements follow a completely random walk if the correlation is zero. The Pearson correlation coefficient is defined as following, where each variable has *n* observations.[7]

$$\rho_{i,j} = \frac{1}{\mathrm{n}-1} \sum_{t=1}^{n} \left(\frac{r_i(t) - m_i}{\sigma_i}\right) \left(\frac{r_j(t) - m_j}{\sigma_j}\right) \tag{5}$$

The symbols m_i and σ_i are the mean and standard deviation of asset *i,* and m_j and σ_j are the mean and standard deviation of asset *j*. Alternatively, the correlation coefficient can be defined based on the covariance of assets *i* and *j*.[8]

$$\rho_{i,j} = \frac{Cov(r_i r_j)}{\sigma_i \sigma_j} \tag{6}$$

[7] Kendall, M.G. (1979).

[8] Fisher, R.A. (1958).

The correlation coefficient is used to quantify the strength of the relationship between two asset returns. In order to test the significance of the results, hypothesis tests have been performed. The t-statistics tests the existence of a linear relationship. It is calculated as the ratio of an estimated coefficient to its standard error and is used to test a hypothesis. The t-statistic can be interpreted when examining the probability of observing the t-statistic, given that the coefficient is equal to zero. First, the null and an alternative hypothesis are specified. The null hypothesis H_0 says that the correlation coefficient between assets *i* and *j* equals 0.[9]

$$H_0\colon\ \rho_{i,j} = 0 \tag{7}$$

The alternative hypothesis says that the correlation coefficient $\rho_{i,j}$ is either larger or smaller than 0 indicating a linear relationship between assets *i* and *j*.

$$H_A\colon\ \rho_{i,j} \neq 0 \tag{8}$$

Second, the value of the test statistic is calculated using the following formula, where *n* gives the sample size and *r* the observed sample correlation.

$$t^* = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \tag{9}$$

Third, the resulting t-value (t^*) is used to derive the P-value. It is obtained from a t-distribution with n-2 degrees of freedom. The P-value gives the probability, if the null hypothesis H_0 were true, of obtaining a result equal to or more extreme than what was actually observed. The smaller the P-value, the larger the significance as the null hypothesis H_0 may not adequately explain the observation. If the P-value is smaller or equal to the predefined level of significance, the null hypothesis H_0 is rejected in favor of the alternative. The null hypothesis H_0 cannot be rejected if the P-value exceeds the significance level. In this case,

---

[9] Lewis, M. (2012).

there is not enough evidence at the significance level to conclude that there is a linear relationship between the two assets.[10]

In order to answer the first research question, the thesis computes correlation coefficients on an annual basis and observes the results over time to examine diversification benefits. Computing mean and standard deviation of an asset's correlation coefficient can reveal possible time-varying diversification benefits. The lower the mean of correlation coefficients, the higher the diversification benefits between the given assets. The higher the standard deviation of correlation coefficients, the less constant these diversification benefits stay over time. Following asset classes are considered: Equity (MSCI World Index); Real Estate (MSCI World Real Estate Index); Commodity (Bloomberg Commodity Index); Oil (WTI Crude Oil Future Index); Gold (LBMA Gold Price Index); Corpo-

Figure 2: Cumulative daily asset returns over the total period from January 01, 2000 to May 31, 2017.

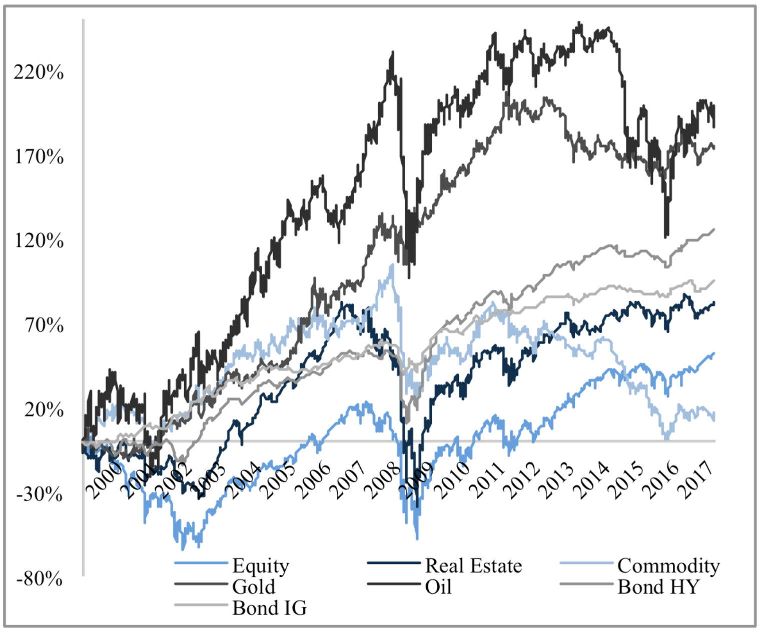
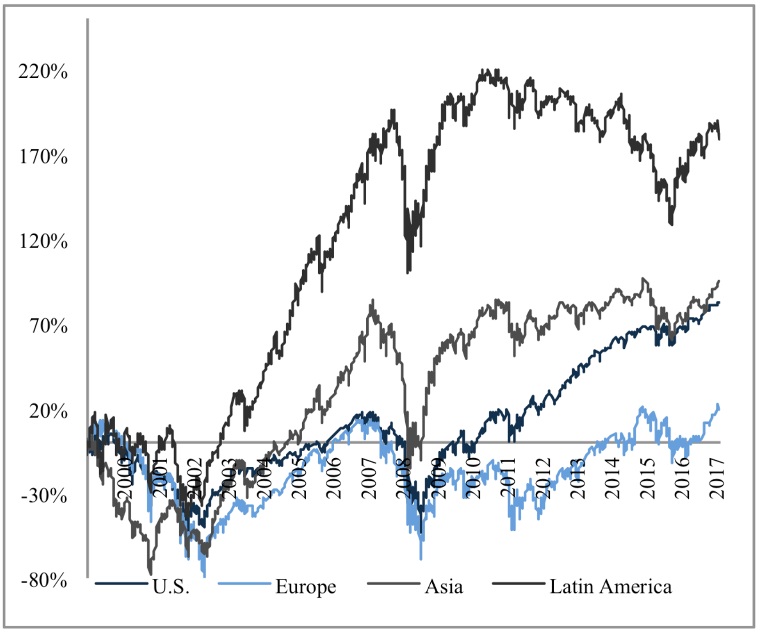


Figure 3: Cumulative daily equity market returns over the total period from January 01, 2000 to May 31, 2017.



[10] Mendenhall, W. et al. (2009).

rate Investment Grade Bond (Global Investment Grade Corporate Index); Corporate Global High Yield Bond (Global High Yield Corporate Index). The cumulative returns over the total period are presented in Figure 2. Although oil and gold can be considered as commodities and investment grade and high yield bonds can be summarized within the fixed income asset class, a broad range of literature has treated those sub-asset classes separately. Thus, special attention will be given to these sub-asset classes also within this paper. Furthermore, relationships between following regional equity assets are analyzed: USA (S&P 500 Index); Europe (Euro Stoxx 50 Index); Asia Pacific (MSCI Asia Pacific Index); Latin America (S&P Latin America 40). The cumulative returns are plotted in Figure 3.

5.2 Effect of financial crises

The second research question examines return relationships during severe financial crises. The consistency of diversification benefits is analyzed by differentiating between periods of crisis and periods of market recovery. For this reason, periods of financial distress need to be determined:

(i) Dotcom crisis

The Dotcom crisis was based on a huge drop in the international equity markets after a period of extreme growth supported by the usage and adaption of the Internet. After the bubble collapsed in 2000 the crisis is considered to persist until 2002.

(ii) Subprime Mortgage crisis

The Subprime mortgage crisis was a mainly U.S. based financial crisis contributing to a large recession in the U.S. and falling markets in many parts of the world. The period is considered to start in 2007 when financial institutions around the world began to default and to last until 2009 when the stock markets showed signs of recovery.

(iii) Sovereign Debt crisis

The Sovereign bond crisis refers to European debt crisis since the end of 2009, where several Eurozone member states were unable to repay their government debt. For this thesis, the period is considered to start with Greece's downgrade in 2011 and to last until 2012.

