Time-varying conditional correlation: Effect on international portfolio diversification in Southeast Asia

University of Jyväskylä

School of Business and Economics

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Author: Teemu Mikkonen
Supervisor: Heikki Lehkonen
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Author
Teemu Mikkonen

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Abstract

This paper investigates the correlations and the portfolio diversification benefits between the stock markets of the US and chosen Southeast Asian emerging markets; Philippines, Indonesia, Malaysia and Thailand. Moreover, this study provides results from both the US and the Indonesian investor's perspectives. The focus is on capturing the time-varying effect of correlation between stock indices by using a DCC-GARCH model first introduced by Engle in 2002. The used data goes from 1988 to the end of 2015. The results provide answers on whether or not the three financial crises, the Asian crisis, the Dot-com bubble and the Global financial crisis, have had an impact on the correlations between the indices of the chosen countries and whether the change has been persistent or not. The impact the time-varying correlations have on international diversification benefits are further studied in Markowitz's portfolio optimization framework. The findings of this study indicate that the correlations vary from time to time, and especially as the result of the Global financial crisis, but the changes in correlations are not found to be persistent. The correlation dynamics do not show clear evidence of reduced diversification benefits in the long run which is further supported by the findings from the portfolio optimization framework. For Indonesian investor, also the regional diversification benefits are found to be highly significant.

Keywords
Emerging Markets; International diversification; Market correlation; Time-varying conditional correlation; GARCH;

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Tiivistelmä

Tämä tutkimus tarkastelee USA:n ja valittujen Kaakkois-Aasian kehittyvien maiden markkinoita; Philippiinejä, Indonesiaa, Malesiaa ja Thaimaata. Tutkimus antaa tuloksia sekä USA:n että indonesialaisen sijoittajan näkökulmasta. Merkittävä rooli tutkimuksessa on ajassa muuttuvan korrelaation havainnollistamisessa osakeindeksien välillä käyttäen apuna Englen vuonna 2002 esittelemää DCC-GARCH mallia. Tutkimuksessa käytetty data on vuodesta 1988 vuoteen 2015 saakka. Tulokset paljastavat kuinka valittujen osakemarkkinoiden välinen korrelaatio on muuttunut kolmen kriisin - Aasian kriisin, teknologiakuplan ja globaali talouskriisin - myötä ja onko muutos ollut pysyvää vai ei. Lisäksi tutkimuksessa tutkitaan ajassa muuttuvien korrelaatioiden vaikutusta kansainvälisiin hajautushyötyihin käyttäen Markowitzin portfolion optimointi -viitekehystä. Tutkimuksen tulokset osoittavat maiden välisten korrelaatioiden vaihdelleen ajassa etenkin globaalin talouskriisin seurauksena, mutta korrelaatioiden muutokset eivät ole pysyviä. Korrelaatioiden perusteella pitkän aikavälin hajautushyödyt eivät näytä vähentyneen. Portfolion optimointiosion tulokset tukevat tätä päätelmää. Tulokset osoittavat myös indonesialaisen sijoittajan kannalta alueellisen sijoitussalkun hajauttamisen olevan erittäin hyödyllistä.

Avainsanat
Kehittyvät markkinat; Kansainvälinen hajauttaminen; markkinakorrelaatio; Ajassa muuttuva ehdollinen korrelaatio; GARCH;

Säilytyspaikka Jyväskylän yliopiston kauppakorkeakoulu

Contents

1. Introduction

According to the Modern Portfolio Theory low correlation between assets reduces the portfolio's risk (Markowitz 1952). If foreign stock markets do not perfectly correlate with the domestic stock market there should, in theory, be gains to be made by diversifying investors' portfolio internationally. Much due to this, and seeing that stock market co-movements and levels of integration are dynamic, during the last three decades portfolio diversification has been a major topic in the financial literature. The recent emergence of new practices that attempt to measure the dynamic nature of correlation has been an ample and a necessary extension to the prevailing research literature.

Many earlier studies provide results showing low correlations even among industrialized countries meaning significant benefits from international diversification (e.g. Grubel 1968, Levy & Sarnat 1970). However, it has lately been shown that especially G7[1] countries' stock indices are becoming more integrated as well as highly correlated and when imposing short-sale constraints they do not necessarily provide the wanted diversification in many cases (Li, Sarkar & Wang 2003, Bekaert & Harvey 1995). To overcome this, the logical step has been to redirect the focus on the study of diversification benefits available from the still developing, smaller and riskier markets.

Much of the literature on international diversification takes on a US perspective but since the US market is as vast and diverse as it is, it seems unreasonable to generalize these results to all other countries. Even when a US investor cannot benefit from international diversification, other, especially smaller and still developing countries, might gain significant benefit from diversifying portfolio internationally (Meric et al. 2001, Driessen & Laeven 2007, Chiou 2008). In this study another perspective is applied by analyzing differences in cross-country correlations and in efficient frontier framework between investors from the US and Indonesia.

Compared to the conventional studies another important distinction in this study is associated with the home bias. As first stated by French & Poterba (1991), home bias means that many investors tend to focus on local equity markets only. The later research has shown that many are willing to include regional markets as well as they are still seen rather familiar than unfamiliar despite being foreign (Grinblatt & Keloharju 2001). In addition to investigating the changes in the correlations and diversification benefits for the US investor, the examination from the Indonesian investor's perspective gives us a proxy on if regional diversification alone would be beneficial, in terms of risk reduction, in the chosen Southeast Asian emerging markets as they all belong to the same region. The emerging markets in this study (Indonesia, Thailand,

[1] G7 includes the US, Canada, the U.K., Germany, France, Japan and Italy.

Philippines and Malaysia) were chosen to answer the research questions at hand. The choice of the above mentioned Southeast Asian equity markets serves as a motive for including the inspection of the Asian crisis in this study.

A significant development in studying cross-market correlations has been in the method correlations are measured by practitioners. Earlier studies have commonly used constant levels of correlation calculated using the average of the inspection period. This approach can easily be questioned as an elementary approach such as a 12-month rolling correlation is enough to show clear discrepancy with the constant correlation hypothesis. Moreover, it is generally accepted that asset correlations increase during times of negative returns, i.e. crises. Thus, the time-varying nature of correlation is obvious. To tackle the difficult question of how to measure correlations using time-series data in an efficient way, in this case between stock market indices, this study employs the DCC-GARCH method first introduced by Robert Engle (2002). The Dynamic Conditional Correlation Generalized Autoregressive Conditional Heteroskedasticity (DCC-GARCH) –model attempts to capture the time-varying conditional correlations without creating too many parameters. It also presents an answer to the heteroscedasticity problem raised for example by Forbes & Rigobon (2002).

A key aspect considered in this study is how the underlying crises have influenced the correlations and international portfolio diversification benefits. As each of the crises are different and the degree of contagion and the way they spread are unique the study on hand should provide interesting results. Though, it should be noted that the efficient frontier is much dependent on market returns, in addition to correlations, and as such the results leave room for speculation and interpretation. In general, the study on correlations is an important one and accurate estimates are vital for many financial applications such as asset pricing, capital allocation, risk management and portfolio hedging.

1.1 Research questions and implementation

This research mainly addresses the stock market co-movements and international portfolio diversification benefits of an investor over time. Furthermore, the dynamic conditional correlations are used to make speculations on the potential international diversification benefits throughout the period and efficient frontiers are constructed from both the US and Indonesian investor's perspectives. Special attention is given to the times of crises i.e. have the crises had a prevailing effect on the levels of correlations and what it means for investors seeking diversification benefits?

The research questions are:

1. Have the correlation levels increased over time?
2. How can the times of crises be seen in terms of stock market correlation and in the context of efficient frontier?
3. Are regional market risk reduction benefits exploitable?

The data used is US Dollar and Indonesian Rupiah denominated monthly total return index from each country's local stock index between 1988 and 2015. For the first part of the research, the US Dollar returns for the whole 337-month period are used to create the bivariate DCC-GARCH (Engle, 2002) estimates in order to capture the time-varying nature of correlations for the chosen time period and stock indices. Some preliminary tests are done in advance to justify the use of the chosen univariate models.

In the second part, the data is divided into different subsets in order to ascertain how the diversification benefits have changed with correlation and especially during the times of crises. Tangency and minimum-variance portfolio are constructed for the US as well as the Indonesian investor. In this part the unconditional correlations are used. Diversification benefits are mainly measured using Sharpe ratio but also the risk reduction benefits are notified in some cases. Short-selling[2] is not allowed.

1.2 Main findings

The results from my study show a significant time-varying conditional correlation to exist among the chosen countries from both the US and Indonesian perspective with the only exception being the US – Philippines pair. The Global financial crisis, in line with the previous literature, was found to have a temporary strong positive impact on the market correlations. The Asian crisis and the Dot-com bubble did not show similar result. Overall, the correlations from Indonesian investor's perspective were much lower than the US investor's indicating more significant international diversification benefits. I did not find significant increases in correlations over time for neither investor.

In this study the equity markets return characteristics were found to dominate the correlation characteristics in determining the significance of the available diversification benefits. This lead to difficulties in interpreting the impact that correlations have for investors seeking diversification benefits. However, the efficient frontier framework suggests that both investors could obtain improvement in Sharpe ratios thus supporting the importance of international diversification. The US investor was found unable to reduce portfolio risk but only to obtain better risk-return relationship via increased return. Indonesian

[2] Selling a security which is borrowed by the investor or not owned at all. For more detail see http://www.investopedia.com/terms/s/shortselling.asp

investor could benefit in both risk-reduction and increasing Sharpe ratio. Moreover, regional diversification was found to provide highly significant improvements to the Indonesian investor's portfolio. I did not find the times of crises to reduce diversification benefits except for the US investor during the Asian crisis.

1.3 The Structure

The paper continues as follows: Chapter 2 provides the basic theory of Modern Portfolio Theory (MPT) which acts as a background for Markowitz's portfolio optimization. MPT framework gives one theoretical example for the use of correlation, motivates the study of it and highlights the importance of it for financial professionals. The chapter also consists of explanations on the concepts which are related to this study; Sharpe ratio, emerging markets, correlation, integration and characteristics of market returns as well as brief description considering each of the three crises. Chapter 3 presents some of the earlier literature on the matter of displaying how correlations and integrations have changed over time and how these changes have been found to affect the international diversification benefits. One subsection is dedicated to the DCC-GARCH model which is presented here with more general review to the existing literature in order to give understanding of the actual model and its usefulness. In addition extra emphasis on the research on co-movements during times of crisis is presented as it serves as a separate area of interest. Chapter 4 presents the vital time series models and Markowitz's portfolio optimization and chapter 5 introduces the data including some preliminary tests. In chapter 6 the empirical research is conducted as explained earlier. Much weight is put on discussing the found results. Chapter 7 provides a conclusion including possible future research topics related to this research.

2 Theory and concepts

The foundation to understand the research at hand is based on correlation. To make correlation valuable in the context of finance this study reflects mainly to the MPT. Other financial theories could be used, such as Value-At-Risk, just to name one. The information the concepts below hold can answer to possible silent questions that might arise while reading. Moreover, this chapter provides the theoretical premise to which the empirical part contributes later on.

2.1 Emerging markets

The term emerging markets, or developing markets, is used for countries which lie somewhere in between developed countries and the least developed countries. The World Bank classifies countries by their Gross National Income per capita into three different economies. The highest economies (>12,746$) by GNI per capita cannot belong to the emerging markets. The economies defined as low and middle economies, by this measure, can but do not necessarily belong to emerging markets if they do not fulfill some of the other criteria required. Other requirements can be such as the market openness to foreign ownership and stability of institutional framework. (The World Bank 2014.)

The biggest emerging markets i.e. so called BRIC-countries are Brazil, Russia, India and China. These countries have been the main source of the world's economic growth and partly due to that the emerging markets have recently received a lot of interest. Rapid growth is usually associated with the emerging markets and this has led some to argue in recent literature that the term growth markets would actually be a more accurate description. However, this is still to gain enough attraction. Even without other developing countries, which there are about 20 depending of the source, it can be seen that the emerging markets contain much of the world's population and the changes in these countries' economies can have a significant effect globally.

Along with high growth the emerging markets have many other common characteristics some of which are negative and some positive. The following table presents the main statistical findings from the stock market indices between 1988 and 2011.

Index	Average returns	Volatility	Correlation	Crises[%]
MSCI World index	2,88	14,28	1,00	0,35
G7	2,50	14,17	1,00	0,35
BRIC	5,44	27,76	0,74	1,96
Emerging markets	8,03	22,36	0,74	0,69
the US	5,40	13,62	0,89	0,00
Indonesia	8,04	41,08	0,37	4,51
Malaysia	4,81	24,16	0,46	1,74
Philippines	3,30	28,76	0,45	1,74
Thailand	4,17	33,97	0,51	4,86

Table 1: Descriptive statistics. Return is continuously compounded local market monthly total return in the US Dollars excess of the US one-month Treasury bill. Volatility is the annualized 12-month standard deviation of excess returns. Correlation is the correlation between the index and MSCI world index. Crises is the ratio between the months when the index has decreased for more than 20% during a month and the total amount of months multiplied with 100. Source: Lehkonen (2014, p.17-18)

From the historical stock price-data it can be seen the emerging markets have a high excess return when compared with G7 countries or with the world index but there is also a downside to it. The volatility of the stock returns is much higher and these countries have had far more big declines in stock indices as measured by Crises in the table. Thus, the risks are much higher.

There exists a good deal of research that attempt to explain the reasons affecting the difference between the markets' behavior. For example, Bekaert et al. (2011) have found institutional structure, e.g. political risk, investor protection and investment restrictions, to be one of the main factors. The same does not apply to developed countries. It is findings like these that motivate the study on emerging markets. The distinctions of the market dynamics between developed and emerging markets work as a reason why the same theories cannot be fully applied to every country. If some can say the market is not efficient in a developed country, it surely is not in an emerging country either.

Moreover, the emerging markets stand apart even among each other. The economic, political, social and financial environment are greatly different in vast majority of the countries in the group. This opens up many possible research topics many of which are still fairly unexplored. Especially when the future importance of developing countries, via increased population and economic impact, is taken into account the current escalating interest in this research area cannot be claimed to be an exaggeration.

2.2 The Crises

The phrase "Bubbles always implode" describes well many historical financial crises that the world economies have faced so far. Despite each crisis being unique some striking similarities are found in a vast majority including; run-up of asset prices, debt accumulation, growth patterns and current account deficit (Reinhart & Rogoff 2008).

In the context of international financial crises, the globalization and integration plays a key role. One main contributor to this fact is the liberalization of financial markets. While the liberalization arguably increases the efficiency of the markets and has many great benefits for some agents it could leave the financial markets more vulnerable for shocks and crises (e.g. Kindleberger & Aliber 2011, Summers 2000).

In this research I focus on three specific crises: The Asian crisis around 1997, the Dot-com bubble around 2000 and the Global financial crisis between 2007 and 2009. The following sub-chapters will go through each of these crises briefly. For the purpose of this study the interest lies on how these periods of downturn spread across countries and what parts of the world they affected. This information is reflected later on in the empirical findings.

