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International Diversification and Performance Prediction in Equity Investing

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by

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Abstract

This thesis focuses on several aspects of international equity investing. The research shows foreign exchange risk is significant in most countries, especially in times of higher volatility, and should be an important consideration for investors. The correlation across international markets has seen a steady increase over time, with peak correlation during the Great Recession. The increased correlation makes investors look beyond developed markets, shifting focus to smaller emerging markets. Lastly, the prediction of daily performance proved to be a difficult task, especially for smaller markets.

Keywords: Financial Markets, Diversification, Global, Correlation, Foreign Exchange

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International Diversification and Performance Prediction in Equity Investing

On August 25, 2015, the front page headline of Wall Street Journal read "Markets Reel in Global Selloff" with a chart illustrating how a decline in Chinese stock transferred into a sell-off in Europe and subsequently the United States on the same day, with markets losing 8.49%, 5.33%, and 3.57% in respective markets that day. Time and time again, similar stories remind investors that international diversification is not a simple concept. A 2017 report by the US Department of the Treasury on US Portfolio Holdings of Foreign Securities showed that the market value of foreign securities held by US residents is approaching 10 billion USD, a 10-fold increase since 1994. Combining the correlation of international markets with the increasing interest in international investing, researching international markets is more important than ever before.

This thesis focuses on several important aspects of international investing. First, *Literature Review* section of this thesis summarizes previous research conducted on similar topics of international investing and introduces data used through the rest of the thesis. A section focused on *Importance of Foreign Exchange* explores the significance of currency risk and how investors should approach that risk in individual markets. The *Correlation Across Markets* section explores the development of correlation across global markets and the magnitude of correlation over time, concluding with a recommendation of markets most suitable for investors seeking diversification. Lastly, the *Prediction & Influence* section introduces regression models predicting the performance of US and several smaller markets. In addition, the section examines the influence of markets among each other during after-hours trading.

Section 2: Literature Review

2.1. International Diversification

Gagnon and Karolyi (2006) summarized the research on international finance over a period of 20 years. They suggested interest in a deep understanding of international diversification was sparked by the International Crash of October 1987 and several following crises in the ‘90s. The work also suggests research conducted over those crises have found that correlation across international markets increases in times of greater volatility, especially if volatility is fed by negative news. While institutional characteristics were originally blamed for the International Crash of October 1987, Roll (1989) argued that the decline should be credited to a normal response of each country's stock market to a worldwide market movement. The crash was significant, as 19 out of 21 markets declined by more than 20% in a very short time period.

A year later, Jorion (1989) showed benefits of international diversification for US investors. Study contained 10 years of data and proved investing abroad yielded higher returns, with lower risk. While he did not suggest excess returns abroad will continue, he strongly recommended international diversification for risk reduction purposes. Several years later, Bartram and Dufey (2001) argued, despite significant development in technology and globalization, it is still relatively difficult for a private investor to invest in individual foreign companies. However, Bartram and Dufey acknowledged that investors can achieve international diversification through international mutual funds. At present, international investing is even easier through exchanged traded funds that trace indexes, some of which are used in this research.

The 2008 Great Recession once again drew attention to the concept of international diversification. Bartram and Bodnar (2009) highlighted, “The crisis drove down equity levels

across the globe, and in nearly every country, sector and industry." (p. 1275) They further suggested that investors will need to rethink strategies for international diversification. Just as the downfall during the Great Recession was synchronous, Foo and Witkowska (2017) explained the recovery from the recessions was also synchronous around the globe without any significant difference between emerging and developed markets. Hence, the Great Depression served as another reminder that markets around the world tend to move together in periods of higher volatility.

In more recent research Horobet and Belaşcu (2014) studied how emerging markets move with respect to developed markets. They found emerging markets provide diminishing returns to the diversification of a portfolio. As emerging markets become more correlated to developed markets. It is also notable that the research found negatively skewed distribution of returns in emerging markets. Another view on international diversification provided by Liu (2016) argued international corporate bonds have been a significantly better diversification tool than equities between 2000 and 2010. While her research provided intuitive and important findings, according to the US Department of Treasury (2017), over 70% of US holdings of foreign securities are in equities. Therefore, this research is focusing on equity diversification.