5.3 Portfolio construction and optimization

After the existence of return relationships will be proven within the first research question the benefits of diversification are examined based on a practical approach. Assets are chosen following a cross-asset or cross-region diversification approach and portfolios are constructed accordingly:

Table 6: Asset allocations to cross-region portfolios, namely Equity, Real Estate, Fixed Income, Commodity, and cross-asset portfolios, namely America, Europe, Asia, Latin America.

I. Cross-Region Portfolios	**II. Cross-Asset Portfolios**
Equity *S&P U.S. 500 Index; Euro Stoxx 50 Index; MSCI Asia Pacific Index; S&P Latin America 40 Index*	America *S&P U.S. 500 Index; MSCI US REIT; BofAML U.S. Investment Grade & High Yield Index; Bloomberg Commodity Index*
Real Estate *MSCI US REIT; Euronext Europe REIT; MSCI Asia Pacific REIT; Solactive Latin America REIT*	Europe *Euro Stoxx 50 Index; Euronext Europe REIT; BofAML Euro Investment Grade & High Yield Index; Bloomberg Commodity Index*
Fixed Income *BofAML US Investement Grade & High Yield Index; BofAML Euro Investment Grade & High Yield Index; BofAML Asia Investment Grade & High Yield Index; BofAML Latin America Bond Index*	Asia *MSCI Asia Pacific Index; MSCI Asia Pacific REIT; BofAML Asia Investment Grade & High Yield Index; Bloomberg Commodity Index*
Commodity *LBMA Gold Price Index; WTI Crude Oil Future Index; London Metal Exchange Index; Bloomberg Agriculture Index*	South America *S&P Latin America 40 Index; Solactive Latin America REIT; BofAML Latin America Bond Index; Bloomberg Commodity Index*

The theory of portfolio analysis describes efficient techniques for selecting portfolios on the basis of predictions about the performance of individual securities. Both, expected return and risk represent the crucial variables when selecting preferred portfolios. Assuming a portfolio consisting out of n different assets where asset i will show the return r_i. The corresponding variance is defined as $\sigma^2{}_i$ and $\sigma_{i,j}$ gives the covariance between r_i and r_j. Suppose that the relative amount of the portfolio value invested in asset i and j is w_i and w_j respectively. If $\mathrm{E}(r_p)$ is the expected return of the portfolio and $\sigma^2{}_p$ shows the portfolio's variance, then:

$$\mathrm{E}(r_p) = \sum_{i=1}^{n} E(r_i)\, w_i \tag{10}$$

$$\sigma^2{}_p = \sum_{i=1}^{n} \sum_{j=1}^{n} \sigma_{i,j}\, w_i\, w_j \tag{11}$$

The portfolio risk indicated by the variance or standard deviation is mainly determined by the covariance indicating how the assets' return move relative to each other. The covariance for assets i and j is derived from the correlation coefficient (ρ) of the pair of assets and the respective standard deviations.

$$Cov(r_i r_j) = \rho_{i,j} \sigma_i \sigma_j \tag{12}$$

The equation given above displays that the lower the correlation, the lower the portfolio variance. It further shows that, unless the assets are perfectly positively correlated, the portfolio's total standard deviation will be less than the weighted average of the asset volatilities. Thus, the lower the correlation of assets within a portfolio, the greater the diversification benefits.[11]

Portfolios are points from a feasible collection of assets that form an asset universe. A portfolio determines weights in individual assets of the asset universe. The fundamental insight of Markowitz, H. M. (1952) claims that portfolios seek minimum risk for a given level of return and maximum return for a given level of risk. The investor's preferred portfolio depends on the individual risk aversion and is allocated between a risk-free asset and the risky portfolio.

[11] Bodie, Z. et al. (2011).

All possible combinations between the risk-free asset and the risky portfolio are located on the capital market line (CML) and form the set of investment opportunities. The slope of the straight line displays the portfolio's annual excess return per additional unit of risk. It is also known as Sharpe Ratio, S:

$$S = \frac{(E(r_p) - (r_f)}{\sigma_p} \tag{13}$$

Assuming the same risk-free asset each risky portfolio shows a different slope of the CML, so that investors will choose a portfolio maximizing the slope and offering the highest expected return for each level of risk.[12] However, the optimal portfolio weights maximizing the slope are only known after the holding period, meaning that this portfolio is rather difficult to realize in practice. In order to examine the third research question, the previously listed portfolios have been constructed and optimized based on following techniques:

(i) Equally Weighted Portfolio

The portfolio gives the same weighting to each asset included in the portfolio. According to Plyakha et al. (2012), equally weighted portfolios outperformed value- and price-weighted portfolios over the last four decades and should be preferably used by investors.

(ii) Minimum Variance Portfolio

The portfolio construction approach optimizes towards an expected portfolio return for the lowest attainable variance. It is the only efficient portfolio whose weights do not depend on the securities' expected returns. The minimum-variance portfolio is located far to the left on the efficient frontier and has a standard devia-

[12] Sharpe, W.F. (1966).

tion smaller than that of each of the individual component assets.[13] Thus, it shows the benefits of diversification by reducing high estimation risk for investors.[14]

(iii) Efficient Portfolio maximizing Sharpe Ratio

Portfolios that maximize the Sharpe ratio are portfolios on the efficient frontier and touched by the tangent line. The tangent line starts at the risk-free rate and runs to the efficient frontier, where it touches portfolios that maximize the Sharpe ratio.[15]

This study compares the performance of portfolios that are actively rebalanced every year based on the above mentioned portfolio construction approaches. While the construction of an equally weighted portfolio can be realized in practice and retains the same annual asset weights, minimum-variance and maximum-Sharpe-ratio portfolios can only be constructed retrospectively. The minimum-variance construction enables to compare portfolios based on the maximum possible diversification. The maximum-Sharpe-ratio construction offers comparisons between portfolios based on the most efficient risk-return relationships. Sharpe ratios are used to compare portfolio performances, where 3-Month U.S. Treasury Bills are considered as the risk-free rate. A short-sale and borrowing constraint is put to the asset weights limiting the range from 0% to 100%, and ensuring to obtain 100% as the sum for all asset weights included in the portfolio.

After portfolio performances have been compared diversification benefits are examined. In order to determine the diversification benefit, the weighted average of the assets' standard deviation is compared with the final portfolio's standard deviation. By looking at the differences, the effect of diversification becomes quantifiable. Lastly, all assets will be used to con-

[13] Markowitz, H.M. (1952).
[14] Kempf, A., Memmel, C. (2003).
[15] Sharpe, W.F. (1966).

struct annual portfolios with the highest Sharpe ratio and lowest variance. Ignoring the previously established cross-asset and cross-region restrictions, the analysis identifies assets providing the best diversification benefits to a mixed portfolio.

6 Results

This chapter presents the results obtained for the analysis. Afterwards, the following chapter discusses the findings considering existing literature.

6.1 Correlation results

6.1.1 Correlation stability

The descriptive statistics for correlations among different asset classes and among geographic regions are presented in Table 7-9. The tables show maximum, minimum and mean values, as well as the standard deviation of annual correlation coefficients.

Table 7: Descriptive statistics of correlation coefficients with global equity markets over the total period from January 01, 2000 to May 31, 2017.

	Real Estate	Commodity	Oil	Gold	Bond IG	Bond HY
Max	0.92	0.64	0.70	0.36	0.33	0.73
Min	0.30	-0.07	-0.21	-0.32	-0.45	0.12
Mean	0.69	0.31	0.24	0.07	0.06	0.48
Std. Dev.	0.17	0.22	0.25	0.20	0.23	0.19

Looking at cross-asset statistics, real estate has a mean correlation coefficient of 0.69 and shows the strongest relationship to international equity markets, followed by high yield bonds and commodities, with correlation coefficients of 0.48 and 0.31 respectively. Gold (correlation coefficient of 0.07) and investment grade bonds (correlation coefficient of 0.06) have the lowest correlation, thus showing the highest diversification benefit within an international equity portfolio.

Table 8: Descriptive statistics of correlation coefficients with U.S. equity markets over the total period from January 01, 2000 to May 31, 2017.

	Europe	Asia	Latin America
Max	0.73	0.38	0.89
Min	0.37	0.02	0.40
Mean	0.57	0.20	0.70
Std. Dev.	0.10	0.10	0.15

The cross-region descriptive statistics show large correlation divergences as well. European equity markets have a correlation coefficient of 0.57 and seem to be highly dependent on U.S equity markets. Asia shows the lowest mean correlation coefficient of 0.20. Latin America has the highest value of 0.70, indicating a strong connection to the U.S equity market.