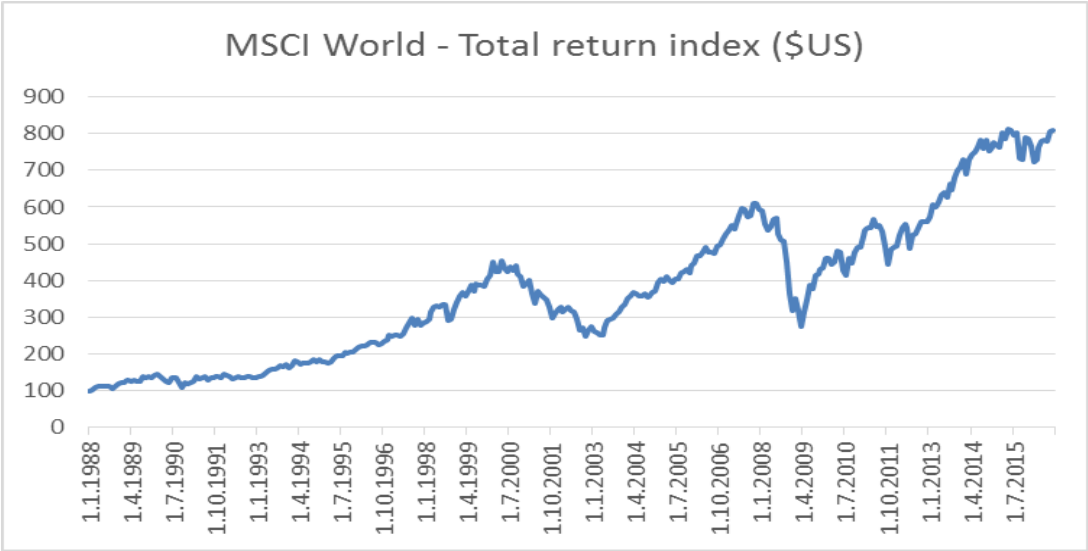


Figure 1: MSCI World total return index. Displays the impact the Asian crisis (1997-1998), the Dot-com bubble (2000) and the Global financial crisis (2007-2009) had on world financial markets in general.

The Asian crisis

The Asian crisis began in July 2nd 1997 as the Thai's Baht collapsed. During the 1990s many Asian countries had evidenced a significant increase in foreign capital inflows. According to Kaminsky & Reinhart (1998) this and the weaknesses in the financial sector could have been the striving forces of the 1997 crises in East Asia. Furthermore, the collapse in Thailand created a currency and equity market turbulence which spread mainly within the financial markets of East and Southeast Asia –Thailand, Malaysia, Indonesia, the Philippines and South Korea to be more precise. These are the markets considered to be in the hearth of the Asian crisis (Baig & Goldfajn 1998). These equity markets began to strengthen finally in the second half of 1998 which marks the end of the Asian crisis. However, the events in Asia might have had some far-reaching consequences as investors experienced a "wake-up call" [3] and became reluctant to lend more money to developing countries in general. Before the millennium at least Brazil, Argentina and Russia suffered economic slowdowns and sharp declines in their equity markets. Overall, the Asian crisis was a currency crisis which had deep consequences on the economies it touched.

The Dot-com bubble

The Dot-com bubble is more sector related than country related matter. The climax, or the burst of the bubble, took place on March 10, 2000, when the US index, the NASDAQ, peaked. The rapid growth in the technology sector stock prices was due to the rise of commercial growth of the internet which was overhyped "by irrational euphoria among individual investors, fed by emphatic media—", as written in Brunnermeier and Nagel (2004).[4] It is hard to define the exact economies affected by the event but like Hon et al. (2007) found the technology, media and telecommunication sectors in much of Europe, Asia, the US and Japan all suffered significant declines in stock prices after the NASDAQ climax. The same was not true for other sectors studied. In light of this evidence, it could be said the Dot-com bubble had the largest impact in countries with high level of market equity coming from these sectors. It should be pointed out that the US is held as the main contributor for the crisis. Overall, the Dot-com bubble hit the certain industries and not so much the economy as a whole with the exceptions of country like Finland which faced a massive consequence due to the economic impact of Nokia. The markets started to recover by the end of 2002.

[3] re-assessment of local fundamentals and information acquisition after observing a crisis elsewhere

[4] Original source: Irrational Exuberance (Schiller 2000)

The 2007-2009 Global financial crisis

The root for financial crisis of 2007 to 2009 can be found in the US lending market, namely the subprime mortgage market. The burst of housing bubble led to a large decline in home prices which resulted in mortgage delinquencies. This started a recession during which households further reduced spending. Second came the equity market reaction during 2008 which escalated into major decline in stock indices after the bankruptcy of Lehman and the bailout of AIG (Bartram & Bodnar 2009). The lion's share of the collapse is attributable to the period between September and October of 2008. Despite the origin being in a rather small segment and only in the US the crisis spread rapidly across borders to affect virtually all economies. As a result, many equity markets declined even more than the US equity market. In general, emerging markets faced most severe declines which can be argued to result from the pre-crisis, uncalled, stock market rise. Overall, the crisis between 2007 and 2009 was global, as evident from the name, meaning it affected more or less all economies.

2.3 Modern Portfolio Theory

MPT was first introduced by Harry Markowitz in 1952. The theory is based on two principles; first, all investors should try to maximize the discounted expected returns of investments and second, while expected return is a desirable thing, the risk of an investment is undesirable thing. The risk is measured by the investment's standard deviation. The aim is to find the best possible weighting of different assets so that the portfolio optimizes investor's risk/reward-ratio. (Markowitz 1952.)

Each asset has systematic (market) risk as well as asset specific risk. According to the theory the latter can be diversified away by creating a portfolio with assets that have a less than perfect positive correlation (<1) with each other as the risks (positive or negative) will cancel out. Similarly, if such an asset is included into an existing portfolio it will reduce its volatility. The inspection is done in a risk-expected return space and the best, minimum-variance portfolios, are shown as an efficient frontier from which investors should pick their portfolio depending on the level of risk they are willing to carry. The higher the risk the higher the expected return. (Sharpe 1964.)

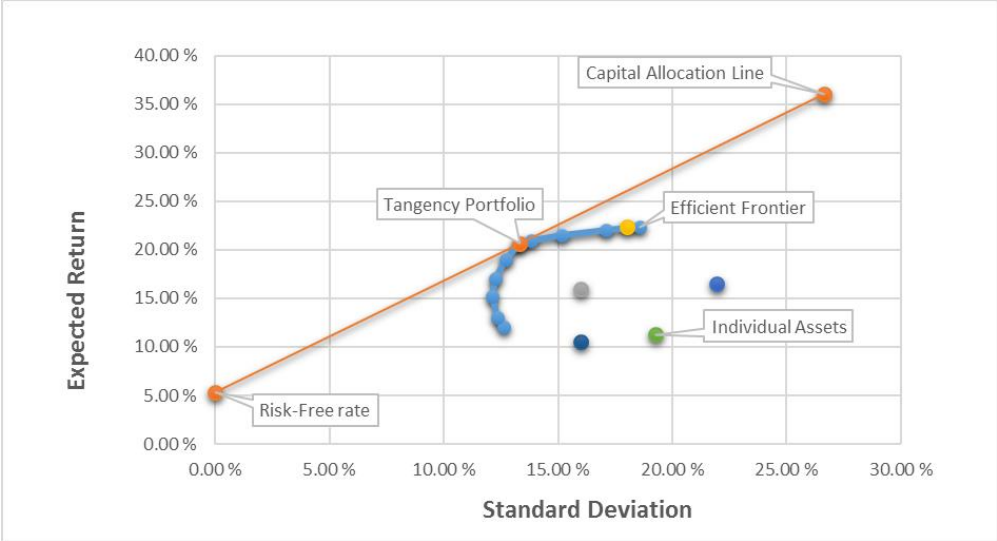


Figure 2: Risk-Expected return setting.

Best combination of individual assets is displayed by the efficient frontier when no risk-free asset is available. When risk-free asset is available, investors can invest in it or borrow with the same %-rate, the straight line in the picture above becomes the efficient frontier (Capital allocation line, CAL). Depending on an individual investor's level of risk-aversion he should pick a point from somewhere in the efficient frontier. Point in CAL to the right of Tangency Portfolio can be obtained by borrowing money and investing this extra money into Tangency Portfolio and to the left by investing some money to risk-free asset instead of Tangency Portfolio. The straight line in the picture depicts all the choices which maximize investors Sharpe ratio. (Brealey & Myers 1996, p.173-188.)

2.4 Sharpe ratio

Sharpe ratio is one of the most used performance measures of a portfolio. It is based on Markowitz's portfolio optimization. It is calculated by dividing the excess return of an investment asset by its volatility. The ratio is defined as:

$$S = \frac{R_a - r_b}{\sqrt{var(R_a - r_b)}} = \frac{R_a - r_b}{\partial_a}, \text{ where}$$

$R_a =$ Asset return
$r_b =$ Risk-free return (could also be index or other benchmark)
$\partial_a =$ Standard deviation of excess return

The higher the ratio is the more reward the investor gets for each unit of risk he is taking. If two investment strategies provide the same return but have different Sharpe ratio, the investor should always pick the strategy that has a higher Sharpe ratio since it means the return is achieved with less risk. (Sharpe 1966.) Main advantage with Sharpe Ratio is that it is easily computed directly

from the series of portfolio returns. Criticism can be cast for example on its convention to treat volatility per se as a negative characteristic. This means that even large positive gain is to be viewed as a negative event in terms of risk.

2.5 Correlation and integration in the stock market framework

It is important to know how correlation and integration differ in the stock market framework. By examining the past stock market indices around the world it can be said that stocks do not move identically with each other. However, it is hard to define whether this discrepancy is due to a low correlation or if the reason is a low level of equity market integration in the indices compared. Even if two markets are perfectly integrated they do not necessarily have a strong correlation (Pukthuanthong & Roll 2009). For example, a change in oil price might affect two countries' oil stocks almost identically meaning they are highly integrated, but the influence to the correlation between the indices of these two countries is dependent on the weight the oil stocks carry within the corresponding indices. Many studies in international portfolio diversification use different methods from one to another as no single method has been able to achieve a superior position.

Correlation is the relationship of two variables that change together. In this case stock indices. If the two move hand in hand to the same direction they have a correlation of 1 and if they move to the opposite direction they have a correlation of -1. Every other kind of co-movement falls in between -1 and 1 with 0 meaning no relationship whatsoever. The results are highly conditional on time-period used. In investing, the correlation is typically measured by taking the monthly returns of one asset class and comparing them to another. Other time-periods, e.g. weekly and daily, are also commonly used. (Ferri 2014.) Two main factors considered to affect correlation between stock indices are integration and the fact that absolute value of correlation seems to increase during a time of crisis (Bekaert, Harvey & Ng 2005b).

The world's economies are becoming more integrated as the globalization continues and international trade sustains its rapid growth. Similar evidence can be found from economies' financial markets despite the fact that home-bias is still evident. Financial integration refers to the process of financial market in an economy to become more closely integrated with other financial markets around the world. As Lehkonen (2014, p. 30) defines: "Markets are said to be integrated when the assets with similar risk structure command the similar expected returns regardless of their domicile, while the markets where the expected return of an asset depends only on its location are said to be segmented".

The results of integration can usually be seen as an increase in capital flows of an economy and as a tendency for asset prices and returns to equalize among countries as investors look for best available returns. This leads to the world

equity markets correlations to become increasingly positive and thus reduces the diversification benefits of an investor. Equity market that used to carry high proportion of market specific risk carries now, along with the increased integration and correlation, mostly systematic risk which cannot be diversified away. In addition, during a time of crisis the absolute value of integration has been found to increase. (Chelley-Steeley 2004.)

2.6 Time-varying and asymmetric characteristic of market returns

The correlations between stock market returns have been observed for a long period of time. Lately, the highly fluctuating nature of market returns has been well documented. Especially, after several crises and turmoil periods, such as the three mentioned earlier, the topic has further raised interest among financial practitioners and researchers. An accurate correlation estimate is an important variable in many situations including portfolio diversification so no wonder numerous new techniques have been introduced to better estimate it.

As Ratner (1992) expressed the value of an accurate estimate: "An unstable relationship indicates that the efficient frontier is constantly changing, which may result in the selection of a suboptimal portfolio strategy." In his research the international market return correlations relationship was found to be stable. Many studies have indeed focused on studying whether the correlations are constant or time-varying. For example, Kaplanis (1988) found similar results to Ratner (1992), meaning the constant correlation hypothesis could not be rejected, by analyzing ten stock market returns between 1967 and 1982 by using Jennrich's and Box's tests[5]. Overall, in the early days the relationship between two country's returns were considered to be somewhat constant. As time has passed the studies have become more and more to support the existence of time-varying conditional correlation supported by the introduction of more explanatory models.

Koch & Koch (1991) summarized their results stating the international markets have become more interdependent from 1972 to 1987. Longin & Solnik (1995) studied the return characteristic with the help of GARCH(1,1)[6] model and found clear evidence in support of ARCH effect as well as time-varying correlation for 4 out of 6 countries in their research. Similar results have been stated in increasing amount of researches.[7] In the presence of ARCH effect the variance of returns is considered heteroscedastic. This heteroscedasticity has been well documented to be true for several national markets. In order to get better estimates of correlation the heteroscedastic attribute in variance has to be taken into account when modeling the dynamics between markets and one

[5] For explanation see: (Jennrich 1970) & (Box 1949)
[6] Closer look in chapter 4.2.1
[7] See for example(Longin & Solnik 2001); (De Santis & Gerard 1997)

effective way to do this is through a GARCH model. Further, the effect volatility has regarding correlation has become an accepted wisdom; as volatility increases so does the correlation. The extensive analysis of the time series volatility is much attributable to the introduction of Autoregressive Conditional Heteroskedasticity (ARCH) model by Engle (1982) and to its extension Generalized ARCH (GARCH) model by Bollerslev (1986). However, ARCH and GARCH models assume the presence of symmetric impacts of unconditional shocks on conditional variances and this has been found troublesome.

Not only have the market returns been observed to be fluctuating over time but also the asymmetric nature of the volatility has been widely documented. Asymmetry in volatility means that positive and negative shocks impact conditional volatility and correlation of asset returns with an unequal magnitude. The impact of a negative shock is observed to be more vicious than that of a positive shock. In fact, some evidence has been reported when volatility has failed to increase at all subsequent to a positive shock for some assets (Cappiello, Engle & Sheppard 2006.) To capture the presence of asymmetric volatility various new econometric models and extensions to the ARCH/GARCH family have been introduced. These models include EGARCH model by Nelson (1991) and GJR model by Glosten et al. (1993) just to name two. Koutmos & Booth (1995), for example, find strong evidence of asymmetry in volatility when implementing an EGARCH model to New York, London and Japan stock markets.

As the GARCH family of models aim to explain the heteroscedasticity and asymmetry in volatility they do not say anything about these characteristics in correlations. But as Kroner & Ng (1998) argue, if the expected return on one asset changes as a results of an asymmetric volatility effect, then the correlation between returns on that asset and others assets must change when the other assets have not been affected by the volatility effect. In addition, they contribute to the existing literature by presenting a robust test for the validity of the model. To answers these limitations of earlier models Cappiello et al. (2006) present an updated version of the DCC-GARCH model (Engle, 2002) which extends the asymmetry to be carried out also in the correlation part resulting in an Asymmetric Dynamic Conditional Correlation-GARCH model. The DCC-GARCH model is an extension of the CCC-GARCH model (Bollerslev, 1990) that restricted the conditional correlation to be constant over time. This restriction on correlation was liberated in the DCC-GARCH model and now further allowed for asymmetries via ADCC-GARCH model.

To sum up, the literature observing stock market volatility and correlation is showing ever evolving characteristics. Here a simplified framework leading to the introduction of DCC-GARCH and ADCC-GARCH models were presented. These models attempt to capture the time-varying, and ADCC also the asymmetric, nature of correlation and volatility. No weight was given to any

model specific notations nor differences between univariate and multivariate models[8]. Even though the literature has come a long way the models are still being further improved as no model has been able to provide fully satisfactory results.