2.2. Foreign Exchange

August 15th, 1971 marked the end of the Bretton-Woods system and the US dollar became a fiat currency. For investors internationally diversifying their portfolios, this event had a tremendous impact. Levy and Sarnat (1978) emphasized this notion in their research by suggesting that investors need to pay strong attention to the foreign exchange risk. While the US dollar has been a free-floating currency since then, other governments decided to peg their currency against the US dollar (USD), or some other currency. For example, when the Brazilian

Real (BRL) was introduced in 1994, it was pegged to the US dollar. Ferreira and Tullio (2002) explained that the cost of pegging the currency became excessive in the second half of 1998, which led to unpegging the currency in January 1999. This lead to The Brazilian Exchange Rate Crisis. During the one month, USD/BRL exchange rate went from 1.21 to 2.05, a staggering 70% loss in value. Another, more well-known, case of a country with pegged currency is China. Aftab, Ahmad, and Ismail (2015) summarized the interesting case of Chinese Yuan, which was pegged until 2015. However, even now the currency is not a free-floating one, but rather a "managed float exchange rate". In practice, this means that Chinese government is preventing excessive movement in the value of its currency. Investors seeking international diversification need to be aware of foreign exchange risk, even if a currency is pegged.

An interesting question to consider is whether a strong performance of financial markets influences the currency strength of a country. Existing research is not in agreement on this question. Aftab et al. (2015) explored this question in their research on Chinese Yuan. They concluded that performance of stock exchange market in China is negatively correlated to the performance of the currency, implying investors could use currency risk as a hedging tool for investing in China. Harald and Rey (2006) generalized the notion of negative correlation between stock markets and currency for the entire world. They based their findings on a portfolio rebalancing theory, stating that as investors pull back excess returns on securities held in a country, they will cause a negative capital flow, causing the currency to depreciate. However, Cho, Choi, Kim, and Kim (2016) argued that Harald and Rey have an invalid assumption of each country having a randomly generated performance of the stock market. Cho et al. (2016) studied correlation between markets in their research and further argued that a financial downturn causes a capital flow from emerging markets to developed markets, leading to a currency depreciation in

emerging markets. Adding to the disagreement on the topic, Kornienko (2010) argues that strong performance of equity markets comes with a strong currency, suggesting a positive correlation between the two. While this research will not attempt to explain the effect of equity markets on currency, it will compare the nominal and foreign exchange adjusted performance of global stock markets.

2.3. Correlation Across Markets

Given the correlation of stock markets around the world, Longin and Solnik (1995) studied how the correlation changed between 1960 and 1990. They found the correlation increased over time and was particularly strong in periods of higher volatility. Goetzmann, Lingfeng, and Rouwenhorst (2005) came to a similar conclusion, as they studied the correlation during the entire 20th century. They argued the correlation pattern is consistent with the "U" shaped hypothesis about the globalization at the start and the end of the 20th century. They supported the argument by showing the correlation was as high in the calm '90s as during the Great Depression in the '30s. They concluded that while globalization expands the possibilities of international diversification, it also makes investors rely on emerging markets.

Many of the authors already mentioned concluded correlation across markets increases in a period of high volatility. There are several authors discussing this issue in-depth. Among other things, Forbes and Rigobon (2002) distinguished between contagion and interdependence. While contagion is "a significant increase in cross-market linkages after a shock to one country (or group of countries)", interdependence is "a continued high level of market correlation [that] suggests strong linkages between the two economies that exist in all states of the world" (p. 2225). Longin and Solnik (2001) used the extreme value theory to reevaluate the notion of increased correlation in times of greater volatility. Their methodology yielded a conclusion

suggesting the increase in correlation occurs only in bear markets, but not in bull markets. Expanding on the idea in a slightly different way, Connolly and Wang (2003) examined intraday comovements across markets. They concluded the correlation in returns cannot be attributed to public information on economic fundamentals, but rather to contagion. The research on correlation across markets is advanced. Hence, this research emphases the magnitude of *Correlation Across Markets* and its development over time.