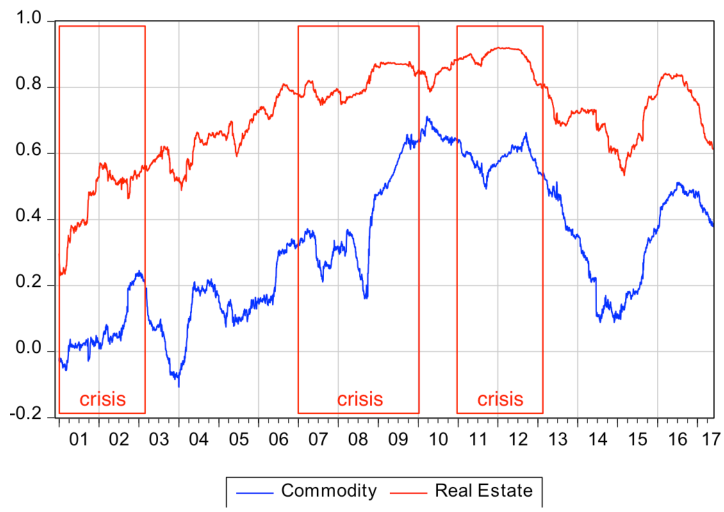
Table 9: Descriptive statistics of correlation coefficients with U.S. equity markets over the total period from January 01, 2000 to May 31, 2017.

	DAX	NIKKEI	IBOVESPA	SSE	MICEX
Max	0.75	0.28	0.79	0.22	0.55
Min	0.36	0.00	0.27	-0.10	0.06
Mean	0.58	0.13	0.56	0.05	0.27
Std. Dev.	0.11	0.08	0.16	0.09	0.14

The same trend can be observed when looking at cross-country statistics. Asian markets, such as Japan or China (correlation coefficients of 0.13 and 0.05), tend to be less dependent on U.S equity markets than European or Latin American countries such as Germany or Brazil (correlation co-efficients of 0.58 and 0.56).

In order to analyze whether the di-versification benefits remain stable over time, the standard deviation of annual coefficients provides first indications. Looking at different

Figure 4: Moving Correlations: Global equity to commodity and real estate markets over the total period from January 01, 2000 to May 31, 2017.



asset classes, Table 7 presents the lowest standard deviation of 0.17 for the real estate correlation coefficient. According to the 1-year moving correlation, as presented in Figure 4, correlations have constantly increased until 2012, followed by a 2-year drop. The correlation of commodities to global equity markets has followed the same trend, however, seems to be more volatile, as indicated by the higher standard deviation of 0.22. The correlation between equity and high yield bond markets, as exhibited in Figure 5, diverged from the correlation between equity and investment grade bond markets in the early 2000s and 2008, maintaining consistently higher levels of correlation. The dependence of investment grade bonds is lower, but more uncertain, given by a standard deviation of 0.23. The correlation coefficient of high yield bonds is less time-varying, with a standard deviation of 0.19. The overall period increase of investment grade bonds' correlation appears to be very low, while other asset classes show a more distinctive increase of correlation over time.

Figure 5: Moving Correlations: Global equity to investment grade and high yield bond markets over the total period from January 01, 2000 to May 31, 2017.

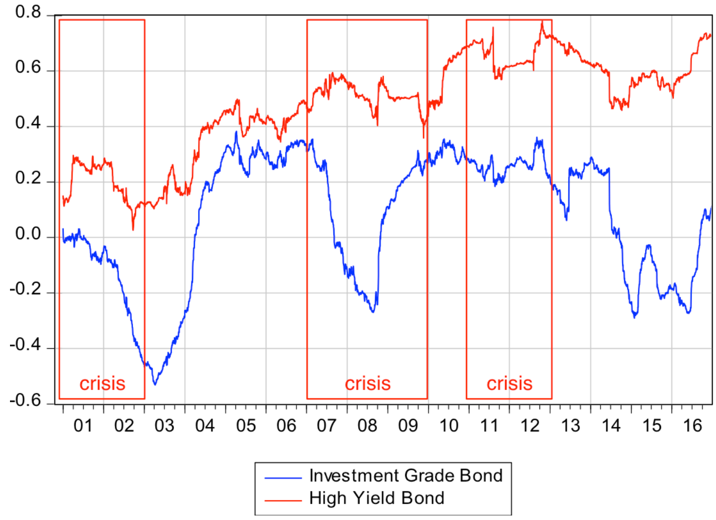
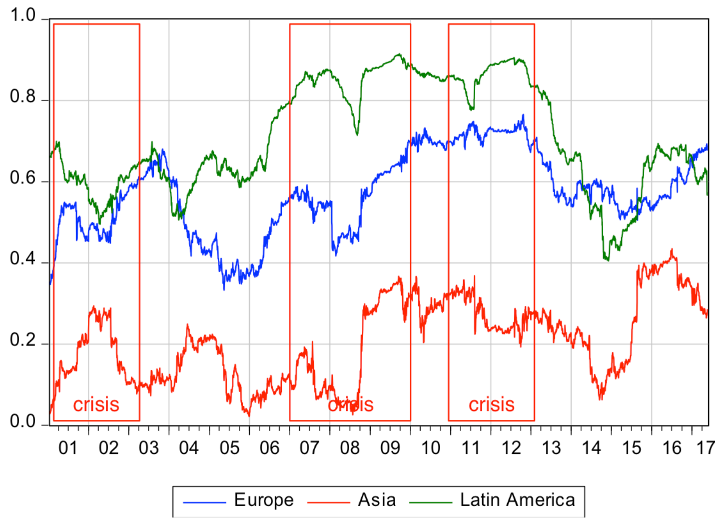


Figure 6: Moving Correlations: U.S. to European, Asian and Latin American equity markets over the total period from January 01, 2000 to May 31, 2017.



Cross-region equity correlations show lower standard deviations than cross-asset correlations. As exhibited in Figure 6, correlations of Asian and European to U.S. equity markets show a similar pattern. Table 8 presents, for both correlation coefficients, the same standard deviation of 0.10. The correlation coefficient of the Latin American to U.S. equity market is more time-varying indicated by the standard deviation of 0.15. Compared to other geographic regions, the overall correlation of Latin America has even slightly decreased over time, as presented in Figure 6.

The graphical illustrations as well as the descriptive statistics, which exhibit standard deviations of the correlation coefficient between 0.10 and 0.25, with highly positive values of 0.89 as maximum and even negative values of -0.10 as minimum, support a rejection of the hypothesis of constant correlation over time. Although, as presented in appendices 1 and 2, the regressions show that some years have significantly stronger explanatory effects than others, on a 5% significance level, the overall picture concludes that correlations are not stable over time.

6.1.2 Effect of financial crises

Correlations have already been proven to vary significantly over time. The focus is now shifted towards correlation movements in times of falling equity markets. The mean correlation coefficients have been computed for periods of crisis, specified in chapter 5.2. When comparing the correlation coefficient during crisis periods with the mean correlation coefficient of the total period, different results can be obtained.

On average, cross-asset correlations with global equity markets are higher during periods of financial distress than in other periods. Apart from gold, commodities and oil in particular show increased dependences on equity markets. Figures 4-6 illustrate the change in correlation during periods of crisis visually. Appendices 1 and 2 exhibit annual correlations and Table 10 quantifies the results during crises. While the correlation of the mixed commodity index has risen above 0.5 during the Subprime and Sovereign Debt crisis, the correlation of oil increased to 0.40 and 0.54 during the same periods. Real estate correlations are also higher during crises, however, at a lower level. The correlation of gold and fixed-income assets to equity markets is slightly higher during the Subprime and Sovereign Debt crisis, but significantly lower during the Dotcom crisis. Nevertheless, gold and investment grade bonds show the lowest absolute correlation to international equity markets during periods of crisis, stressing their diversification benefits.

Same as cross-asset correlations, regional correlations to U.S. equity markets tend to be higher during crises. Among all considered regions, Latin American correlations are the highest. European equity markets show risen dependences as well, while Asia's correlation coefficient is only slightly higher. The same trend can be observed among certain countries' equity markets. Brazil, as a Latin American market, is more connected and countries such as Japan or China even reduce the correlation to U.S. equity markets during crises.

As indicated by the overall low P-values, the results show a high level of significance. Only the results for gold show a lower significance due to high P-values in several time periods. Finally, correlations and diversification benefits are affected differently by financial crises. While some assets, such as gold and bonds, move in opposite direction of the stock market, others increase its correlation and reduce diversification benefits.