Some of the main findings of previous research relating chapter two will be presented in the next chapter. As the research on these fields is so vast, only some parts of the area are covered. The chapter explains in more detail how correlation and integration are related, if at all, and how the results obtained by these measures have changed over time. The DCC-GARCH model is given its own subsection as it is the model used later on the empirical study part of this paper. Whereas correlation and integration literature review is focused on certain areas, the DCC-GARCH section is a broader overview of the use of the model and its feasibility relative to simple GARCH models and other competitors such as VECH (Bollerslev, Engle & Wooldridge 1988) and BEKK (Engle & Kroner 1995). Moreover, the influence of financial crisis in this study's context is brought to light.

[8] Univariate = dependent on one variable; Multivariate = dependent on more than one variable

3 Earlier research

For many decade diversification literature has focused on co-movements of stock returns. For asset managers the findings can provide important information which helps to improve their performance. Thus it is not surprising the research area has gained a lot of attention. The main focus has been on international diversification but also cross-industry benefits have been observed (Cavaglia, Brightman & Aked 2000). On top of affecting assets' diversification benefits, the study on market integration contributes to topics such as the international risk-sharing and economies' cost of capital (Bekaert et al. 2011).

As the globalization trend has continued and countries have lifted their trade and investment barriers the equity markets have likely become more integrated. This has raised many questions among practitioners some of whom started to question whether benefits of international diversification even exist anymore. It should be noted that when comparing the Sharpe ratios of single developed and emerging markets between 1988 and 2011 the two markets can be considered almost equal with the US having the highest ratio of 0.72 (Lehkonen 2014, p. 17-19). Thus no emerging market alone would have been better than home market to the US investor.

The research on international diversification benefits can be divided into three different subsets; correlation, integration and time of crisis. It is generally thought that increased cross-country correlation goes hand in hand with increased equity market integration (Bekaert, Hodrick & Zhang 2009). As economies' globalization continues and countries become more dependent on each other the integration of equity markets is supposedly unavoidable leading to an increase in cross-country stock co-movement (Phylaktis & Ravazzolo 2002). Moreover, the data describing the times of crises has been found to produce abnormal results on both integration and correlation framework and has thus been a fruitful research area on its own (Bekaert, Harvey & Ng 2005b, Tai 2007).

The DCC-GARCH model steps in to the equation as a way to measure the correlation while allowing it to be dynamic over time. Many studies on market correlations use different approaches and no single approach has been deemed superior. The DCC-GARCH model was created to provide more accurate and more efficient correlation estimates (Engle 2002). As these estimates are critical inputs for many financial tasks, the performance and applicability of the model will be reviewed here. One interesting thought rising from this is whether the results found in many correlation studies would be completely different had the correlations been measured in a different, and perhaps, a better way?

3.1 Research on market correlation

As pointed out in the example by Driessen & Laeven (2007), early research on international diversification benefits concentrated much on the risk reducing benefits among industrialized countries[9]. Later it became evident that more advantage could be available by diversifying to less developed countries even though their equity markets' returns exhibit higher volatility. The excess benefit was due to emerging markets having a low level of correlation with the US market.

In one of the earlier research papers on potential emerging markets' diversification benefits Harvey (1995) studies the significance of the change in efficient frontier when 18 emerging markets are added as investable markets on top of 18 developed markets. This is so called mean-variance spanning test. The results state significance at the 10% confidence level. By adding the emerging markets to the global minimum variance portfolio, the standard deviation reduces from 14.5% to 7.5%. The paper also provides evidence on the impracticality of global asset pricing models on explaining the prices and returns on emerging markets. They test for one- and two-factor models and find the betas to be "-- unable to explain any of the cross-sectional variation in expected returns." This is a much known issue today and researchers are trying to find a better model to explain the fluctuation in returns on emerging markets.[10]

In their research, Meric et. al (2001) focus on international diversification benefits among the four largest Latin American equity markets (Brazil, Chile, Argentina, Mexico) and the US. They divide the data into three periods; pre-crash (1984-1987), after the crash when the equity markets are not open to foreigners (1987-1991) and after the crash and equity markets are open to foreigners (1991-1995). First, a rolling correlation graph is created for each four markets with the US to study the co-movement of the stock indices over time. Second, Markowitz's portfolio optimization procedure is done for each period to find out the effects of the changes in the co-movement trends on international diversification benefits to the US investor. Short selling is not allowed.

They find that after the crash in 1987 the four Latin American equity markets do not provide a significant reduction in portfolio volatility to the US investor without good stock picking. They state that broad indices have become more integrated with the US market. For investor to benefit from these equity markets good individual stock picking is required or higher returns all around. They also point out that increased correlation is not the sole explanatory on international diversification gains: "—regime changes (such as financial

[9] See for instance; (Grubel 1968, Levy & Sarnat 1970, French & Poterba 1991, Solnik, Boucrelle & Le Fur 1996)

[10] e.g. D-CAPM by Estrada (2002)

liberalization) may reduce market risk and increase expected returns, potentially offsetting the effects of greater correlation".

It is important to notice that their findings do not mean that international diversification benefits to the US investor have disappeared but instead, only, that the four equity markets fail to reduce the volatility of the US investor's portfolio. For example, the risk-reward ratio may be improvable if the investor chooses to optimize it via increasing volatility and choosing a portfolio with asset weights so that it lies on the efficient frontier. This would also mean a higher Sharpe ratio.

Driessen & Laeven (2007) address the problem of earlier studies focusing on the US investor's perspective. They contribute to the subject by measuring cross-country and time-varying international diversification benefits of a local investor. The study also contributes to the home bias research by examining whether regional diversification alone would be profitable. They consider the cross-country benefits for two types of diversification opportunities. First, investors are allowed to invest in a regional equity index along the local one and second, investors can use the global MSCI indices for the US, Europe, and Far East on top of the local one. To measure the benefits, statistical and economical significance tests are conducted, i.e. mean-variance spanning test and calculations on the changes in Sharpe ratios. The time-varying effects of potential benefits are measured using the ICRG composite risk index as a proxy. The data used is monthly stock market index returns from 1985 to 2002 for 52 countries.

The diversification benefits are decreasing for most countries over their sample period. Regardless, for the mean-variance spanning test the null hypothesis is rejected at the 1% confidence level for all of the countries when global diversification is allowed and similarly for 50 out of 52 countries when only regional diversification is possible. These results are obtained without assuming any market constraints. When short selling is constrained for all countries the global benefits are found to be statistically significant for 34 out of 52 countries.

For the economic significance test the increase in Sharpe ratio is measured and found significant. The average Sharpe ratio over all countries without market frictions increases from 0.10 to 0.21 which is equivalent to a 0.98% increase in monthly returns. Even when controlling for short-sales constraints in developing countries, the diversification benefits are significant both for developed and emerging markets in terms of Sharpe ratio.

In the time-varying model the expected returns are considered to be a linear function of country's risk (ICRG index). When the risk of a country reduces, the diversification benefits should decrease as well. The inspection focuses on comparing the diversification benefits for January 1985 and August 2002

instead of comparing them yearly. They find, for example, that in Asia monthly US Dollar expected returns have decreased from 1.9% to 0.0% and standard deviation from 15.2% to 9.0%. They also find Sharpe ratio to decrease significantly in many regions. However, they point out that these results do not mean that the diversification benefits have to reduce. The increased correlation and reduction in volatility could be offset by the decrease in local returns and in some cases even increase the available diversification benefits.

Moreover, their findings state that countries with higher risk profile are more potential to benefit from international diversification and that regional diversification benefits are also available. Even when all the markets are prohibited from short-selling any assets, which is a conservative approach, there still remains substantial international diversification benefits for many countries' investors. This is despite the increased correlation over time.

3.2 Research on market integration

The research on integration can be separated into different groups. Some of the studies highlight the factors that affect the level of integration in an economy and others highlight the effects the changes have on diversification benefits or on economic growth of the country.[11] Although the research field of market integration is diverse and there is no general measure to calculate the level of it, some of the factors affecting it are found to be significant in most of the models.

Bekaert et. al (2011) state that emerging markets and some of the developed markets are still only partially integrated despite increased integration over time. They find some of the main factors affecting the level of integration to be openness of the financial markets, openness of the foreign trade, development of the capital markets, the US credit spread and political risks associated with the country. The openness of the financial market is found to be the single most significant variable. Together these variables succeed to explain close to 30% of the variation in the level of market integration. They also underline the fact that despite globalization (regulatory openness) being one of the main contributors to the integration there are reported reversals in this trend. Economies can become less integrated even while increased globalization is observed.

As many studies point out, the general intuition has been that increased market integration also increases the market correlations.[12] Bekaert & Harvey (2000, 2003) illustrate results that support this idea. They show that 17 out of 20 countries in their data experience an increase in correlations after market liberalization - the remaining three experience a decrease but only by a small

[11] 1. Factors affecting (Bekaert & Harvey 2003, Bekaert et al. 2011)
2. Diversification benefits (de Jong & de Roon 2005, Pukthuanthong & Roll 2009)
3. Economic growth (Edison et al. 2002, Bekaert, Harvey & Lundblad 2005a)
[12] See (Bekaert, Harvey & Ng 2005b, Chelley-Steeley 2004)

amount. Interestingly, there are no signs of changes in volatility despite the fact that markets' co-movements and returns approach the world market (IFC composite index).

Pukthuanthong & Roll (2009) argue this idea and present different results using Principal Component (PC) analysis. They find similar, increasing, results in integration over time but fail to find evidence on relationship with correlation. They also claim the level of integration to be "-- better depiction of the true benefits from international diversification". According to them, increased integration leads to reduction in diversification benefits instead of correlation. In later study, Berger, Pukthuanthong & Yang (2011), find the emerging markets to be as highly integrated to the world market as many developed countries meaning they do not provide the wanted diversification benefits. Frontier markets[13], on the other hand, still offer high diversification benefits while being highly segmented. Carriere, Errunza & Hogan (2007) also find results that support the idea that correlation and integration are not well related. They claim correlation to underestimate the degree of integration.

The third area of focus takes a note on the economic growth aspect of a country related to the level of integration. Bekaert et al. (2005a) regress real per capita gross domestic product (GDP) growth on an equity market liberalization index. Their results indicate an increase of 1% annual real economic growth when equity markets are liberalized. On the contrary, Edison et al. (2002) find mixed results. One major variable affecting the results in their research was found to be the wealth of a country since poor countries in general produced higher linkages between growth and international financial integration (IFI). In the end they summarized their findings: "—the data do not support the view that IFI per se accelerates economic growth –" and "—we do not reject the null hypothesis that IFI is unrelated to economic growth—". They emphasize that more research is needed.

Even though integration has been studied a lot in recent two decades, the results leave much to uncertainty. As several studies have pointed out, the market integration is affected by many different factors, it is increasing in time and it has a role in various matters within an economy. But still it is not clear what the magnitude, timing and importance of integration is.

3.3 How financial crises affect international diversification

Research in market crises has an important role in international diversification. It is the time when diversification benefits are needed the most since investors are generally trying to reduce their risk. This goal is challenged if different markets react similarly during times of crises by being exposed to contagion.

[13] Frontier markets are countries which are too small to be included in emerging markets but still more developed than " the least developed countries"

Moreover, contagion has no clear definition in the literature and practitioners measure it in different ways.

Forbes & Rigobon (2002) define contagion as "—significant increase in cross-market linkage—", in terms of correlation. Their research finds no evidence of contagion, measured by unconditional correlation coefficients, during or after any of the three crises; 1987 US market crash, 1994 Mexican crisis or 1997 Asian crisis. According to them, correlation coefficient is conditional on market volatility and the increased correlations during the crisis periods are just consequences of the increases in volatility as shown by their VAR model approach. They argue that heteroskedasticity bias is the reason for differing results from many other researchers. The relationship between volatility and correlation is generally accepted by others as well but the findings on contagion are still mixed.

Bekaert et al. (2005b) on the other hand define contagion as excess correlation, and they use a two-factor model in their research while allowing for asymmetric volatilities with the help of GARCH component thus answering the heteroskedasticity problem raised earlier. In their model, the increase in correlation is dependent on the factor loadings and contagion is measured by the correlation of model residuals. The two factors used are the US equity market return and a regional equity portfolio return. The model uses an asset pricing perspective and volatility is an increasing component of the factor loadings. The part of the changes in correlations explained by their model's betas (factor loadings) provide insights about the market integration over time while the unexplained correlation is defined as contagion. They find no significant evidence on increased contagion as a result of the Mexican crisis but for the Asian crisis in 1997 the residual correlations are economically significant, especially within Asian markets, stating meaningful increase in contagion. They do point out, however, that their model could fail to fully capture the asymmetric volatility of the markets leading to a false interpretation of the market integration and contagion. Nevertheless, these findings on the effects of Asian crisis on contagion are supported by Tai (2007).

The Dot-com bubble and its effects on the contagion in the international stock markets has been studied example by Hon et al. (2007). They construct the test using two different models. The first model being the one proposed by Forbes & Rigobon (2002) and the second model applying the GARCH framework. They demonstrate that the latter qualifies better from the task. By studying the market co-movements pre- and post-crisis they suggest the collapse in many countries stock markets was due to sectoral similarities and that the resulting increase in co-movements is primarily restricted to the technology, media and telecommunication sectors and not to a widespread contagion.

Bekaert et al. (2014) have a similar approach to the two-factor model mentioned earlier but this time a three-factor model is used and, instead, the focus is on

the 2007-2009 financial crisis with a start date on August 7, 2007. They attempt to capture the reasons why and how the crisis spread virtually all over the world. The three factors in question are a US-specific factor, a global financial factor and a domestic factor. The unexpected increases in the factor loadings due to a transmission of shocks are compared with the benchmark factor model which is constructed pre-crisis. The changes during crisis for each factor loading presents the corresponding exposure relative to the underlying factor and to a change in contagion. The return correlations unrelated to the three factors are presented as residual contagion.

Their main findings are somewhat controversial with the current hypothesis about reduced diversification benefits during times of crises due to increase in integration and correlation. The results actually show that highly diversified and global portfolios declined less than what could have been expected from the pre-crisis exposures to the factors. Moreover, the domestic factor was found to be the most significant in explaining an individual portfolio's return during the crisis. This, again, is said to be a result of "wake-up call" which was set in motion by the crisis in the US resulting in huge declines in equity markets all around the world. "The countries with weak economic fundamentals, poor sovereign ratings, and high fiscal and current account deficits experienced more contagion, —, and were overall more severely affected by the Global financial crisis." This is an interesting result as the market's external exposure and linkage was not the main victim for the Global financial market crash, and instead of reducing the international portfolio diversification benefits the crisis, in a sense, raised the demand for it. It should be noted that these results do not mean the integration of the world equity markets is an insignificant component but instead, even while the integration might be unavoidable, it is still possible to diversify one's risks internationally. And while the above results were found true in their research for the period of financial crisis the same was not achieved for the period of the Dot-com bubble meaning the effects integration and volatility changes have in relevance to diversification benefits are not straightforward.

Bartram & Bodnar (2009) take a very different approach in analyzing the Global financial crisis period of 2007-2009 by dividing it into pre-crisis, crisis and post-crisis subsets. They focus on comparing the returns and volatilities within different frameworks such as sector and country performance. Furthermore, they analyze how some commonly used portfolio strategies performed vis-à-vis each other. In their study for correlation the heteroscedasticity problem is not considered and no time-series analysis is constructed but simply each subsets' average is used. To summarize some of their findings: The correlations increased during the crisis period being highest as the crisis peaked but reduced back to around the starting value post-crisis. This is possibly explained by the increase in volatility which has been proved to affect correlation positively. As for the returns, the emerging markets suffered more which is in line with Bekaert et al. (2014) study mentioned earlier. The same reason can

also be applied here even though they did not use the notion "wake-up call". As for the investment strategies compared, the results point out that growth portfolios outperformed both in the US and other developed markets[14].