2.4. Prediction Capabilities

Knowing international markets are correlated, the important question for daily investors is, whether the performance of one market can be predicted based on the performance of other markets. Lin, Engle, and Ito (1994) studied US and Japanese markets. They found trading in Japan can influence after-hours trading in the US. However, according to the research, US daytime trading influences Japanese after-hour trading twice as much as the other way around. While this research established the influence of US markets in the world, it looked at movements occurring simultaneously in different time zones. Koch and Koch (1991) found the interdependence of markets with the same trading hours grew over time. More importantly, they found that inter-market responses around the world happen within the first 24 hours. There was almost non-significant responses across markets beyond a 24-hour period. Becker, Finnerty, and Gupta (1990) also studied the relationship between US and Japanese markets. However, they studied how movements in one market affect movements in the other market either later that day (Japan affecting the US), or the next day (the US affecting Japan). While Japanese markets were not influencing US markets as much, the influence of US markets on Japanese markets was still significant. Becker et al. used their conclusion to simulate an investment strategy and, while the strategy did generate positive returns, the returns disappeared after accounting for transaction

cost. Rapach, Strauss, and Zhou (2013) looked at the influence of US markets more recently, using monthly returns, rather than daily returns. They agreed with the other research, stating that while the US is affecting markets around the world, worldwide markets have a less influence on US markets. The *Prediction & Influence* section of this thesis explores both the possibility of predicting market performance and the influence of markets around the world on each other.

Section 3: Data and Methodology

3.1. Data Selection

A total of eight major stock exchanges were selected for the purpose of this research. Using the December 2017 report of the largest stock exchanges in the world by market capitalization constructed by The World Federation of Exchanges (2017), the largest five stock exchanges were selected. Those were NYSE Group, Nasdaq, Japan Exchange Group, the Shanghai Stock Exchange, and Euronext. The largest stock exchange of each non-represented continent was added, to span a broader geographical area. More specifically, the Australian Securities Exchange, the Johannesburg Stock Exchange, and BM&FBOVESPA S.A. (Sao Paulo, Brazil). All stock exchanges selected were ranked among the 20 largest exchanges by market capitalization.

To quantify the performance of every stock exchange, an index representing each was selected. Usually, the most widely used capitalization-weighted index[1] representing an exchange was selected. The only exception was a selection of Standard & Poor's 500 (S&P 500) index to represent both NYSE and Nasdaq, as companies traded at either exchange are included in the index. As the focus of this thesis is to compare international markets, it was intuitive to group

[1] Capitalization-weighted, as opposed to price-weighted index, weights individual components according to respective market capitalization and is more accurate for the purpose of this thesis.

both stock exchanges under one index representing the entire US market. Table 1 summarizes indexes representing stock exchanges, with respective shortened names used later in the thesis.

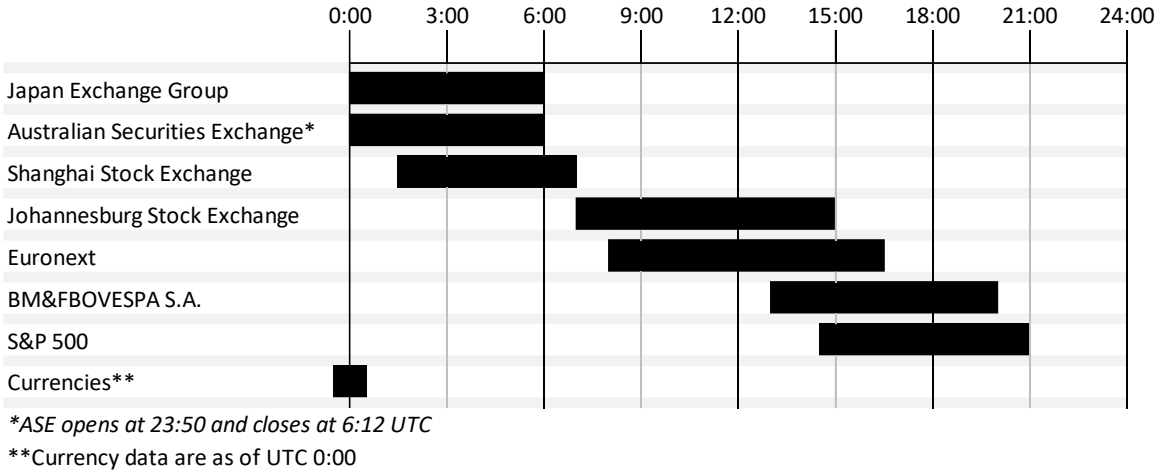
Table 1: List of Stock Exchanges Selected and Representing Indexes