The correlation results, presented in this chapter, focus on the perspective of an equity investor. For this reason, assets with great diversification benefits for equity portfolios have been identified. These benefits might vanish for investors with existing real estate or fixed income portfolios. Diversification benefits for real estate or fixed income investors might be different. This topic was not considered in this thesis and left open for further research.

Table 10: Correlation coefficients and respective significance values of different asset classes with world equity markets, and geographic equity markets with U.S. equity markets during the Dotcom crisis, Subprime Mortgage crisis and Sovereign Debt crisis as specified in chapter 5.2.

		Dotcom Crisis	Subprime Mortgage Crisis	Sovereign Debt Crisis
Real Estate				
	Coefficient	0.4441	0.8467	0.8918
	t-value	13.84	44.49	44.90
	P-value	0%	0%	0%
Commodity				
	Coefficient	0.0857	0.5119	0.5626
	t-value	2.40	16.66	15.50
	P-value	2%	0%	0%
Oil				
	Coefficient	0.0248	0.4020	0.5403
	t-value	0.69	12.28	14.63
	P-value	49%	0%	0%
Gold				
	Coefficient	-0.1337	0.0939	0.1783
	t-value	-3.77	2.64	4.13
	P-value	0%	1%	0%
Bond IG				
	Coefficient	-0.1975	0.1457	0.2459
	t-value	-5.63	4.12	5.78
	P-value	0%	0%	0%
Bond HY				
	Coefficient	0.1707	0.5038	0.6440
	t-value	4,84	16,31	19,18
	P-value	0%	0%	0%
Europe				
	Coefficient	0.4976	0.6032	0.7102
	t-value	16,02	21,15	22,98
	P-value	0%	0%	0%
Asia				
	Coefficient	0.1177	0.2646	0.2431
	t-value	3,31	7,67	5,71
	P-value	0%	0%	0%
Latin America				
	Coefficient	0.6148	0.8721	0.8725
	t-value	21,77	49,83	40,69
	P-value	0%	0%	0%
DAX				
	Coefficient	0.5750	0.6307	0.7312
	t-value	19.63	22.73	24.42
	P-value	0%	0%	0%
NIKKEI				
	Coefficient	0.1271	0.1100	0.1276
	t-value	3.58	3.09	2.93
	P-value	0%	0%	0%
IBOVESPA				
	Coefficient	0.4578	0.7436	0.7091
	t-value	14.38	31.10	22.91
	P-value	0%	0%	0%
SSE				
	Coefficient	-0.0339	0.0502	0.1064
	t-value	-0.95	1.40	2.44
	P-value	34%	16%	2%
MICEX				
	Coefficient	0.1328	0.3134	0.5253
	t-value	3.74	9.23	14.07
	P-value	0%	0%	0%

6.2 Portfolio performances

Following the analysis of correlations and the effect of financial crises, the focus is now put on the actual benefits of cross-asset and cross-region diversification during the 18-year period between 2000 and 2017. By looking on the direct effect on investment performance figures, cross-asset and cross-region diversification strategies are compared. Firstly, the performance results over the total holding period, without an annual rebalancing of portfolio weights, are presented. Secondly, the effects of crises on the portfolio performances are investigated by considering an annual portfolio weight rebalancing.

6.2.1 Diversification benefits

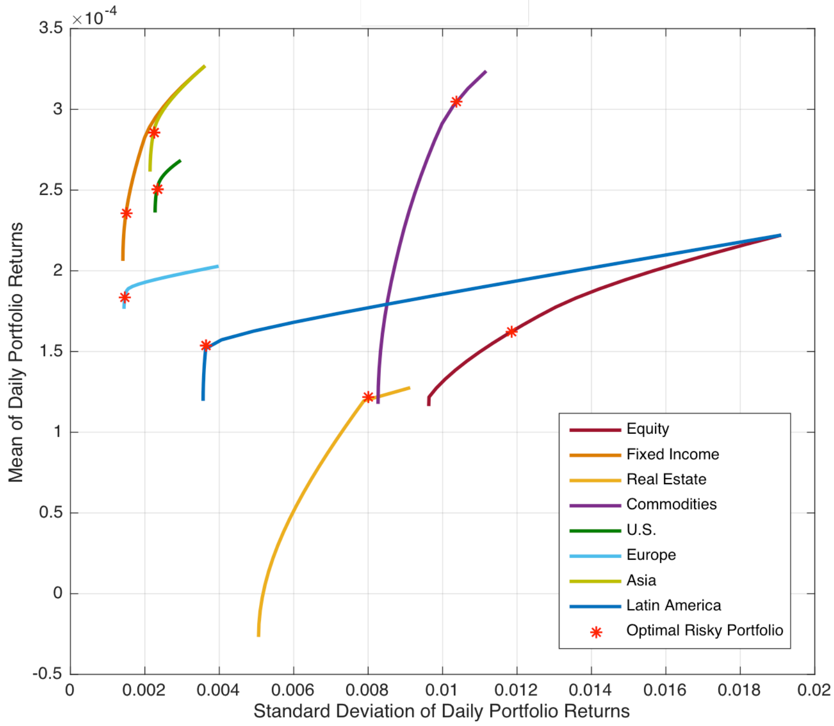
Table 11 shows the annual average performance of cross-asset and cross-region portfolios for each optimization approach. The maximum Sharpe ratio is used to compare the overall portfolio performance. The equally weighted portfolio provides more feasible results in practice, as portfolio weights for the maximum Sharpe ratio are not known in advance. The minimum-variance portfolio is used to compare the benefits of diversification.

Table 11: Annual average performance and Sharpe ratios for cross-asset and cross-region portfolios over the total period from January 01, 2000 to May 31, 2017.

	MAX SHP			EQ WEIGHT			MIN VAR		
	Return	**STD**	**SHP**	**Return**	**STD**	**SHP**	**Return**	**STD**	**SHP**
Equity	5.0%	22.5%	0.15	2.6%	18.5%	0.05	3.1%	15.5%	0.09
Real Estate	3.3%	13.3%	0.12	1.4%	11.8%	-0.02	-0.7%	8.1%	-0.29
Fixed Income	6.6%	2.5%	1.96	6.5%	3.2%	1.54	5.5%	2.3%	1.70
Commodity	8.5%	17.4%	0.40	2.9%	16.5%	0.07	3.1%	13.3%	0.11
CROSS-REGION	**5.9%**	**13.9%**	**0.66**	**3.3%**	**12.5%**	**0.41**	**2.7%**	**9.8%**	**0.40**
U.S.	6.8%	3.8%	1.36	3.5%	10.2%	0.18	6.3%	3.7%	1.28
Europe	5.0%	2.4%	1.38	2.2%	9.7%	0.05	4.7%	2.3%	1.32
Asia	7.7%	3.6%	1.69	4.4%	8.0%	0.35	7.0%	3.4%	1.56
Latin America	4.1%	5.9%	0.41	1.6%	11.9%	0.00	3.2%	5.7%	0.26
CROSS-ASSET	**5.9%**	**3.9%**	**1.21**	**2.9%**	**10.0%**	**0.15**	**5.3%**	**3.8%**	**1.11**
EM	7.4%	3.7%	1.54	3.5%	13.0%	0.14	7.3%	3.7%	1.52
World	6.8%	4.4%	1.17	3.4%	8.9%	0.20	6.4%	4.2%	1.13

Looking at the maximum possible Sharpe ratios, cross-region portfolios achieve an average value of 0.66. The globally diversified bond portfolio, including investment grade and high yield bonds from different regions, performs the best with expected returns of 6.6% at a low standard deviation of 2.5%. The efficient frontier is located far to the left, with a steep curve, indicating a low risk and good risk-return relationship. Compared to other asset classes, the high Sharpe ratio of 1.96 represents an outperforming risk-return relationship. While investing in the globally diversified bond portfolio, investors obtain higher additional return for every unit of risk. The diversified equity portfolio (Sharpe Ratio 0.15; Standard Deviation 22.5%) shows a standard deviation, which is about ten times higher.

Figure 7: Efficient frontiers of cross-asset and cross-region portfolios based on daily return and standard deviation over the total period from January 01, 2000 to May 31, 2017.