Overall, times of crises can be considered a special case in the financial markets research field. During these turmoil periods the behavior in the market changes: The volatilities and returns do not follow the typical distributions observed during stable market periods. To answers the changing characteristics in market's behavior researchers have developed new measures to gain more accurate results for example in regard to market integration and correlation. How does a crisis spread across borders? Does a crisis result in a temporary or permanent shift in the market dynamics? One definitely good improvement has been the introduction of GARCH-model to the field since it can tackle the dynamic nature of volatility and its asymmetry at least to some extent. But as shown above each crisis has a unique impact on the market dynamics and more research is needed.

3.4 Review of the DCC-GARCH model

In chapter 2 the basic idea behind the DCC-GARCH model was briefly explained. Here, the model's applicability is shown through reviews to earlier literature. Many studies include stock market indices return data but the research literature has also found various other uses for the model that seem to suit its purpose. Some of these "other uses" were already observed in the seminal paper by Engle (2002).

Engle compared the newly invented DCC models' (IMA, LL INT, LL MR) fit against models from the BEKK family (Scalar&Diag), Moving Average(100), Exponential smoothing (.06) and Orthogonal GARCH (OGARCH) using daily data from 1990 to 2000. The empirical setting was constructed for three different interesting series; the correlation between Dow Jones and NASDAQ, the correlation between domestic stocks and bonds and the correlation between certain currencies. The main findings suggest that the DCC family of models perform superior to other models in almost every case. The measures used to test the accuracy of the models included mean absolute error, diagnostic tests and test based on value-at-risk. As the DCC family of models is parsimonious, these results were encouraging since even large covariance matrixes could possibly be estimated in the future without a model that is too complex to provide sensible results. In support to basic DCC-GARCH model, Sadorsky (2012) found similar results when comparing it against many other models (e.g. CCC-GARCH). He estimated the correlations and spillover effects between clean energy and technology indices with oil futures concluding that the DCC model captured the co-movements best. He stated the findings to be important when considering optimal hedge ratios for portfolio; "1$ long position in clean

[14] Measured using the MSCI EAFE index. Developed markets excluding North-America.

energy companies can be hedged for 20 cents with a short position in the crude oil futures market."

Hsu Ku & Wang (2008) implement five different GARCH models, of which two are univariate and three multivariate, into a Value-at-Risk framework by testing the number of prediction failures each model results in using the exchange rate data for the US Dollar, Japanese Yen, British Pound and Euro. They also compare "--the average deviation between VaR and realized return series." In general, they found the multivariate models to outperform the univariate models. Moreover, the DCC-GARCH model outperformed the others significantly when looking at the number of prediction failures.

Celik (2012) use the exchange rate data for several emerging and developed countries to study the effect the Global financial crisis had on the levels of financial contagion between the markets. He finds evidence that supports contagion effect in most markets while arguing the DCC model to be suitable fit for the data. Syllignakis & Kouretas (2011) investigate the relationships between the stock market returns focusing on correlations between the US, Germany and Central and Eastern European stock markets. They found the conditional correlations to vary significantly from time to time supporting the DCC model approach. This was found true especially for the time of financial distress such as the Global financial crisis. Similar findings are done by Syriopoulos & Roumpis (2009) for the correlations that the Balkan region equity markets have with the US and Germany. All these studies support the use of a model that captures the time-varying correlation between assets and as such the DCC model should not be neglected when working with portfolio risk management.

The DCC-GARCH model has also been of interest in some other very different frameworks. Jones & Olson (2013) concentrate on more macroeconomic matter in their research. They want to shed light into the time-varying correlations of uncertainty-inflation and uncertainty-output relationships. To do this they use monthly data from 1985 to 2012 and the DCC-GARCH model. They found the latter relationship to remain negative for the whole period but the former to change from negative to positive around the year 2000. Malo & Kanto (2006) analyze the Nordic electricity markets spot and future prices. They found that none of the models used succeeded in the task particularly well. Despite the Jones and Olson (2013) study results not being compared with other models and the latter lacking further analysis, the existence of the DCC model in such frameworks is encouraging and shows how the time-varying nature of correlation should not be overlooked. Moreover, even the Nordic electricity markets were deregulated no earlier than 1990s. There still exists many markets and relationships that are waiting to be analyzed thoroughly and the knowledge on the DCC-GARCH model and other multivariate correlation models provide an important perspective when searching for the best results.

4 Methodology

The importance of volatility and correlation in financial activities has been presented in the earlier chapters. In general, the volatility of an asset can be considered as the key measure in assessing the asset's risk level. Similarly, correlation can be interpret as the relationship between assets or asset portfolios. Arguably, in portfolio diversification context it is desirable to own a portfolio of assets which carries a low level of volatility while providing as high a return as possible, thus resulting in a high Sharpe ratio. To capture the conditional volatility of individual return series the Autoregressive Conditional Heteroskedasticity (ARCH) and its Generalized extension (GARCH) models have been widely used in financial analysis and literature. As a side note, in some financial situations outside this researches framework, volatility carries at least equally important role such as the pricing of on option through the Black-Scholes formula.

4.1 ARCH & GARCH

ARCH model was first introduced by Engle (1982). The model's basic idea is that it allows for time-varying conditional variances in time series which is a crucial relief regarding financial time series. Many financial asset returns have been observed to have non-constant variance of the errors while also volatility clustering is widely accepted feature of financial data. This means the variance of errors to be heteroskedastic and that large changes in asset prices tend to be followed by large changes and small changes to be followed by small changes. Testing for ARCH effect simply means testing for heteroskedasticity in the error term. This is done by running a simple regression, saving and squaring the residuals, and regressing the squared residuals on q own lags to test for ARCH of order q, known as ARCH(q). ARCH(1) model could be expressed like equation (2). Equation (1) presents a simple regression with error term constrained to be normally distributed with zero mean and varying conditional variance, h_t.

$$\gamma_t = \beta_1 + \beta_2 x_{2t} + \beta_3 x_{3t} + u_t \qquad u_t \sim N(0, h_t) \qquad (1)$$

$$h_t = \alpha_0 + \alpha_1 u_{t-1}^2 \qquad (2)$$

Univariate GARCH model by Bollerslev (1986) is an extension that generalizes the ARCH model. ARCH model itself contains at least two unwanted features; first, the number of lags of the squared residuals, q, might be very large in order to capture the dependence in the conditional variance. Second, as the number of parameters increases the model becomes harder to interpret and some lags could violate the non-negativity constraint which states that variance at any point in time should be positive. GARCH model overcomes these problems by allowing the conditional variance to depend also on its own lags. This makes the model more parsimonious while at the same time reducing the risk of negative parameters. The model is expressed as GARCH(p,q) where the new

notion, p, stands for the lags of the conditional variance. Generally, in financial literature GARCH(1,1) has been found to be able to capture the heteroscedasticity in data. Desirable property is $\alpha_1 + \beta < 1$ meaning stationarity in variance and convergence towards a long-term average. GARCH(1,1) follows the equation (3) for modeling conditional variance where h_t is the conditional variance of the error term.

$$h_t = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta h_{t-1} \quad (3)$$

Univariate GARCH model, such as equation (3), involves only an analysis of one series. This is not enough to analyze the volatility behavior or co-movement pattern within multiple assets or portfolios. For this purpose, a multivariate GARCH model such as the DCC-GARCH is needed. However, AR-GARCH(1,1) model will be utilized to derive standardized residuals which are critical inputs for the DCC-GARCH model. In our model specification the GARCH mean equations (return equations) will follow an AR(p) process as shown in equation (4)

$$r_t = \mu_0 + \sum_j^p \vartheta_j r_{t-j} + u_t \quad (4)$$

4.2 DCC-GARCH

To capture the time-varying nature of correlations between asset returns this paper uses a bivariate version of the DCC-GARCH model (Engle 2002). It is a generalization of Bollerslev's (1990) constant conditional correlation model (CCC). The DCC model has some attractive features to study financial data as stated by Engle (2002) himself: "—flexibility of univariate GARCH but not the complexity of multivariate GARCH." [15] The model is estimated in two steps: first, univariate GARCH models are calculated to obtain the standardized residuals. Second, these parameters are used to obtain the correlation coefficients. To find optimal values, the model employs the maximization of a log-likelihood function.

Consider a *(Nx1)* vector γ_t which is conditionally multivariate normal

$$u_t | I_{t-1} \sim N(0, H_t) \quad (5)$$

where I_{t-1} is the information set at time t-1 and H_t is a (NxN) covariance matrix. To obtain the parameters in question this covariance matrix needs to be decomposed into a diagonal matrix of time-varying conditional standard deviations from univariate GARCH models, $D_t = diag\{\sqrt{h_t}\}\,(NxN)$, and a

[15] For presentation of multivariate GARCH models and their complexity see (Bauwens, Laurent & Rombouts 2006)

time-varying conditional correlation matrix, $R_t(NxN)$. This multivariate conditional variance is shown in equation (6).

$$H_t = D_t R_t D_t \tag{6}$$

After the standardized residuals are obtained, estimating the correlation matrix becomes the problem to be solved. As the estimation is done with log-likelihood function the correlation part of the maximization problem becomes

$$l_{corr}(\emptyset) = -\frac{1}{2}\sum_t (log\,|R_t| + \varepsilon_t R_t^{-1}\varepsilon_t' - \varepsilon_t'\varepsilon_t) \tag{7}$$

where $\varepsilon_t = \frac{u_t}{\sqrt{h_t}}$ and $\emptyset$ denotes the parameters in R_t. To ensure R_t, the time-varying conditional correlation matrix, is positive definite with ones on the diagonal and off-diagonal elements less than one in absolute value, it needs to be decomposed by the equation (8)

$$R_t = \big(diag(Q_t)\big)^{-1/2} Q_t \big(diag(Q_t)\big)^{-1/2} \tag{8}$$

Under the DCC framework the time-varying (NxN) covariance matrix, Q_t, of u_t is specified as

$$Q_t = (1-\alpha-\beta)\bar{Q} + \alpha\varepsilon_{t-1}\varepsilon_{t-1}' + \beta Q_{t-1} \tag{9}$$

where $\bar{Q} = E[u_t u_t']$ is the (NxN) unconditional covariance matrix of u_t. The parameters α and β capture the effects of previous shocks and previous dynamic conditional correlations on current dynamic conditional correlations. Furthermore, these parameters need to be non-negative and satisfy similar condition as in GARCH model such that $\alpha + \beta < 1$. Here, the restriction implies that the correlation between underlying assets converges back to a long-run average after a shock, such as new information regarding the returns. The parameters α and β contain the velocity of this adjustment. In case $\alpha + \beta = 0$, the model reduces to constant conditional correlation model.

$$l_t(\theta, \emptyset) = \left[-\frac{1}{2}\sum_t (nlog(2\pi) + log|D_t|^2 + u_t' D_t^{-2} u_t)\right] + \left[-\frac{1}{2}\sum_t (log\,|R_t| + \varepsilon_t R_t^{-1}\varepsilon_t' - \varepsilon_t'\varepsilon_t)\right] \tag{10}$$

The final estimation is done using two-stage approach to maximize the log-likelihood function as expressed in equation (10). The first part corresponds to maximizing the volatility term θ over parameters in D_t. The second stage takes this value as given and maximizes the correlation coefficients in $\emptyset$ over parameters in R_t.

4.3 Portfolio optimization

To measure the portfolio diversification benefits of an investor this study uses the Sharpe ratio. In chapter 2 the theory behind the Sharpe ratio and the Modern Portfolio Theory was presented. To recall, when no risk-free rate is available the efficient frontier is the subject of interest but when the risk-free rate is available the portfolio optimization problem becomes such that investor seeks to find the tangency portfolio. The tangency portfolio and a risk-free rate are the two points that are needed to create the Capital Allocation Line (CAL) from which the investor can then choose a fitting risk-return tradeoff. This leads our constrained maximization problem, in simplicity, to be equal to Sharpe ratio: [16]

$$S = \frac{R_a - r_b}{\partial_a}$$

which in case of a portfolio with N assets becomes

$$\frac{\sum_{i=1}^{N} Wi(\bar{R}_\iota - R_b)}{[\sum_{i=1}^{N} W_i^2\, \sigma_i^2 + \sum_{i=1}^{N}\sum_{j\neq 1}^{N} W_i W_j \sigma_{ij}]\text{^}(\frac{1}{2})}$$

subject to,

$$\sum_{i=1}^{N} W_i = 1$$

$$X_i \geq 0 \; for \; all \; i$$

where $\sum_{i=1}^{N} Wi(\bar{R}_\iota - R_b)$ is the expected total return of the portfolio excess of the risk-free market return with given weight, Wi, in each asset in the portfolio and $[\sum_{i=1}^{N} W_i^2\, \sigma_i^2 + \sum_{i=1}^{N}\sum_{j\neq 1}^{N} W_i W_j \sigma_{ij}]\text{^}(1/2)$ is the portfolio variance with the same weights. The first restriction states that the combined weight of the assets in the portfolio must equal one. The second says that no negative values are allowed for any individual asset meaning no short-selling is allowed. Usually $\bar{R}_\iota > R_b$ meaning that the ratio has a positive sign.

[16] Elton, E. J. 2003. Modern portfolio theory and investment analysis. (6th ed. painos) New York: Wiley. p. 100-106

5 Data

The programs used in this empirical research were Rats and Excel. Rats was the program used for the DCC-GARCH section and Excel worked as a main software when constructing the efficient frontier and calculating the Sharpe ratios. All the data were obtained from Datastream. The indices used were the monthly MSCI Total return indices for each country in US dollar and Indonesian Rupiah currencies. For the DCC-GARCH part the data were transformed into first logarithmic difference for each series as shown by equation (11). However, as the mean-variance framework in the original paper by Markowitz (1952) assumed arithmetic and normally distributed returns the first logarithmic differences are not used in the second part of the research. In that part I used arithmetic returns instead (12).[17]

$$y_t = 100 * \log(\frac{y_t}{y_{t-1}}) \quad (11)$$

$$y_t = 100 * (\frac{y_t - y_{t-1}}{y_{t-1}}) \quad (12)$$

The time period goes from January 1988 to December 2015 which was the maximum availability for data in full years for the chosen total return indices. The data includes 337 observations for each country leading to 336 values for each return series. The monthly stock index descriptive statistics for the log-returns are computed in US Dollar terms for the indices in table 2.

	N	Min	Max	Mean	Std. Dev.	Skewness	Ex. kurtosis	Jarque-Bera
US	336	-18.533	14.676	0.823	4.485	-0.805	2.160	101.611
Indonesia	336	-53.359	66.600	0.781	12.926	0.167	5.384	407.439
Malaysia	336	-37.023	40.222	0.573	8.004	-0.201	4.579	295.771
Thailand	336	-41.558	36.588	0.569	10.643	-0.435	2.272	82.839
Philippines	336	-33.783	36.419	0.654	8.597	-0.103	1.884	50.272

Table 2: Descriptive statistics for logarithmic returns ($US). The table summarizes the minimum, maximum, mean, standard deviation, skewness, excess kurtosis and Jarque-Bera normality test.