Furthermore, the efficient frontier is presented as a flat curve, illustrating the weak risk-return relationship. Investors would have to take high additional risks to get slightly increased returns. The commodity portfolio shows a return of 8.5%, which is the highest compared to other cross-region portfolios. However, the high returns go in hand with excessive risk, indicated by the standard deviation of 17.4%. Although the efficient frontier seems to be steep, the commodity portfolio presents a Sharpe ratio of only 0.4. The real estate portfolio has performed the worst with low returns at 3.3% at a standard deviation of 13.3%, leading to a

Sharpe ratio of 0.12. These results imply that risk-averse investors would prefer the globally diversified bond portfolio to all other cross-region portfolios. Risk loving investors, in turn, might seek for the commodity portfolio with the outlook of possible higher returns. In theory, investors would neglect the equity and real estate portfolio due to underperformances.

While the cross-region average Sharpe ratio of 0.66 was mainly driven by the performance of the bond portfolio, cross-asset portfolio performances seem to be more balanced. The cross-asset Asian portfolio outperforms with annual returns of 7.7% at a standard deviation of 3.6% and a maximum Sharpe ratio of 1.69. The U.S. portfolio shows a lower return of 6.8% at a higher standard deviation of 3.8%. Thus, all investors would prefer to invest into the Asian cross-asset portfolio and neglect the U.S. one. European and U.S. cross-asset portfolio show similar maximum Sharpe ratios of 1.36 and 1.38. However, the European cross-asset portfolio has lower returns of 5.0% annually at a very low standard deviation of only 2.4%. Although the European cross-asset portfolio shows a lower Sharpe ratio, its efficient frontier is located far on the left. Thus, risk-averse investors might favor this portfolio over others. The Latin American cross-asset portfolio has the lowest performance, with below average returns of 4.1% at an above average standard deviation of 5.9%. Due to the low return at a high risk, investors would not seek this portfolio.

On average, cross-asset portfolios have shown a better performance than cross-region portfolios. Although the average return is the same, cross-region single asset portfolios show on average higher standard deviations, leading to a lower Sharpe ratio. The same can be observed when looking at the efficient frontiers. Cross-asset portfolios are located further to the left. While risk loving investors might prefer the commodity portfolio, risk-averse investors would most likely decide for the global bond or European cross-asset portfolio.

In practice, realizing the maximum Sharpe ratio is rather unlikely. Equally weighted portfolios show lower Sharpe ratios and change performance differences between cross-asset and cross-region portfolios. All portfolios show lower Sharpe ratios, however, cross-asset portfolio performances have decreased more distinctively (Sharpe ratio of 0.15) than cross-region portfolios (Sharpe ratio of 0.41). Although the cross-asset portfolio has shown a higher possible maximum Sharpe ratio, when aligning the same equal portfolio weights, cross-region portfolios perform better. These average numbers are mainly driven by the strong performance of the diversified bond portfolio, with a Sharpe ratio of 1.54, pushing the average number of cross-region portfolios. Among the cross-asset portfolios, the diversified Asian portfolio performs well, showing a Sharpe ratio of 0.35.

When optimizing the portfolios towards the lowest possible variance, the results of diversification become obvious. The cross-region average shows a reduced standard deviation of 9.8% compared to 12.5% for the equally weighted and 13.9% for the maximum Sharpe ratio portfolio. On average, cross-asset portfolios could reduce the standard deviation even more. Despite an average standard deviation of 10% for the equally weighted portfolios, the minimum possible value is only 3.8%.

In order to highlight the effect of diversification, Table 12 shows the actual diversification benefits, calculated based on the percentage drop between the weighted average standard deviation of included assets and the final portfolio's standard deviation. The minimum-variance construction reduces the standard deviation for cross-region portfolios on average by 43.5% and for cross-asset portfolios by 73.3%, which outlines the high diversification benefits for all portfolios. Cross-region portfolios have higher diversification benefits (28.2%) when weighted equally than at their maximum Sharpe ratio (20.0%). Cross-asset portfolios benefit less from diversification when weighted equally (29.8%) than at their maximum Sharpe ratio

(72.4%). Nevertheless, comparing the benefits of diversification between cross-asset and cross-region portfolios the results are unequivocal. Cross-asset portfolios benefit from diversification more than cross-region portfolios.

Table 12: Annual diversification benefit of cross-asset and cross-region portfolios based on the reduction of the portfolios standard deviation compared to the weighted average standard deviation of the portfolio's assets.

	MAX SHP	EQ WEIGHT	MIN VAR
Equity	4.9%	21.6%	34.3%
REIT	27.1%	35.5%	55.3%
FI	46.0%	32.5%	51.5%
Commodity	24.5%	28.4%	42.1%
CROSS-REGION	**20.0%**	**28.2%**	**43.5%**
U.S.	74.6%	31.6%	75.4%
Europe	82.6%	29.7%	83.2%
Asia	70.5%	35.0%	71.9%
Latin America	62.8%	24.2%	63.5%
CROSS-ASSET	**72.4%**	**29.8%**	**73.3%**
EM	79.5%	28.2%	79.5%
World	63.5%	26.2%	64.9%

6.2.2 Effect of financial crises

Performances and effects of diversification have been presented and compared between cross-asset and cross-region portfolios. The focus is now shifted to annual Sharpe ratios during times of financial distress according to specifications in chapter 5.2. Table 13 presents the average Sharpe ratios for cross-asset and cross-region portfolios, constructed according to the three approaches. The difference between the average crisis and non-crisis Sharpe ratio is called “crisis-discount”.

Looking at the maximum Sharpe ratios, cross-region portfolios show a value of 1.67 during crises, which is 0.91 lower than the average value during non-crisis periods. The internationally diversified equity portfolio shows the lowest crisis performance and the largest crisis-discount of 1.41 points, followed by real estate. The diversified bond portfolio shows a crisis discount of 0.87 but remains clearly the best performing cross-region portfolio. Diversified commodities have performed on average slightly better during periods of crisis. Cross-asset portfolios, as exhibited in Table 13, show a high maximum Sharpe ratio of 2.70 and a lower crisis-discount (0.35) than the average cross-regional portfolio (0.91). American and European portfolios show large crisis discounts of 0.77 and 1.16, indicating a high sensitivity to the health and stability of global financial markets. In contrast to the more developed markets, Asia and Latin America show less sensitivity and perform better during crisis than non-crisis periods.

Table 13: Annual average Sharpe ratios for cross-asset and cross-region portfolios during crisis and non-crisis periods as specified in chapter 5.2. The crisis discount is computed as the difference between the Sharpe ratio of non-crisis and crisis periods.

	MAX SHP			**EQ WEIGHT**			**MIN VAR**		
	Crisis	**Non-Crisis**	**Dis-count**	**Crisis**	**Non-Crisis**	**Dis-count**	**Crisis**	**Non-Crisis**	**Dis-count**
Equity	0.50	1.91	1.41	-0.18	0.95	1.13	-0.21	1.37	1.58
REIT	0.64	1.94	1.30	-0.02	0.95	0.98	0.12	1.35	1.23
FI	4.03	4.90	0.87	1.99	2.19	0.19	2.29	3.68	1.39
Commodity	1.21	1.18	-0.03	0.20	0.19	-0.02	0.19	0.29	0.10
CROSS-REGION	**1.67**	**2.58**	**0.91**	**0.48**	**1.12**	**0.64**	**0.59**	**1.75**	**1.16**
America	2.70	3.48	0.77	-0.12	1.05	1.17	1.34	2.82	1.48
Europe	2.82	3.98	1.16	-0.39	1.00	1.39	1.30	2.80	1.51
Asia	3.77	3.45	-0.32	0.40	1.13	0.73	2.71	2.72	0.01
Latin America	1.53	1.29	-0.23	0.07	0.66	0.59	1.09	1.00	-0.09
CROSS-ASSET	**2.70**	**3.05**	**0.35**	**-0.01**	**0.96**	**0.97**	**1.61**	**2.34**	**0.73**
EM	2.88	2.42	-0.46	-0.07	0.97	1.04	2.55	1.98	-0.57
World	2.41	3.17	0.76	-0.23	1.13	1.36	0.97	2.50	1.53

Weighting the portfolios equally changes the performance results. Table 13 exhibits on average a lower crisis-discount (Crisis-discount of 0.64) and a better performance (Sharpe ratio of 0.48) for cross-region portfolios than for cross-asset ones (Crisis-discount of 0.97; Sharpe ratio of -0.01). Looking at cross-region portfolios, only the bond and commodity portfolio show positive Sharpe ratios of 1.99 and 0.20 during crises. Among the cross-asset portfolios, Asia and Latin America show positive crises performances, indicated by Sharpe ratios of 0.40 and 0.07. An equal asset weighting impacts cross-asset and cross-region portfolios differently.

In contrast to portfolio performances at the maximum Sharpe ratio, equal asset weightings cause the cross-region portfolio to outperform the cross-asset portfolio during crises at a lower crises discount.

Optimizing the portfolios towards a minimum variance provides insights into the benefits of diversification during financial distress. Cross-region portfolios show the largest crisis discount at the point of their lowest variance. With an average crisis Sharpe ratio of 0.59 the value is 1.16 points lower than under normal conditions. All cross-region portfolios show high crisis-discounts and even the commodity portfolio, previously moving opposed financial crises, performs worse in crises. The average crisis-discount of 0.73 for cross-asset portfolios is distinctive, however not as high as under an equally weighting. While the cross-region portfolio shows a higher crisis-discount than under an equally weighting, in times of crisis, cross-asset portfolios perform better at its minimum variance. Also in terms of the total value, cross-asset portfolios have reached a lower crisis-discount at higher Sharpe ratios. This is mainly driven by the good performance of the Asian and Latin American portfolio, showing crisis discounts about 0.01 and -0.09 respectively. In contrast to this, Table 13 exhibits high discounts for Europe and the U.S. indicating close linkages to the overall situation of the financial market.

6.2.3 Optimal portfolio

After cross-asset and cross-region portfolios have been kept separated throughout the previous analyses, all assets become available to find the annual minimum variance and maximum Sharpe ratio. By looking at the respective asset weights, the most valuable assets can be identified. Table 14 shows the performance of the integrated portfolio over the total period as well as during crisis and non-crisis periods. The derived difference is called “crisis-discount“. Considering all available assets, the annualized holding period Sharpe ratio shows 3.12 for the portfolio at the lowest possible variance and 5.13 as the maximum value. Comparing the performance during crisis and non-crisis periods, minimum-variance and maximum-Sharpe ratio portfolios clearly underperform during times of financial distress. The Sharpe ratios show crisis discounts of 1.98 and 1.22 respectively. Furthermore, the performance deviation between the two portfolios is larger during crisis periods. While the portfolio's Sharpe ratio is 120% higher at its maximum than at the point of the minimum variance during crisis-periods, the differences amounts to only 42% during non-crisis periods.

Table 14: Portfolio performances of minimum-variance and maximum-Sharpe ratio portfolios based on all available assets over the total period from January 01, 2000 to May 31, 2017.

	AVERAGE		CRISIS		NON-CRISIS		DISCOUNT	
	MIN-VAR	MAX-SHP	MIN-VAR	MAX-SHP	MIN-VAR	MAX-SHP	MIN-VAR	MAX-SHP
RETURN	6.58%	14.09%	5.83%	15.34%	7.17%	13.08%	-1.34%	2.27%
STANDARD DEVIATION	1.81%	4.31%	2.08%	6.85%	1.59%	2.28%	0.49%	4.56%
SHARPE RATIO	3.12	5.13	2.02	4.45	4.00	5.67	-1.98	-1.22

Table 15 exhibits the respective portfolio weights. On average, bonds are the major performance drivers and have the highest portfolio weightings among all available asset classes. High yield bonds show higher weights at the portfolio's maximum Sharpe ratio, investment grade bonds are higher weighted to reach a lower portfolio variance. On average, Asian bonds have the largest contribution to reach the maximum Sharpe ratio with weightings about 22%. While the focus of the minimum-variance weighting is based on fewer bonds with higher weights, reaching the maximum Sharpe ratio requires a more equal weighting among all bonds. Commodities have a lower importance for portfolio optimization and show weights below 1%. Only gold gains in importance at it's maximum Sharpe ratio with a 7.2% weighting. Overall, real estate and equity assets show small weightings below 1.5% within the presented portfolios. Referring to the regional aspect, Asian, Latin American and U.S. assets have stronger weightings at the portfolio's maximum Sharpe ratio. European assets show a higher contribution to reduce portfolio variance and seem to be valuable for diversification.

Furthermore, Table 15 presents asset weightings during financial crises, helping to outline the impact of financial distress on portfolio diversification. The table reveals much higher weightings of investment grade bonds during crisis than non-crisis periods. On the other hand, high yield bonds lead to better portfolio performances during non-crisis periods. Also gold seems to be a good performing asset during crises as its portfolio weighting increases to 14.9%. The table does not provide clear results for regional differences and their respective asset weightings during financial distress. It seems that rather the inclusion of asset classes, such as bonds and gold, than regional differences show positive effects on the portfolio performance during crisis periods.

Table 15: Optimal portfolio weights for minimum-variance and maximum-Sharpe ratio during crisis- and non-crisis periods based on annual portfolio performances.

PORTFOLIO		**AVERAGE**		**CRISIS**		**NON-CRISIS**		**DIFFERENCE**	
		MIN-VAR	MAX-SHP	MIN-VAR	MAX-SHP	MIN-VAR	MAX-SHP	MIN-VAR	MAX-SHP
EQUITY	U.S	1.2%	1.4%	1.4%	0.7%	1.0%	1.9%	-0.5%	1.2%
	EUROPE	0.8%	0.4%	1.2%	0.1%	0.4%	0.5%	-0.8%	0.4%
	ASIA	0.1%	0.8%	0.1%	0.7%	0.0%	0.9%	-0.1%	0.2%
	LATIN AMERICA	0.0%	0.9%	0.0%	0.9%	0.0%	0.8%	0.0%	-0.1%
REAL ESTATE	U.S	0.0%	0.1%	0.1%	0.0%	0.0%	0.1%	-0.1%	0.1%
	EUROPE	0.2%	0.6%	0.0%	0.1%	0.3%	0.9%	0.3%	0.8%
	ASIA	0.3%	1.7%	0.2%	0.0%	0.3%	2.6%	0.1%	2.6%
	LATIN AMERICA	-	-	-	-	-	-	-	-
COM-MODITY	GOLD	0.3%	7.2%	0.6%	14.9%	0.1%	1.1%	-0.5%	-13.7%
	OIL	0.3%	0.9%	0.3%	1.4%	0.3%	0.4%	0.0%	-1.0%
	METALS	0.4%	0.5%	0.2%	0.2%	0.5%	0.7%	0.2%	0.5%
	AGRICUL-TURE	0.5%	0.7%	0.7%	1.1%	0.3%	0.3%	-0.4%	-0.8%
BONDS	U.S. IG	0.0%	4.7%	0.0%	9.2%	0.0%	1.2%	0.0%	-8.0%
	U.S. HY	7.2%	8.3%	11.1%	3.6%	4.1%	12.1%	-7.0%	8.6%
	EUROPE IG	50.0%	11.7%	59.9%	14.5%	42.0%	9.5%	-17.8%	-5.0%
	EUROPE HY	12.2%	14.9%	0.7%	1.9%	21.5%	25.4%	20.8%	23.5%
	ASIA IG	13.3%	21.5%	14.9%	32.5%	11.9%	12.8%	-3.0%	-19.7%
	ASIA HY	12.6%	22.1%	6.7%	13.7%	17.3%	28.9%	10.6%	15.2%
	LATIN AMERICA	0.9%	1.7%	2.2%	4.1%	0.0%	0.0%	-2.2%	-4.1%

7 Analysis

The following part analyzes the results presented in section 6 and discusses the findings of this thesis by drawing connections to existing literature. Furthermore, implications for investment management and suggestions for further research are outlined.

First, the thesis aimed to challenge the existence of constant asset correlations. Moving correlations and significant results of cross-asset and cross-region correlations have proven that correlations vary distinctively over time. These results are in line with the findings of Coaker (2006), Garcia and Tsafack (2008) and Longin and Solnik (2001) revealing inherently unstable correlations among international asset classes. The standard deviation of annual cross-asset correlation coefficients shows higher values than for cross-regional equity correlations. Thus, the persistence of cross-asset diversification benefits is more uncertain for equity investors. The benefits of cross-region equity diversification seem to be more predictable.

When analyzing correlation coefficients over time, dependences seem to increase, indicating stronger linkages between international financial markets and different asset classes. Moreover, it was observed that, on average, correlations are higher during periods of crisis. These observations are consistent with the findings of Goetzman et al. (2002) showing increased correlation between international financial markets and Longin and Solnik (1995) presenting increased correlations in periods of high volatility. Also, Filis et al. (2011) exposed stronger linkages between asset classes during crisis periods.