The table indicates how stable the US has been compared to the emerging markets. Both min and max as well as standard deviation has been smallest for the US during the period. This is also what was expected to be found when comparing emerging markets to a highly developed country with strong financial institutions. Surprisingly the US has had the highest return despite being least volatile, or least risky. This is not something the financial theory supports. The Jarque-Bera test clearly shows that the return series' do not follow a normal distribution which is also visible in the skewness and excess kurtosis columns. Interestingly Indonesian returns show positive skewness

[17] The question of "to log or not to log" is not studied in this paper and we go with the original theory. Similarly, one could argue the whole MPT to be worse approach than other options such as VaR.

indicating that the distribution of returns is more skewed to the right. Loosely analyzing, this could mean the Indonesian return index possess a low correlation with other indices providing 'excess' international portfolio diversification benefits.

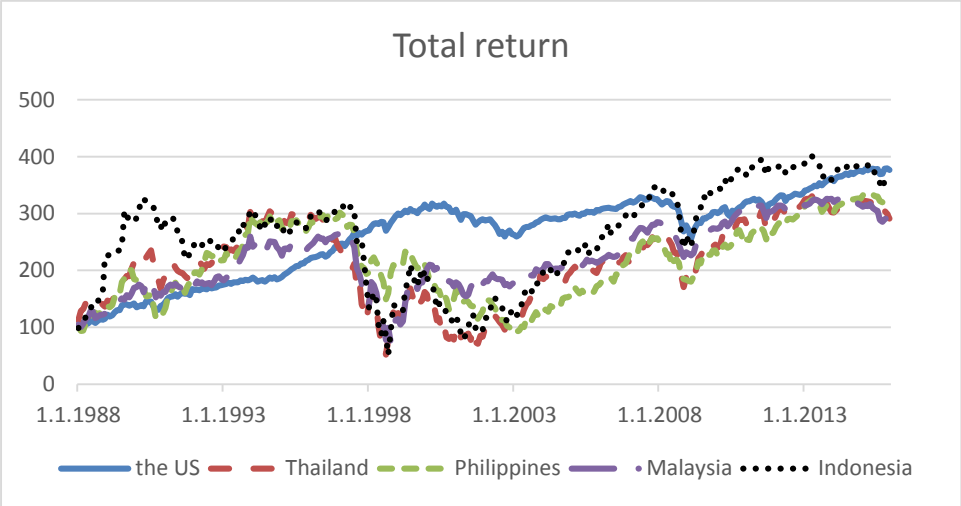


Figure 3: Logarithmic total index returns ($US).

The total return for each series is visible in figure 2. The graph illustrates the different prevailing trends in the market returns for each country. It is evident that the Asian crisis around 1997 shook all the other markets quite harshly but the US which continued its economic boom until the Dot-com bubble. Thailand, Indonesian and Malaysian markets dropped in 1998 to even lower than the initial level in 1988. It is also obvious that the Global financial crisis was indeed felt in all the financial markets for the countries in question. Moreover, the Malaysian return index seems to be less volatile than the other emerging market indices just like the descriptive statistics table show when measured with standard deviation (8.004). The graph fails to show any clear permanent increase in markets unconditional correlations.

Also, the expected returns of the indices become important when calculating the Sharpe ratios and optimal portfolios. To answer the market expectations and risk premiums, the data for 3-month US Treasury bill is used as a standard risk-free rate when calculating from the US investor´s perspective. For the Indonesian investor a 4% premium is added to it to catch the profile of a riskier market.[18]

Preliminary tests

In order to use the time series data at hand for the DCC-GARCH estimation some basic requirements should first be checked. To justify the use of AR-GARCH(1,1) model each individual data series should be stationary, and

[18] No local risk-free rate available for the whole period. This leads to small bias in my analysis as the risk-free rate affects tangency portfolio and Sharpe ratio. Still, the effect is rather small.

ARCH effect as well as volatility clustering should be present. Also, the AR(p) equation must be such that it captures the movement in the underlying.

First, the stationarity was tested using the Augmented Dickey-Fuller test to check the individual series for unit roots. The null hypothesis is stated such that a unit root is present whereas the alternative hypothesis is stated as no unit root meaning stationary series. As evident from table 3, all the countries return series' test values were significant at 1% critical level indicating stationarity in the series. To support the ADF test results, a KPSS test for stationarity was also estimated. All the return series failed to reject the null hypothesis of stationarity thus further supporting the stationarity in all the series. The stationarity of a series is required to enable one to make reliable inferences from the data.

Augmented Dickey-Fuller unit root test				KPSS stationarity test		
H0 = Unit root	Test value	1 %		H0 = Stationary	Test value	1 %
US	-18.06	-3.44		US	0.212	0.739
Indonesia	-13.01	-3.44		Indonesia	0.109	0.739
Malaysia	-10.09	-3.44		Malaysia	0.079	0.739
Thailand	-17.51	-3.44		Thailand	0.116	0.739
Philippines	-15.06	-3.44		Philippines	0.135	0.739

Table 3: ADF and KPSS tests ($US). The table summarizes the Augmented Dickey-Fuller test values and KPSS stationarity test values for each return series. The 1% presents the value for when the null hypothesis is rejected at 1% significance level. H0 was rejected for all in ADF test and for none in KPSS.

To test for ARCH effect in the returns the Engle (1982) ARCH-LM test was estimated. It showed clear evidence of ARCH in data for all the series meaning the null hypothesis of constant variance and no serial correlation was rejected for every country. The result can also be accepted by eyeballing each return series graphically as it shows evidence of volatility clustering. From the figure 3 it is evident that large changes tend to be followed by large changes even with monthly data.[19]

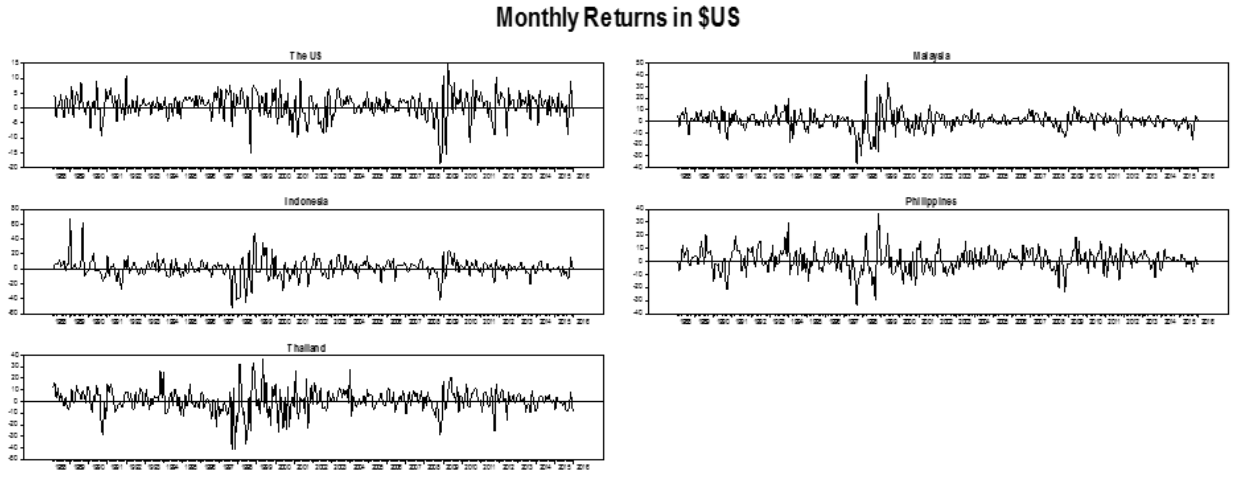


Figure 4: Monthly logarithmic returns ($US). Big swings indicate higher volatility.

[19] Frequency has an important role. Generally, the higher the frequency more clustered the volatility.

All the univariate AR(p)-GARCH(1,1) models, with p indicating the lag length, were chosen based on the same criteria. Each series was estimated with mean plus 0 to 12 lags (no discrete) and the resulting standardized residuals were tested. First, the Ljung-Box Q test was done to confirm the null hypothesis of no serial correlation in residuals. If the null could not be rejected the model was chosen into further examination by testing the Akaike information criterion (AIC). The model with the smallest AIC test value for each return series was chosen to be used in the DCC part. All the chosen models also passed ARCH-LM and LB squared (McLeod-Li) tests which were done as robustness tests.

Univariate	AR(p)	LB(12)
US	Mean	8.4
Indonesia	Mean+r{1}	13.66
Malaysia	Mean+r{1}	11.39
Thailand	Mean	15.36
Philippines	Mean+r{1}	17.23

Table 4: Univariate mean equation and Ljung-Box Q statistic ($US). AR(p) presents the chosen mean equation for each univariate return series to be used in the DCC framework. LB(12) shows the Q statistic for the chosen univariate model standardized residuals with lags=12 and span=1. All the LB(12) test values are insignificant supporting the null hypothesis of no ARCH effect in the standardized residuals.

The tables and figures corresponding to the data from Indonesian investor´s perspective can be found in Appendix 1. The main empirical interest lays in the chapter to come which is where the Indonesian perspective is also analyzed with more depth. It must be noted that none of the univariate AR(p)-GARCH(1,1) models succeeded to take into account the serial correlation in the Indonesian return series if put under same requirements as before. All the models, lags 0 to 12, failed the robustness tests. However, the chosen model did pass the Ljung-Box Q test and as it became evident from the autocorrelation function the lag 8 seemed to be the problem. This was considered to be ok as the earlier lags behaved well and the standardized residuals of the AR-GARCH(1,1) model seemed to support the existence of outliners in the data, also visible in figure 4.

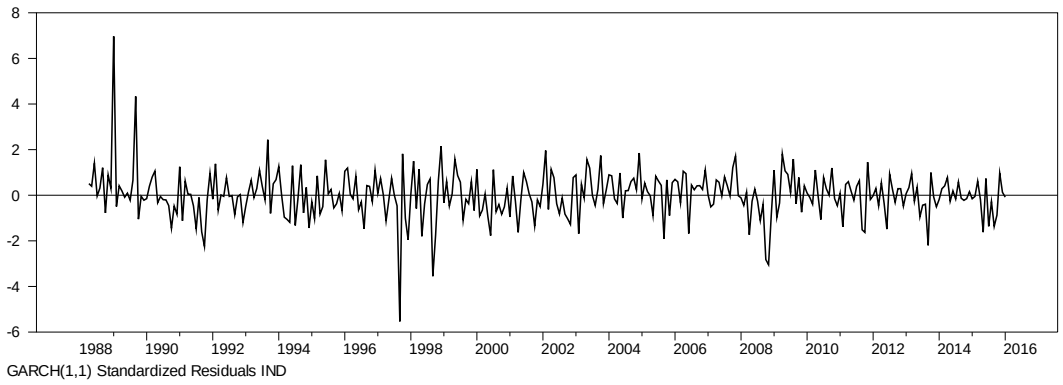


Figure 5: Standardized residuals (RpIDN). The figure shows the standardized residuals for the chosen AR-GARCH specification for the Indonesian return series in Indonesian Rupiah. Clear outliners which most likely result in the Q^2 and ARCH-LM tests to show problematic significance levels (lag 8).

6 Empirical Results

This research studies the dynamic conditional correlations and potential international diversification benefits among the following countries: the US, Philippines, Indonesia, Malaysia and Thailand. This is done using DCC-GARCH (Engle 2002) model and Markowitz's portfolio optimization. In contrast to many studies focusing only on the US perspective, the analysis here shows how the benefits vary between the US and the Indonesian investor. The question of whether the Indonesian investor exhibit decreasing international diversification benefits is interesting and important. Even if some country's investors, e.g. the US, gain no international diversification benefits it should not be generalized to mean that the benefits have disappeared altogether. Moreover, the four chosen Southeast Asian emerging markets were chosen to provide a framework for research that aim to find out if regional diversification alone would have been good for the Indonesian investor. This brings light on whether or no "regional" home bias eliminates international diversification benefits. Main focus of this empirical analysis is on analyzing the times of crises in relation to diversification benefits and time-varying conditional correlations.

6.1 DCC-GARCH

6.1.1 The US

In this section I present the DCC-GARC results from the US perspective. I find other than the US-Philippines pair to have dynamic conditional correlation. I also find the correlations to increase right after the Global financial crisis. However, I do not find strong support for increase in correlations in the long-run and thus the results support portfolio diversification benefits.

The table 5 and figure 5 present the results obtained from the bivariate DCC-GARCH estimates for the four stock indices with the US. The figure shows pairwise trends in time-varying conditional correlations and the table sums up some of the descriptive statistics of the correlation dynamics. Alpha and Beta of the DCC model capture the effects of previous shocks (lagged standardized shocks) and dynamic conditional correlations on current dynamic conditional correlations. Under the null hypothesis of constant market correlations, the significance of these coefficients indicates the presence of time-varying (dynamic) market correlation.

The pairwise estimated coefficients for the US show that Indonesia, Malaysia and Thailand have highly significant Alpha and Beta revealing a substantial time-varying correlation. Moreover, the conditional correlations seem to be highly persistent yet mean reverting with the sum of the two coefficients being over 0.90 but below 1.00. The US-Philippines pair deviates from the rest by not having statistically significant alpha or beta coefficients. Thus, their correlation can be said to exhibit constant conditional correlation. The table also reports

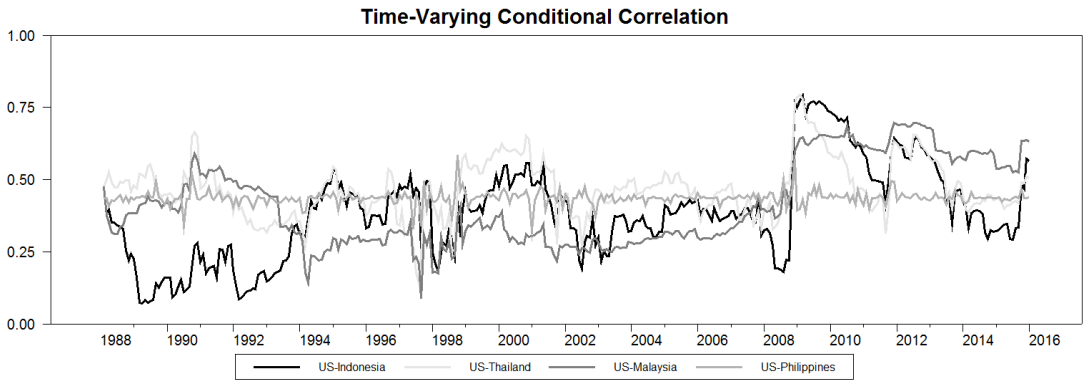
the minimum, maximum, mean dynamic conditional correlation and unconditional correlation for each pair.