The analysis has shown with statistical significance that investment grade bonds seem to be very good diversifier during times of financial distress as the low correlations remain stable. While assets, such as commodities and real estate, increase linkages with global equity markets and thus loose diversification benefits, gold and bonds move in opposite directions and foster diversification. These results are consistent with Büyükşahin et al. (2010) agreeing that diversification benefits from commodities dropped during the Subprime crisis and Knight et al. (2005) revealing higher real estate correlations in falling equity markets. Furthermore, the strong performance of gold in bear markets has been revealed by Hoang et al. (2015).

In order to quantify the actual benefits of diversification over the 18-year period, different portfolios have been constructed. The analysis has presented cross-asset portfolios outperforming cross-region ones when optimized towards the maximum Sharpe ratio or minimum variance. Cross-region portfolios in turn show better results when being equally weighted. Nevertheless, cross-asset portfolios have proven higher diversification benefits than cross-region portfolios. On average, the effect of diversification within a set of different assets seems to be higher than when mixing regional securities from one single asset class. As the majority of existing literature has either focused on cross-asset, such as Filis et al. (2011), or cross-region diversification, such as Fletcher and Marshall (2005), there are difficulties in finding comparable studies. Nevertheless, the results are in accordance with Coaker (2006) providing evidence for lower correlations between equity and other asset classes, such as natural resources or bonds, than between different regional equity indices. This thesis expands existing literature by exposing that not only cross-regional equity, but also other cross-regional asset portfolios show lower diversification than the majority of cross-asset portfolios.

Due to lower diversification benefits, cross-region portfolios show larger performance drops during periods of crisis. However, weighting cross-region portfolios equally can limit the downside potential in bear markets. The low correlation of gold has led the commodity portfolio to perform opposed to the majority of assets during financial crises. Also, Asian and Latin American cross-asset portfolios are less affected by crises and should be considered under financial distress. Looking at performance figures of an emerging market portfolio, it appears that asset returns of less developed markets profit from financial crises in particular, which is consistent with the findings of Bekaert and Harvey (2013) and Gilmore and McManus (2002). Adding assets from emerging markets to a portfolio can thus increase diversification benefits. The same evidence has been provided by Christoffersen et al. (2014) revealing low correlation between emerging and developed markets. At the minimum variance, diversification benefits are more distinctive for cross-asset portfolios during financial crises, driven by low gold and investment grade bond correlations. Ayman et al. (2017) obtained similar results stating that bonds can potentially protect investors from falling equity prices during international crises. Białkowski et al. (2015), Bredin et al (2015) as well as a broad range of further literature has described the role of gold during financial crises as a "safe haven", which supports the findings of this thesis regarding gold's low correlation and stable performance.

Asset weights of the optimal portfolio highlight these findings. While high yield bonds show higher weights and thus a higher contribution to reach the maximum Sharpe ratio, investment grade bonds seem to be more crucial to reach a lower portfolio variance. The high yield bond market provides low diversification potentials, however can be seen as a good alternative for equity investors, as it has outperformed the stock market in terms of higher Sharpe ratios, which is in line with Coaker (2006) and Reilly and Wright (2001). It is concluded that, together with gold, investment grade bonds are the most powerful equity portfolio diversifier, which is indicated by low correlations, high portfolio weightings and stable movements in falling equity markets.

8 Conclusion

International equity markets are getting stronger connected and show increased linkages during financial crises in particular. Higher correlations in falling equity markets creates the demand for diversification alternatives. Cross-asset and cross-region investment strategies have been examined based on possible diversification benefits. Cross-asset diversification stays less constant over time, however, provides higher benefits compared to cross-region diversification. Diversification mitigates the sensitivity of portfolio returns to volatilities within the financial markets and encourages a more robust performance. Investment grade bonds and gold have shown outstanding diversification benefits for equity portfolios. These assets were observed to perform opposed to crisis movements with overall low correlations to equity markets. Furthermore, especially emerging market cross-asset portfolios seem to be less correlated to declining equity markets, which indicates a weak linkage between different asset groups in those countries. High yield bonds are not great diversifier during crises, however have shown the best performance among all assets and should be considered as an alternative for equity investors.

References

Ayman, O., Wisniewski, T.P., Nolte, S. 2017. "Diversifying away the risk of war and cross-border political crisis." *Journal of Energy Economics*, 64: 494-510.

Baur, D.G., Lucey, B.M. 2010. "Is Gold a Hedge or a Safe Haven? An Analysis of Stocks, Bonds and Gold." *Financial Review*, 45: 217-229.

Bekaert, G., Campbell, R.H. 2013. "Emerging Equity Markets in a Globalizing World." *National Bureau of Economic Research*.

Bergin, Paul R., Pyun, Ju Hyun. 2016. "International portfolio diversification and multilateral effects of correlations." *Journal of International Money and Finance*, 62: 52-71.

Białkowski, J., Bohl, M.T., Stephan, P.M., Wisniewski, T. 2015. "The gold price in times of crisis." *International Review of Financial Analysis*, 41: 329-339.

Bodie, Z., Kane, A., Marcus, A.J. 2011. *Investments and Portfolio Management*. United Kingdom.: McGraw-Hill Higher Education.

Bredin, D., Conlon, T., Poti, V. 2015. "Does gold glitter in the long-run? Gold as a hedge and safe haven across time and investment horizon." International Review of Financial Analysis, 41: 320-328.

Büyükşahin, B., Haigh, M.S., Robe, M. A. 2010. "Commodities and Equities: Ever a market of One?" *Journal of Alternative Investments*, 12: 76-95.

Christoffersen, P., Errunza, V., Jacobs, K., Xisong, J. 2014. "Correlation dynamics and international diversification benefits." *International Journal of Forecasting*, 30: 807-824.

Coaker, W.J. 2006. "The Volatility of Correlation." *Journal of Financial Planning*, 19: 58-69.

Coeurdacier, N., Guibaud, S. 2011. "International portfolio diversification is better than you think." *Journal of International Money and Finance*, 30: 289-308.

Conover, M., Friday, S., Sirmans, S. 2002. "Diversification Benefits from Foreign Real Estate Investments." *Journal of Real Estate Portfolio Management*: 8: 17-25.

Driessen, J., Laeven, L. 2007. "International portfolio diversification benefits: Cross-country evidence from a local perspective." *Journal of Banking & Finance*, 31: 1693-1712.

Emons, B. 2015. *Mastering stocks and bonds: understanding how asset cross-over strategies will improve your portfolio's performance*. New York: Palgrave Macmillan.

Fabozzi, F., Gupta, F., Markowitz, H. 2002. "The legacy of modern portfolio theory." *Journal of Investing*, 11: 7-22.

Filis, G., Degiannakis, S., Floros, C. 2011. "Dynamic correlation between stock market and oil prices: The case of oil-importing and oil-exporting countries." *International Review of Financial Analysis*, 20: 152-164.

Fisher, R.A. 1958. *Statistical Methods for Research Workers*, 13th Ed., Hafner.

Fletcher, J., Marshall, A. 2005. "An empirical examination of the benefits of international diversification." *Journal of International Financial Markets, Institutions & Money*, 15: 455-468.

Garcia, R., Tsafack, G. 2008. "Dependence Structure and Extreme Comovements in International Equity and Bond Markets with Portfolio Diversification Effects." *SSRN Electronic Journal*, March 2008.

Gilmore, C.G., McManus, G.M. 2002. "International portfolio diversification: US and Central European equity markets." *Emerging Markets Review*, 3: 69-83.

Goetzmann, W.N., Li, L., Rouwenhorst, K.G. 2002. "Long-term global market correlations.", *Working Paper National Bureau of Economic Research*.

Hoang, T., Lean, H., Wong, W. 2015. "Is gold good for portfolio diversification? A stochastic dominance analysis of the Paris stock exchange." *International Review of Financial Analysis*, 42: 98-108.

Hoesli, M., Lekander, J., Witkiewicz, W. 2004. "International Evidence on Real Estate as a Portfolio Diversifier." *Journal of Real Estate Research*, 26: 161-206.

Kearney, C., Poti, V. 2006. "Correlation dynamics in European equity markets." *Research in International Business and Finance*, 20: 305-321.

Kempf, A., Memmel, C. 2003. "On the Estimation of the Global Minimum Variance Portfolio." *CFR-Working Paper*, No.05-02.

Kendall, M.G. 1979. *The Advanced Theory of Statistics*, 4th Ed., Macmilllan.

Knight, J., Lizieri, C., Satchell, S. 2005. "Diversification when it hurts? The joint distributions of Real Estate and Equity markets." *Journal of Property Research*, 22: 309-323.

Lewis, M. 2012. *Applied Statistics for Economists*, 1st edition, Routledge.

Liu, E.X. 2016. "Portfolio Diversification and International Corporate Bonds." *Journal of Financial and Quantitative Analysis*, 51: 959-983.

Longin, F., Solnik, B. 1995. "Is the correlation in international equity returns constant: 1960-1990?" *Journal of International Money and Finance*, 14: 3-26.

Longin, F., Solnik, B. 2001. "Extreme Correlation of International Equity Markets." *Journal of Finance*, 56: 649-676.

Mangram, M. 2013. "A simplified perspective of the Markowitz portfolio theory." *Global Journal of Business Research*, 7: 60-66.

Markowitz, H. M. 1952. "Portfolio Selection." *Journal of Finance*, 7: 77-91.

Mendenhall, W., Beaver, R., Beaver, B. 2009. *Introduction to Probability and Statistics*, 13th edition, Brooks/Cole CENGAGE Learning.

Plyakha, Y., Uppal, R., Vilkov, G. 2014. "Equal or Value Weighting? Implications for Asset-Pricing Tests.".

Ramchand, L., Susmel, R. 1998. "Volatility and cross correlation across major stock markets." *Journal of Empirical Finance*, 5: 397-416.

Reilly, F.K., Wright, D.J. 2001. "Unique Risk-Return Characteristics of High-Yield Bonds." *Journal of Fixed Income*, 11: 65-82.

Rezayat, F., Yavas, B.F. 2006. "International portfolio diversification: A study of linkages among the U.S., European and Japanese equity markets." *Journal of Multinational Financial Management*, 16: 440-458.

Sharpe, W.F. 1964. "Capital Asset Prices: A theory of market equilibrium under conditions of risk." *Journal of Finance*, 19: 425-442.

Sharpe, W.F. 1966. "Mutual Fund Performance." *Journal of Business*, 39: 119-138.

Zivot, E., Wang, J. 2006. *Modeling financial time series with S-Plus*, Heidelberg and New York: Springer.

Appendix

Appendix 1: Annual correlation coefficients with global equity markets and respective significance values over the total period from January 01, 2000 to May 31, 2017.

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Real Estate									
Coefficient	0.2970	0.5272	0.5356	0.5164	0.6611	0.7243	0.7776	0.7884	0.8626
t-value	4.99	9.99	10.21	9.71	14.21	16.87	19.87	20.62	27.50
P-value	0%	0%	0%	0%	0%	0%	0%	0%	0%
Commodity									
Coefficient	-0.0297	0.0275	0.2282	-0.0724	0.1691	0.1496	0.3211	0.3181	0.4727
t-value	-0.48	0.44	3.77	-1.17	2.77	2.43	5.45	5.40	8.65
P-value	63%	66%	0%	24%	1%	2%	0%	0%	0%
Oil									
Coefficient	-0.0265	-0.0465	0.1479	-0.2066	-0.0226	0.0473	0.1453	0.1539	0.3937
t-value	-0.42	-0.75	2.41	-3.40	-0.36	0.76	2.36	2.51	6.90
P-value	67%	45%	2%	0%	72%	45%	2%	1%	0%
Gold									
Coefficient	0.0087	-0.0667	-0.3221	-0.0137	0.3431	0.1788	0.2157	0.3171	0.0351
t-value	0.14	-1.08	-5.48	-0.22	5.89	2.92	3.55	5.38	0.57
P-value	89%	28%	0%	83%	0%	0%	0%	0%	57%
Bond IG									
Coefficient	0.0331	-0.0546	-0.4529	-0.2869	0.3083	0.2812	0.3297	-0.1065	0.1082
t-value	0.53	-0.88	-8.17	-4.82	5.23	4.71	5.61	-1.72	1.75
P-value	60%	38%	0%	0%	0%	0%	0%	9%	8%
Bond HY									
Coefficient	0.1515	0.2623	0.1208	0.1600	0.4558	0.4103	0.4829	0.5574	0.5276
t-value	2.46	4.37	1.96	2.61	8.26	7.23	8.86	10.80	10.02
P-value	1%	0%	5%	1%	0%	0%	0%	0%	0%

	2009	2010	2011	2012	2013	2014	2015	2016	2017
Real Estate									
Coefficient	0.8479	0.8818	0.9202	0.8071	0.7287	0.6117	0.7790	0.7524	0.3683
t-value	25.74	30.09	37.77	22.00	17.12	12.44	19.99	18.38	4.04
P-value	0%	0%	0%	0%	0%	0%	0%	0%	0%
Commodity									
Coefficient	0.6399	0.6403	0.5703	0.5564	0.3510	0.1140	0.3660	0.4783	0.2519
t-value	13.40	13.42	11.15	10.78	6.03	1.85	6.33	8.76	2.65
P-value	0%	0%	0%	0%	0%	7%	0%	0%	1%
Oil									
Coefficient	0.4913	0.6999	0.5158	0.6083	0.3189	0.1507	0.3227	0.4799	0.1453
t-value	9.08	15.77	9.67	12.33	5.41	2.45	5.49	8.80	1.50
P-value	0%	0%	0%	0%	0%	1%	0%	0%	14%
Gold									
Coefficient	0.1226	0.2581	0.0930	0.3630	0.2880	-0.1933	0.0061	-0.2158	-0.1760
t-value	1.99	4.30	1.50	6.27	4.84	-3.17	0.10	-3.56	-1.82
P-value	5%	0%	13%	0%	0%	0%	92%	0%	7%
Bond IG									
Coefficient	0.2760	0.2794	0.2558	0.2197	0.2726	-0.2334	-0.1852	0.1108	-0.0819
t-value	4.62	4.68	4.25	3.62	4.56	-3.86	-3.03	1.79	-0.84
P-value	0%	0%	0%	0%	0%	0%	0%	7%	40%
Bond HY									
Coefficient	0.4383	0.6891	0.6147	0.7283	0.6299	0.5443	0.5309	0.7288	0.5528
t-value	7.85	15.30	12.52	17.10	13.05	10.44	10.08	17.13	6.76
P-value	0%	0%	0%	0%	0%	0%	0%	0%	0%

Appendix 2: Annual correlation coefficients with U.S. equity markets and respective significance values over the total period from January 01, 2000 to May 31, 2017.

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Europe									
Coefficient	0.4108	0.4552	0.5772	0.6281	0.4237	0.3747	0.5603	0.5411	0.5662
t-value	7.24	8.23	11.38	12.99	7.54	6.49	10.87	10.36	11.07
P-value	0%	0%	0%	0%	0%	0%	0%	0%	0%
Asia									
Coefficient	0.0610	0.2044	0.1055	0.1151	0.2119	0.0234	0.1242	0.0927	0.2753
t-value	0.98	3.36	1.71	1.86	3.50	0.38	2.01	1.50	4.62
P-value	33%	0%	9%	6%	0%	71%	5%	14%	0%
Latin America									
Coefficient	0.6648	0.5856	0.6087	0.6094	0.6552	0.6024	0.7965	0.8742	0.8737
t-value	14.29	11.63	12.35	12.37	13.98	12.12	21.16	28.98	28.96
P-value	0%	0%	0%	0%	0%	0%	0%	0%	0%

	2009	2010	2011	2012	2013	2014	2015	2016	2017
Europe									
Coefficient	0.6981	0.7003	0.7301	0.6773	0.5559	0.5649	0.5370	0.6484	0.6021
t-value	15.69	15.79	17.16	14.81	10.76	11.02	10.25	13.71	7.69
P-value	0%	0%	0%	0%	0%	0%	0%	0%	0%
Asia									
Coefficient	0.3164	0.3279	0.2329	0.2717	0.2280	0.1356	0.3786	0.3394	0.0847
t-value	5.37	5.59	3.85	4.54	3.77	2.20	6,58	5.81	0.87
P-value	0%	0%	0%	0%	0%	3%	0%	0%	39%
Latin America									
Coefficient	0.8839	0.8600	0.8880	0.8355	0.6542	0.4518	0.6305	0.6619	0.4029
t-value	30.41	27.12	31.02	24.47	13.92	8.15	13.07	14.21	4.49
P-value	0%	0%	0%	0%	0%	0%	0%	0%	0%