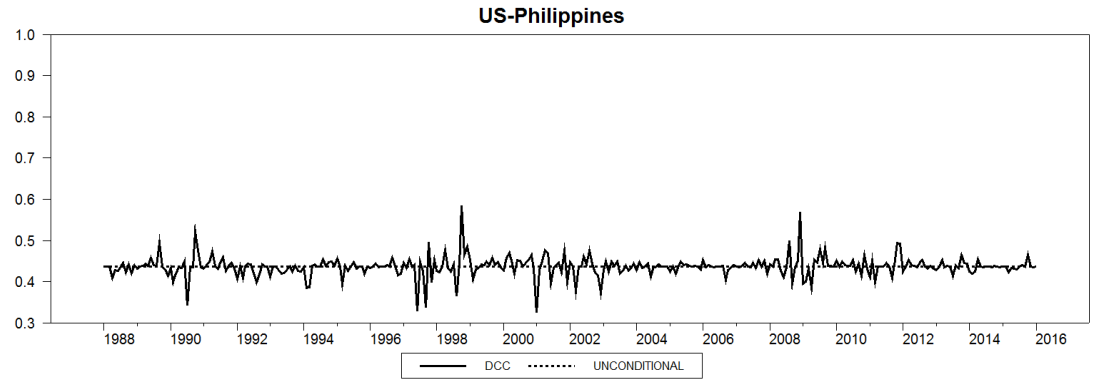
	α	β	$\alpha + \beta$	Min	Max	Mean DCC	UC
Indonesia	0.0675***	0.9074***	0.9749	0.0712	0.7903	0.3861	0.3841
	(0.0017)	(0.0000)					
Malaysia	0.0344***	0.9614***	0.9958	0.0867	0.6976	0.4115	0.3771
	(0.0000)	(0.0000)					
Thailand	0.0687**	0.8362***	0.9049	0.141	0.7927	0.4684	0.4756
	(0.0211)	(0.0000)					
Philippines	0.0283	0.0000	0.0283	0.3241	0.5845	0.4366	0.4363
	(0.6152)	(1.0000)					

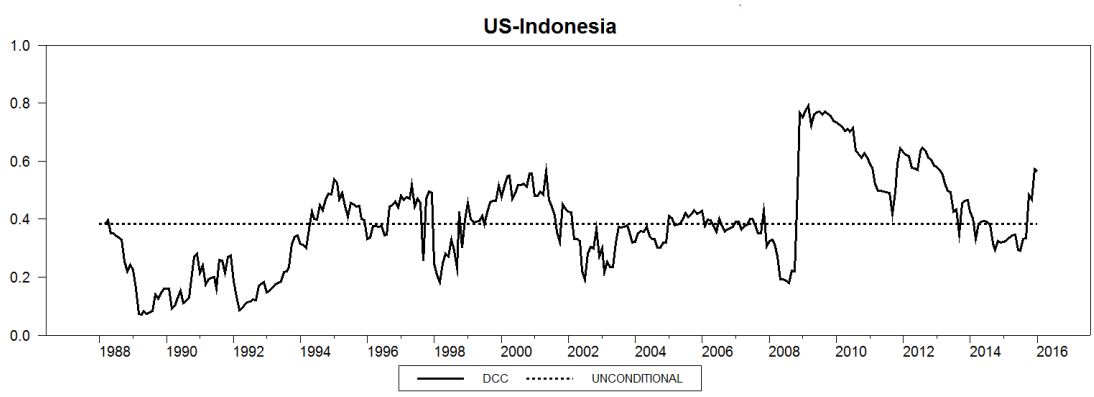
Table 5: Parameter estimates for the bivariate DCC models with the US ($US). α and β are the DCC parameters that capture the effects of previous shocks (lagged standardized shocks) and dynamic conditional correlations on current dynamic conditional correlations. Min is the minimum and max is the maximum correlation during the period. Mean DCC is the average correlation obtained with the estimation and UC is the unconditional correlation between the market returns.

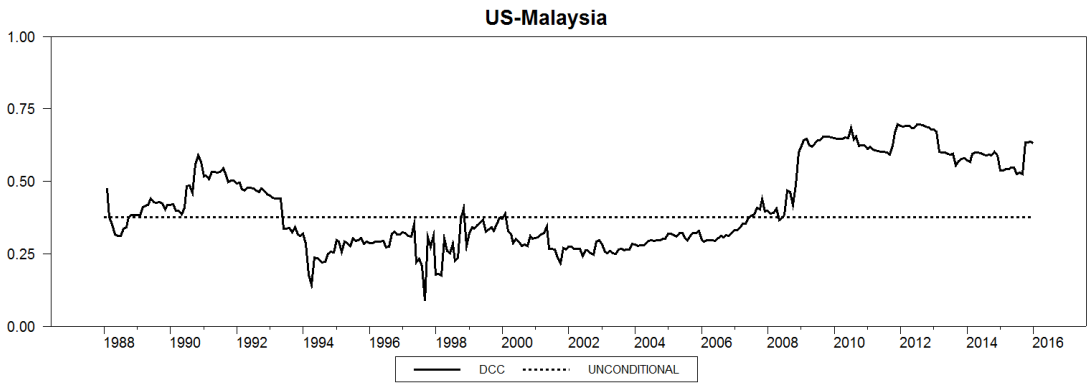
The results reveal both encouraging and disappointing information when interpreting them from the portfolio diversification aspect. First, the conditional correlations seem to be unique for each pair despite some clear similarities. This was to be expected since no country indices behave equally. The correlations (DCC and UC) are also rather low, with highest being 0.4756 which is the unconditional correlation between the US-Thailand pair. The bivariate conditional correlations for the US-Thailand and the US-Philippines pairs fail to show clear increase in the trend. The US-Indonesia and the US-Malaysia exhibit uptrend in the series mainly due to the contribution of the Global financial crisis.

In general, the results indicate high diversification benefits for the US investor relative to these countries meaning the US investor should indeed consider financial markets in excess of the domestic one. However, there is some clear evidence of increased correlation in certain periods. Especially the Global financial crisis seems to have increased the conditional correlations by a great amount with e.g. the US-Indonesia pair correlation moving from around 0.2 to 0.8 almost immediately after the start of the crisis. This excess correlation could be interpreted as an effect of contagion on the equity markets and for the investor seeking to reduce portfolio risk this is a highly negative and unwanted event. Overall, the DCC-GARCH results from the US investor's perspective seem to support the hypothesis of increased contagion during market crisis but fail to show strong evidence of increased co-movement over time.


Time-Varying Conditional Correlation
1.00
0.75
0.50
0.25
0.00
1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016
US-Indonesia
US-Thailand
US-Malaysia
US-Philippines


US-Philippines
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016
DCC
UNCONDITIONAL


US-Indonesia
1.0
0.8
0.6
0.4
0.2
0.0
1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016
DCC
UNCONDITIONAL


US-Malaysia
1.00
0.75
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0.00
1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016
DCC
UNCONDITIONAL

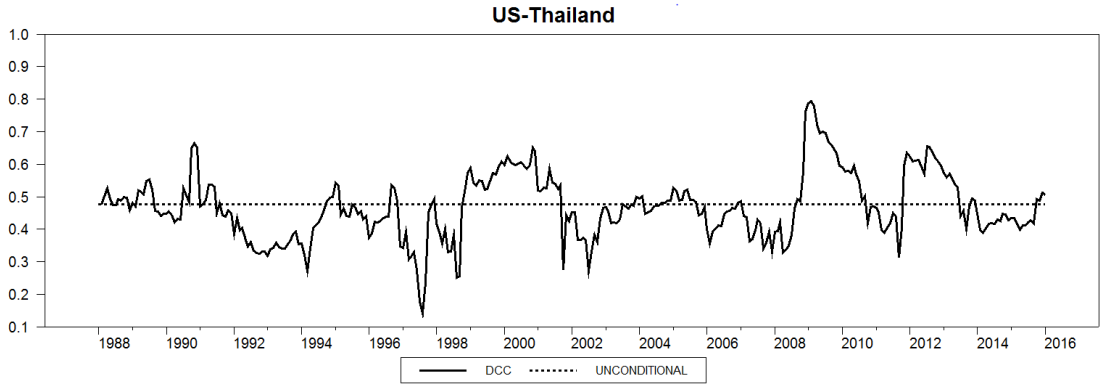


Figure 5: Time-Varying Conditional Correlations ($US). The graphs present the time-varying conditional correlations obtained from the bivariate DCC setting. The "all-in-one" graph shows the changes relative to each other on a same scale and the pairwise graphs display the changes in each pair correlation plus the unconditional correlation for the corresponding pair. Colored "all-in-one" graph in appendix 3.

6.1.2 Indonesia

In this section I present the DCC-GARCH results from Indonesian perspective. I find the conditional as well as unconditional pairwise correlations to be extremely low. The DCC model parameters are in general significant. The results support portfolio diversification benefits.

The table 6 and figure 6 present the bivariate DCC-GARCH results from the Indonesian investor's perspective. The DCC model for the Indonesia-US pair failed to find convergence with any reasonable amount of iterations so for that pair a BEKK model was used instead. As a result of this, the Alpha and Beta values were not obtained and as such those two cells are shown blank in table 6. However, the resulting time-varying correlation graph is used in figure 6 with identical interpretation to if it was a DCC-GARCH constructed graph.

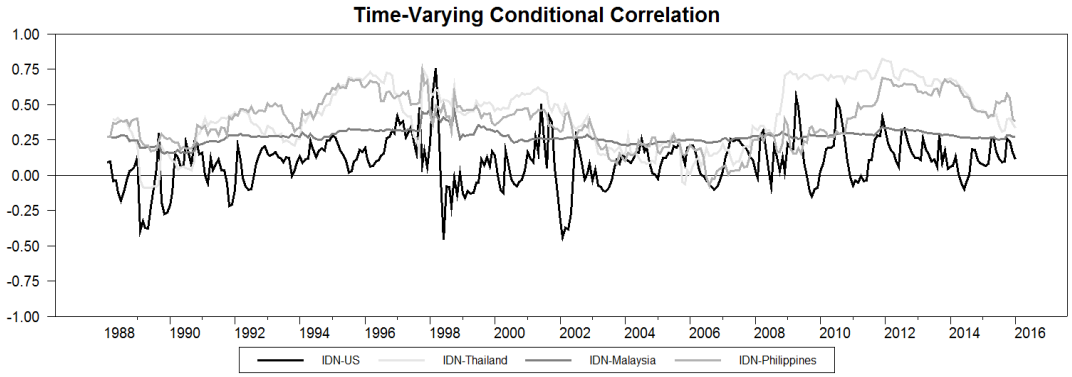
The pairwise estimated coefficients for Indonesia show that Philippines and Thailand have highly significant Alpha and Beta whereas Malaysia has highly significant Beta but not Alpha (p-value 0.3179). Overall the results reveal a substantial time-varying correlation between the market returns. Similar to the results from the US investor's perspective, the conditional correlations seem to be highly persistent yet mean reverting with the sum of the two coefficients being over 0.90 but below 1.00.

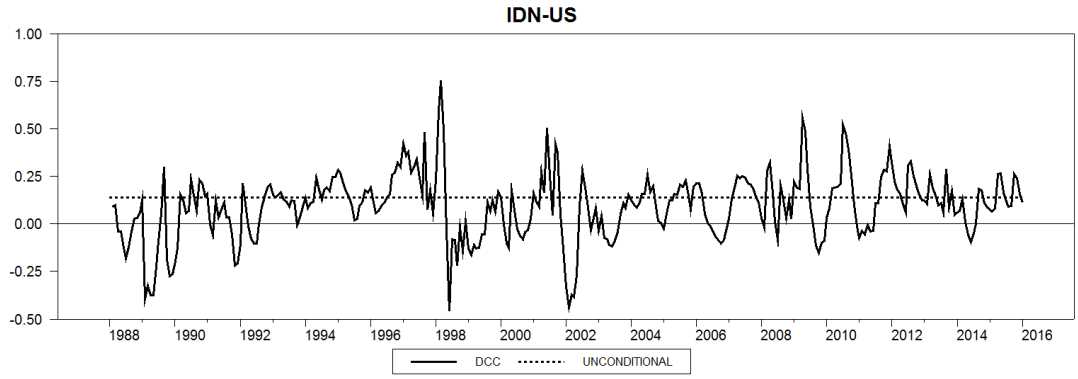
	α	β	$\alpha + \beta$	Min	Max	Mean DCC	UC
US				-0.5419	0.7640	0.0981	0.1394
Malaysia	0.0181	0.9428***	0.9609	0.1527	0.4714	0.2739	0.2728
	(0.3179)	(0.0000)					
Thailand	0.0775***	0.9193***	0.9968	-0.0902	0.8239	0.4242	0.3939
	(0.0009)	(0.0000)					
Philippines	0.0728**	0.9205***	0.9933	-0.0744	0.7384	0.38385	0.3688
	(0.0122)	(0.0000)					

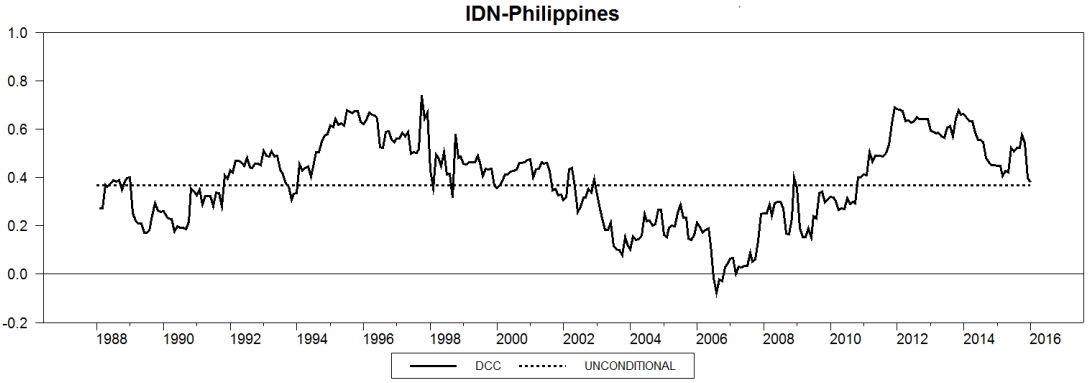
Table 6: Parameter estimates for the bivariate DCC models with Indonesia ($Rp). α and β are the DCC parameters that capture the effects of previous shocks (lagged standardized shocks) and dynamic conditional correlations on current dynamic conditional correlations. Min is the minimum and max is the maximum correlation during the period. Mean DCC is the average correlation obtained with the estimation and UC is the unconditional correlation between the market returns.

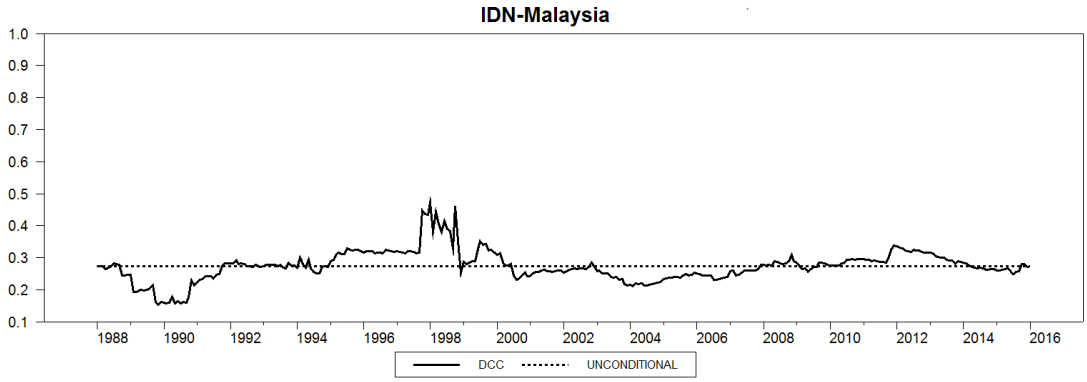
The time-varying correlation graphs in figure 6 together with the data from table 6 reveal important information. The overall bivariate correlations are lower from Indonesian, measured by both Mean DCC and UC, than those from the US point of view. This is despite Indonesia being geographically as well as politically and structurally much closer related to the other countries in question. From the table 6, the highest overall correlation for Indonesia is found with Thailand which is only 0.4242 (mean DCC). This result is surprising since one could have expected the financial markets in these countries to act more similar to each other. Actually, Indonesia-Malaysia pair does not even go above 0.50 at any point in time and all the other pairs have also even negative values at times. Highest single correlation value is reached in 2012 at 0.8239 which is between Indonesia and Thailand but come year 2015 and this pairwise correlation has decreased to under 0.60 again.

The low level of co-movement between the countries greatly supports the international diversification benefits for an Indonesian investor. As it seems, even regional diversification alone would be highly economical. The general hypothesis of increased market correlation and integration over time is not supported as none of the pairwise correlations reveal significant uptrend. There are times, such as the Asian crisis in 1997, when the correlation clearly rises but the rise seems to be only temporary.


Time-Varying Conditional Correlation
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016
IDN-US
IDN-Thailand
IDN-Malaysia
IDN-Philippines


IDN-US
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016
DCC
UNCONDITIONAL


IDN-Philippines
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016
DCC
UNCONDITIONAL


IDN-Malaysia
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016
DCC
UNCONDITIONAL

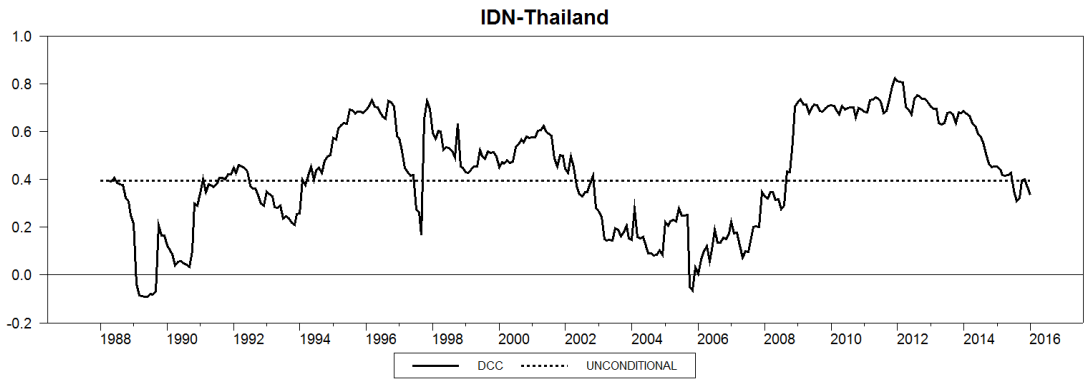


Figure 6: Time-Varying Conditional Correlations ($Rp). The graphs present the time-varying conditional correlations obtained from the bivariate DCC setting. The "all-in-one" graph shows the changes relative to each other on a same scale and the pairwise graphs display the changes in each pair correlation. Colored "all-in-one" graph in appendix 3.

Overall, the DCC-GARCH results are in favor of investors seeking international portfolio diversification as well as regional portfolio diversification. The co-movement dynamics are not such that the benefits of diversification disappear. The levels of correlations vary greatly from time to time but are not found to have increased significantly within the researched countries neither from the US nor Indonesian perspectives. The different crises affect the correlations in different ways as was to be expected; the Asian crisis increased the correlation between the Asian countries for the time being, the Dot-com bubble was close to being insignificant and the Global financial crisis had an impact on all countries in question but mostly from the US investor's perspective. The changes in correlations are not found to be persistent.

From the US investor's perspective, the results are similar to those of i.e. Bartram & Bodran (2009) who studied the time of Global financial crisis and found the correlations to be highest during the peak of the crisis but reduce back to normal afterwards. Their research did not take into account the volatility effect on correlation but as this research did the volatility could not have been the sole reason for the increase in correlations. From Indonesian perspective the results do not have a direct comparison to earlier research but generally they are in line with i.e. Bekaert et al. (2011) and Bekaert & Harvey (2000, 2003) who found the emerging markets to be only partially integrated meaning lower correlation. However, the obtained correlation values found here for Indonesian investor are even much lower than anticipated and no clear evidence of increase in co-movements in the long-run were found. How much of the dynamicity of the correlations is attributable to changes in the levels of integrations between the countries' financial markets was not studied here.

6.2 Portfolio optimization

Earlier literature suggests that international portfolio diversification benefits have reduced as financial markets have become more integrated. I did not find support for this hypothesis when looking at time-varying correlation with DCC-GARCH model as no significant uptrend was detected for the stock market indices co-movements. However, when considering diversification benefits investor should also be interested in asset's returns in excess of its risk reduction properties. This inspection can be done using Markowitz's portfolio optimization and efficient frontier framework. Furthermore, the data from 1988 to 2015 is split into three subsets to provide meaningful answers to the three research questions brought to light in section 1.1 of this paper.

The first subset goes from January 1988 to end of 1998.[20] This leads the returns on other than the US financial market to have been negatively impacted by the Asian crisis making them almost certainly unattractive targets for the US investor. However, this lets our Indonesian investor to gain important information whether regional diversification helps during a market meltdown. The Asian crisis can also be seen as a structural breakpoint for the Asian equity markets thus making the study of diversification benefits after it of a great interest. The second subset goes from January 1999 to end of 2009 containing the Dot-com bubble and the Global financial crisis and the third subset includes the rest of the data. This helps us to study how the diversification benefits have changed, if at all, after the Global financial crisis.

6.2.1 The US

In this section I present the findings from the US investor's point of view. I find the diversification benefits to vary greatly from time to time. The correlation dynamics found and analyzed earlier could be one reason for this, especially when looking at minimum-variance portfolio, but it seems like the return characteristics of each equity market provide more important factor when considering the tangency portfolio.

Figure 7 illustrates the arithmetic risk-return characteristic of each equity market used in this study measured in $US. It can be seen that the return/volatility characteristics are not same as when looking at logarithmic returns as was done earlier. Most importantly, despite the US still having the lowest risk they do not have the highest overall return. Instead, the returns of Malaysia, Philippines and Indonesia are all greater than the US.

[20] The end date of the Asian crisis is controversial. Different dates have been used in literature.

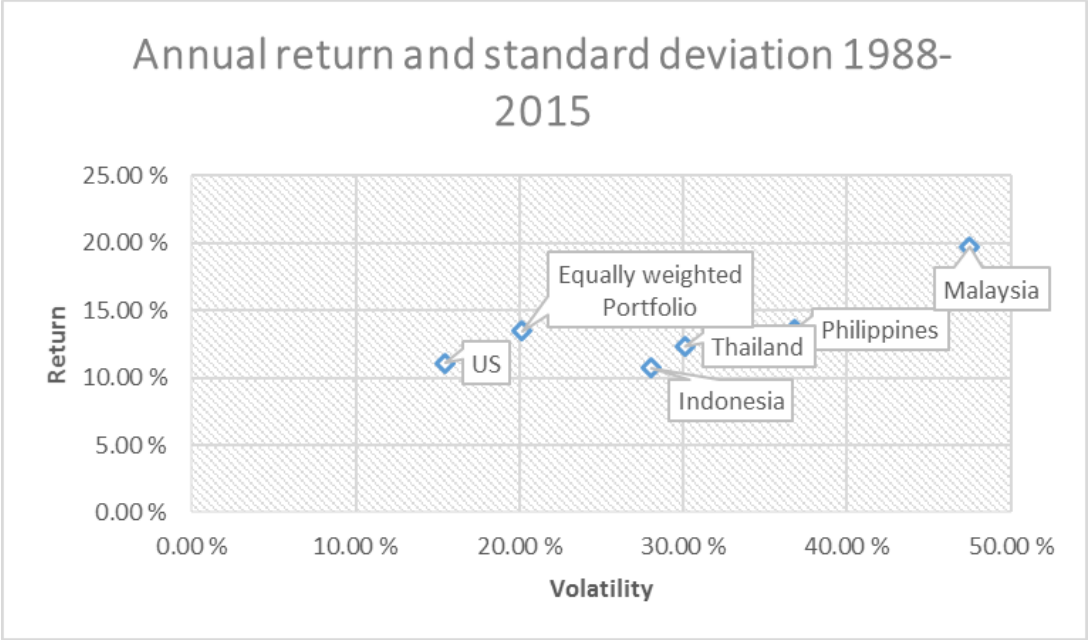


Figure 7: Average arithmetic risk-return of each country index from 1988 to 2015 ($US).

For the first subset the efficient frontier framework shows results that were much expected. In figure 8 (1988-1998), the efficient frontier is not really even an efficient frontier as the upper part of the curve does not exist. 100% allocation in the US equity market provides the only efficient solution resulting in a Sharpe ratio of 1.02. Looking back to the study by Baig & Goldfajn (1998) it happens that the countries mostly affected by the Asian crisis were the ones used in this study: The crisis resulted in low returns and high volatilities for the Southeast Asian equity market indices making them unattractive for the US investor who did not feel the impact of the crisis in his domestic market. The low correlations amongst the countries did not help the diversification as the returns of the Southeast Asian equity markets were too low.

The second subset studied includes both the Dot-com bubble and the Global financial crisis. It also tells a whole different story than the first subset as seen in figure 8 (1999-2009). The US market performed terribly gaining even less than the risk-free rate of 3.63% per annum while having a standard deviation of 17.41%. All the four Asian equity markets outperformed the US by a significant margin in terms of return but they also carried higher risks. The capital allocation line consists of a risk-free rate, Indonesian and Malaysian stock indices with the tangency portfolio having a Sharpe ratio of 0.64 while 100% in the US index had -0.08. The US investor should have only had money invested in domestic market had he wanted to lower his risk with the expense of return resulting in a lower Sharpe ratio (point on the efficient frontier to the left of the tangency portfolio). Similar to the first subset, in the DCC-GARCH part, this period was found to have rather low correlations. This, helped by the return characteristics of the period, resulted in the US investor benefitting greatly from diversifying his portfolio to the chosen Asian equity markets. This is despite the crises having effect on all the chosen equity markets as mentioned

in section 2.2 of this paper. Thus, it is clear the disappearance of diversification benefits was not supported this time.

The third subset provides results landing somewhere between the results of the first two. The tangency portfolio has a Sharpe ratio of 0.95 while the US portfolio has 0.88. This means the diversification could have been only slightly beneficial but probably not at all after taking transaction costs into calculation. Moreover, it was only beneficial to include the Thailand equity market in the portfolio as the other Asian indices performed badly meaning a diversification would have most likely resulted in a lower Sharpe ratio than offered by the US portfolio. During this time the correlations were found to be highest which could be one of the reasons for low diversification benefits.

		The US only			Global	
	Return	St.Dev	Sharpe ratio	Return	St.Dev	Sharpe Ratio
Period 1 (1988-1998)	18.79 %	13.02 %	1.02	18.79 %	13.02 %	1.02
Period 2 (1999-2009)	2.20 %	17.41 %	-0.08	21.70 %	28.35 %	0.64
Period 3 (2010-2015)	13.39 %	14.78 %	0.88	14.27 %	14.75 %	0.95

Table 7: The US portfolio vs. the tangency portfolio ($US).

Table 7 compares the US portfolio with the Global portfolio that would have been possible to achieve.[21] To sum up, in timely order, it would have been non-beneficial, highly beneficial and possibly slightly beneficial for the US investor to diversify portfolio to the Southeast Asian equity markets in terms of Sharpe ratio given these subsets. Risk-reduction opportunities were available during subset 2 and 3. Moreover, the figure 8 shows clearly how the risk-return characteristics of the chosen equity market indices vary from time to time highlighting the fact that the change in time-varying correlation is not the sole characteristic to be considered when making portfolio diversification decisions. Also, it is clear the times of crises increase market volatility as earlier research suggests.

[21] Includes only the chosen Southeast Asian equity markets used in this study.

When looking at the whole subsets, however, the increased correlation and possible contagion effect are not enough to make the different equity indices "look similar" in the risk-reward framework and overall the weights put on each asset in a portfolio will have a great impact on the portfolio performance. The latest subset does not encourage much diversification for the US investors as a portfolio with 100% in the US index lies so close to the tangency portfolio. However, the overall findings from DDC-GARCH and portfolio optimization framework suggests the reason to be more in the bad performance of the Southeast Asian equity markets in the short- to medium-run and not so much in the correlation dynamics.

For the whole time-period, in figure 7, the equally weighted portfolio provides higher return than the US index supporting diversification in the long-run. Also, when looking at the second subset, which is when the US investor faced most severe times, international diversification would have most likely resulted in highly significant positive results. Despite possible diversification benefits, the risk-reduction hypothesis does not look so good. In general, the US domestic market was found to provide the investor with almost minimum-variance portfolio. This finding is in line with the results found between the US and Latin American equity markets presented by Meric et al. (2001).

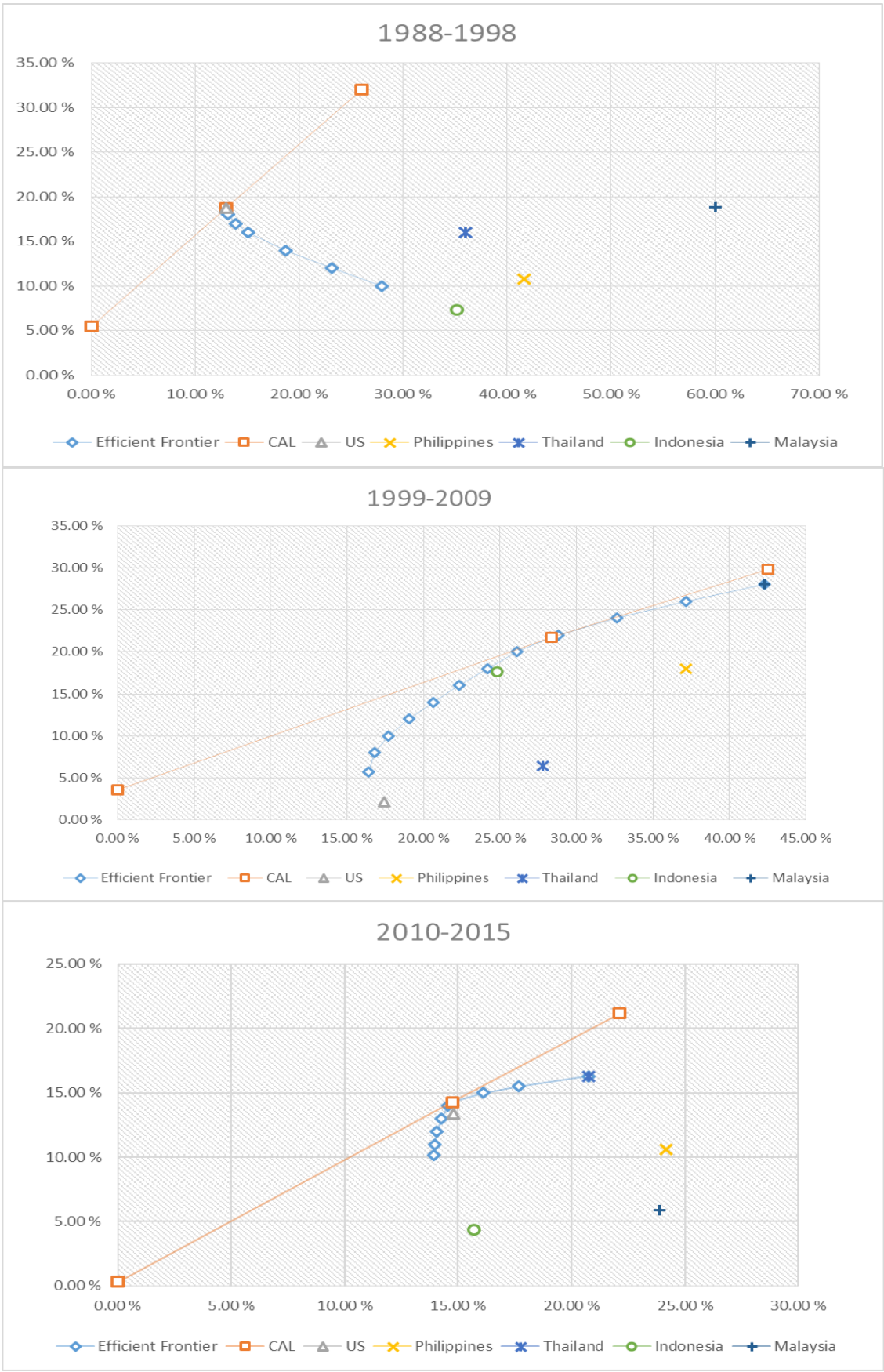


Figure 8: The efficient frontier framework ($US). CAL presents the best possible combination of risk-reward with the middle square presenting the tangency portfolio.

6.2.2 Indonesia

In this section the portfolio optimization analysis from the Indonesian investor's point of view is done. I present the results with and without the US index being available thus providing answers to the home bias question. I find the Indonesian investor to benefit greatly from both global and regional portfolio diversification. Surprisingly to me, the regional equity markets provide extremely significant benefits meaning they possess different kind of "unsystematic risk" despite sharing many similar characteristics. The DCC-GARCH section supports my findings.

Figure 9 shows the arithmetic risk-return characteristics of each equity market used in this study measured in $Rp. First, the returns differ significantly from the $US returns due to exchange rate fluctuations as expected. Second, it is interesting to see how similar returns each index possessed during this period. The figure also depicts clearly how well the equally weighted portfolio would have performed. This is almost like a textbook example of how diversifying portfolio internationally can provide risk-reduction possibilities while keeping the return equal. One should also notice that the optimal portfolio would be even further left. From Indonesian point of view, the domestic index has performed rather well by having the highest overall return. Yet, it has also been the second most volatile suggesting the investor could seek for risk-reduction opportunities.

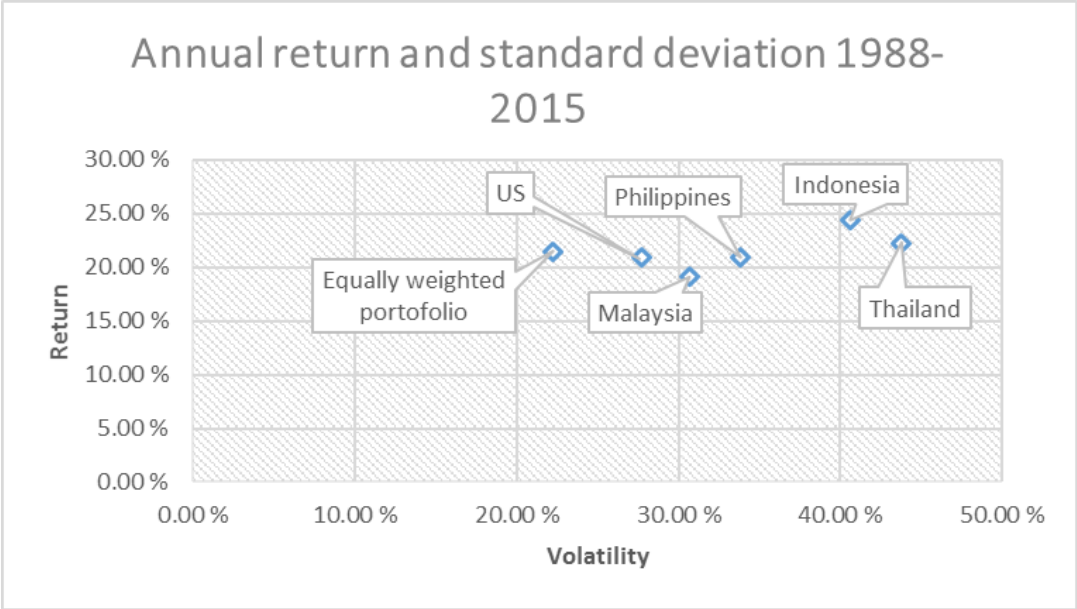


Figure 9: Average arithmetic risk-return of each country index from 1988 to 2015 ($Rp).

For the subset including the Asian crisis, the markets were even more volatile when measured in $Rp. During this period the Indonesian domestic index had a Sharpe ratio of 0.36 while the global tangency portfolio would have achieved a Sharpe ratio of 0.79 as can be seen in table 8. The resulting efficient frontier in figure 10 clearly shows how the domestic market was nowhere near optimal in

terms of risk and reward. While the local portfolio offered 29.06% return with 54.32% standard deviation the minimum-variance portfolio, for instance, would have given 33.41% return while reducing the risk to 32.34% (Table 9).

Between the years 1999 and 2009 the Indonesian equity market was the top performer in terms of market return with a return of 25.83%. With a standard deviation of 31.93% the Sharpe ratio set at 0.54 which did not lose much to the optimal ratio possessed by the tangency portfolio, at 0.63. This rather small difference is also visible in figure 10 (1999-2009) where the Indonesian risk-return point lies not much below the capital allocation line. Despite the Sharpe ratio being rather close to the optimal one the Indonesian investor could have benefitted greatly from international diversification in terms of risk reduction. The minimum-variance portfolio, of course in exchange for return, would have been able to split the portfolio risk in half from 31.93% to 15.28%.

For the third subset, the time after all the crises, the Indonesian market return was somewhat low coming in at 11.27% with standard deviation of 19.28%. This lead to a Sharpe ratio of 0.31. The tangency portfolio exceeded the domestic significantly having a 20.66% return and a Sharpe ratio of 1.15. Also, the minimum-variance portfolio could have lowered the standard deviation to 12.21% while maintaining higher return than the one achieved by the domestic portfolio.

Overall, I found every subset used in this study to support the international diversification for the Indonesian investor no matter whether interested in portfolio risk-reduction or increasing the Sharpe ratio. This is much in line with the previous research done for emerging equity markets. The DCC-GARCH section of this paper presents one possible explanation for the reasons behind this as the time-varying correlations were found to be extremely low and even negative at times. But again, despite the last subset being characterized by the highest pairwise correlations, both unconditional and conditional, the actual benefit from international diversification would have been the highest when measured with Sharpe ratio. This supports the findings done from the US investor's point of view. The correlation dynamics alone are not enough to explain the diversification potential each equity index has on each other.

	Indonesia only				Global	
	Return	St.Dev	Sharpe ratio	Return	St.Dev	Sharpe Ratio
Period 1 (1988-1998)	29.06 %	54.32 %	0.36	36.71 %	33.37 %	0.79
Period 2 (1999-2009)	25.83 %	31.93 %	0.54	22.16 %	21.52 %	0.63
Period 3 (2010-2015)	11.27 %	19.28 %	0.31	20.66 %	13.32 %	1.15

	Regional		
	Return	St.Dev	Sharpe ratio
Period 1 (1988-1998)	32.30 %	39.52 %	0.55
Period 2 (1999-2009)	22.16 %	21.52 %	0.63
Period 3 (2010-2015)	22.32 %	18.58 %	0.92

Table 8: Indonesian portfolio vs. the tangency portfolio vs. regional portfolio ($RP).

		Minimum-Variance	
	Local	Regional	Global
Period 1 (1988-1998)	54.32 %	35.99 %	32.34 %
Period 2 (1999-2009)	31.93 %	18.53 %	15.28 %
Period 3 (2010-2015)	19.28 %	13.09 %	12.21 %

Table 9: The minimum-variance portfolios' risks ($Rp).

The above analysis provided results on the international diversification benefits. In this study another important question is also answered. Is the regional diversification alone economically beneficial for an investor? Basically, this tackles the financial literature topic known as home bias. In this paper the focus is on the Indonesian investor as earlier mentioned but the findings could possibly be similar to many other regions in the world.

As it turns out, the regional diversification would have been extremely good diversification strategy for the Indonesian investor. This is shown in more detail in tables 8 and 9. I found that most of the "best results" explained earlier are associated with the introduction of regional equity markets and to include the global markets into Indonesian investor's strategy is not a necessity. When looking at table 8 and comparing the regional and the global portfolios during each of the three subsets, it is found that the optimal regional portfolio alone is able to increase the Sharpe ratio by 53%, 16% and 197% while the percentages are 119%, 16% and 271% for the global portfolio. Surely, this result supports the global diversification strategy but given an investor who is "suffering" from home bias while accepting the regional equity markets as possible investment diversification targets the decision of "to diversify regionally or no" is an easy one.

Second important notion should be given to the risk-reduction opportunities offered by the regional markets. When considering an investor from an emerging market such as Indonesia the risk-reduction might often be the main goal of diversification. I found the regional markets to provide great results when looking at minimum-variance portfolio available with regional portfolio. Overall, the average risk-reduction achievable with the regional portfolio for the Indonesian investor was 12.6% during a period while including the US equity market further reduced risk by an average of 2.6% as seen in table 9.

Figure 10: The efficient frontier framework ($Rp). CAL presents the best possible combination of risk-reward with the middle square presenting the tangency portfolio.

Overall, I found the Indonesian investor to benefit significantly from international portfolio diversification. This was expected since the DCC-GARCH section found extremely low pairwise conditional correlations between the equity markets. Both of the above findings are in line with previous literature about correlations, integrations and portfolio diversification benefits for an emerging market. It was also found that the market specific risk-return characteristics are important as was to be expected. The times of crises did not change the outcome.

The findings also support the regional portfolio diversification. This is quite often neglected perspective in financial literature. Even if investor is willing to include only their surrounding countries' equity markets in their investment strategy the portfolio could be expected to benefit significantly, at least when looking at emerging and frontier markets. This is a great finding. From Scandinavian point of view, the Southeast Asian equity markets are often seen as sharing similar risks and being close substitutes for one another but as it turned out this prejudice is misleading. A thorough analysis should always be made before executing an investment decision.

7 Conclusion

In recent decades, the financial literature on market correlations has focused on catching the time-varying characteristic of this important measurement. This has led to an introduction of many new models one claimed to be a better fit for the task than the other. This thesis has examined one of these models, the DCC-GARCH by Engle (2002), using five equity market indices with the return data reaching from 1988 to 2015. Moreover, this thesis has analyzed the impact the dynamic conditional correlations have on international portfolio diversification benefits both from the US and Indonesian investors perspective using Markowitz's (1952) modern portfolio theory. To be more specific, I have further divided the data into three subsets for this latter part in order to analyze the impact of different financial crises on international portfolio diversification. I have also analyzed whether regional diversification strategy would provide significant improvement for an Indonesian investor thus tackling the topic of home bias briefly.

I found a majority of the pairwise correlations to be time-varying with the only exception being the US-Philippines pair. This was to be expected since a constant correlation does not make much sense considering how equity markets behave in general.. These findings are in line with the recent existing literature about correlation and integration between equity markets. I also found evidence of contagion as many of the conditional correlations examined showed clear upward movement around the times of crises and especially during the Global financial crisis. On the other hand, the tranquil periods in my data were more commonly characterized by downward movement in pairwise correlations. This could result from the correlation returning towards its long-run equilibrium.

Overall, my DCC-GARCH model results imply the correlation levels to be such that international diversification benefits do exist and will keep on existing. Despite changes in the correlations and uptrends at times, there are no significant persistent increases reported except for the US-Malaysia pair. If correlation is considered to co-move with integration, my results do not support the general consensus of increasing equity market correlations as found i.e. by Bekaert et al. (2011). One possible explanation could be, as this thesis included only few countries, that these results depict only a minority of the world equity markets and the chosen markets deviant characteristics are not to be generalized.

I find no clear evidence of increased correlation reducing diversification benefits despite correlation being an explicit factor in the researched framework. The results from the efficient frontier framework show that the market specific return and risk play an extremely important role in assessing the benefits from diversifying portfolio internationally and as such usually surpass the effect the change in correlation has. My results are in line with

Pukthuanthong & Roll (2009) who, similar to me, state the correlation to be a bad measure of diversification benefits. For the US investor, I find similar results with Meric et al. (2011) about the difficulties of obtaining lower risk by international diversification. The reason for this could be partly from correlation dynamics but my subsets did not provide clear answer to this. However, again, my sample is too small to make any generalizations.

More importantly, my findings highlight the fact that diversification should be looked from individual's perspective. Even if one country's domestic equity market is characterized by being vast and diverse and thus reducing risks, this is not reality for all. The Indonesian investor could benefit extremely significantly in terms of risk reduction and achieving a better Sharpe ratio. I.e. Driessen & Laeven (2007) pointed out the same important aspect. I do not find the times of crises to reduce the international diversification benefits except for the US during the Asian crisis. But this was due to the poor performance of other available equity markets in my research.

Finally, by accepting regional equity markets in the home bias topic, as suggested by Grinblatt & Keloharju (2001), I find significant benefits for Indonesian investor when comparing with the domestic portfolio. The results mean the Southeast Asian equity markets do not share similar unsystematic risks and as such should not be treated similar despite many peculiar characteristics between the countries and their equity markets as found i.e. by Bekaert et al. (2011).

For future, there are still many different areas that could be researched. The inspection could be done using different frequencies of the data as well as shorter time periods, and focusing more closely on certain crisis periods. This would help to obtain better understanding on the effect each crisis has and also on the persistency on changes in correlation for example. Second, the velocity at which the crises affect the correlations could be an interesting area of focus. Third, the research could be done for more countries to gain better consensus. Fourth, instead of efficient frontier framework the diversification benefits could be analyzed using value-at-risk.

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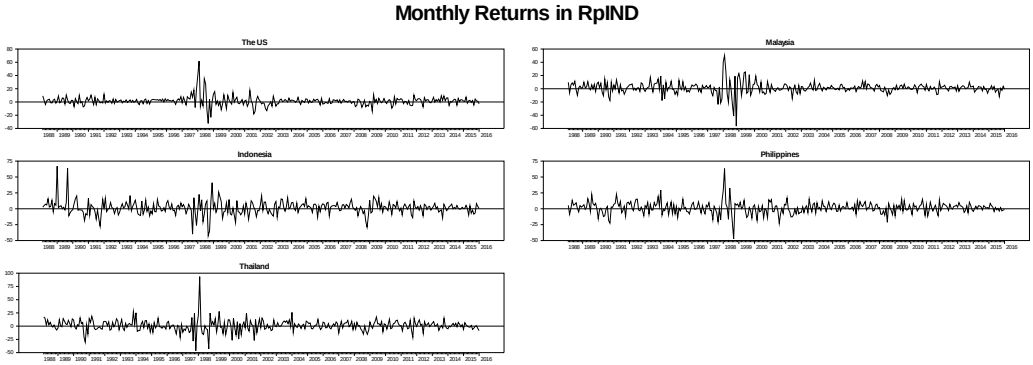
Appendices

Appendix 1. Data (Indonesia)

	N	Min	Max	Mean	Std. Dev.	Skewness	Ex. Curtosis	Jarque-Bera
US	336	-32.371	61.920	1.463	7.043	2.352	21.635	6862.703
Indonesia	336	-42.652	67.006	1.419	10.666	0.782	8.872	1136.367
Malaysia	336	-56.441	50.302	1.213	8.643	-0.379	11.481	1853.604
Thailand	336	-46.287	93.536	1.209	10.834	1.287	16.996	4136.808
Philippine	336	-47.448	63.248	1.294	9.187	0.444	8.407	1000.438

Augmented Dickey-Fuller unit root test					KPSS stationarity test			
H0 = Unit root	Test value	1 %	5 %		H0 = Stationary	Test value	1 %	5 %
US	-7.318***	-3.44	-2.87		US	0.227	0.739	0.463
Indonesia	-16.33***	-3.44	-2.87		Indonesia	0.124	0.739	0.463
Malaysia	-17.206***	-3.44	-2.87		Malaysia	0.086	0.739	0.463
Thailand	-18.751***	-3.44	-2.87		Thailand	0.084	0.739	0.463
Philippines	-15.606***	-3.44	-2.87		Philippines	0.090	0.739	0.463



Appendix 3. Time-Varying conditional correlation (color)