Stock Exchange	**Stock Index**	**Market Capitalization (Global Rank)**		**Shortened Name**
NYSE Group	S&P 500	$22.1M	(1)	sp
Nasdaq	S&P 500	$10.0M	(2)	sp
Japan Exchange Group	Topix	$6.2M	(3)	topix
Shanghai Stock Exchange	SSE Composite Index	$5.1M	(4)	sse
Euronext	Euronext 100	$4.4M	(5)	euronext
Australian Securities Exchange	S&P/ASX 200	$1.5M	(13)	asx
Johannesburg Stock Exchange	FTSE/JSE All Shares	$1.2M	(16)	jse
BM&FBOVESPA S.A.	Ibovespa	$1.0M	(18)	ibovespa

Note: The table shows all stock exchanges selected for this research, along with stock index representing each stock exchange. Market capitalization column indicates the market capitalization and global ranking of each exchange based on December 2017 report of World Federation of Exchanges (WFE, 2017). The last column indicates shortened name used to represent each stock exchange through the research.

A key factor to consider is individual stock exchanges around the world are in different time zones and hence open for trading at different times. Through the entire thesis, time information is presented in UTC±00:00 (Coordinated Universal Time) which is used, for example, in Great Britain. Price data were obtained at opening and closing time of each exchange. In addition, currency prices were obtained every day at 0:00. Figure 1 graphically depicts when individual stock exchanges are open during the day.

Figure 1: Timeline Depicting Trading Hours of All Exchanges on a Single Day



Note: The timeline shows the trading hours of all stock exchanges (black blocks) included in this research aligned in UTC time zone. Trading hours of Australian Stock Exchange are rounded to the nearest half-hour and currency data were collected once a day at 0:00 UTC.

Another important factor when investing internationally is the performance of foreign exchange market. This thesis is constructed from the perspective of a US investor. Hence, the USD is used as a base currency. Given the selection of stock exchanges presented earlier, historical exchange rates for six currencies were obtained. To obtain returns on foreign exchange from the perspective of US investors, the quoting of some currencies was inverted from convention[2]. Table 2 summarizes the currencies used.

[2] In most parts of the world, currency pairs are quoted according to a convention which dictates that currency earlier in the order is quoted as fixed currency. The order is as follows: EUR – GBP – AUD – NZD – USD – other

Table 2: Currencies of Individual

Stock Exchange	Currency	Quote Used	Shortened Name
Japan Exchange Group	Japanese Yen	JPY/USD *	jpyusd
Shanghai Stock Exchange	Chinese Yuan Renminbi	CNY/USD *	cnyusd
Euronext	Euro	EUR/USD	eurusd
Australian Securities Exchange	Australian Dollar	AUD/USD	audusd
Johannesburg Stock Exchange	South African Rand	ZAR/USD *	zarusd
BM&FBOVESPA S.A.	Brazilian Real	BRL/USD *	brlusd

Note: The table lists all stock exchanges, with exception of NASDAQ and NYSE, and currencies used to invest in respective stock exchanges. Quote, used column shows quote used in data collection, with an asterisk (*) depicts usage of quote flipped from convention used. The last column reveals a shortened name of currency pair through the research.

3.2. Data Collection

All data for this thesis were collected from either Bloomberg Terminal or Yahoo Finance. More specifically, all historical prices of currencies and Johannesburg Stock Exchange historical prices were collected using Bloomberg Terminal, while all other historical prices of indexes were collected from Yahoo Finance. As explained above, historical prices of currencies were collected once a day at 0:00 UTC. For all the indexes, daily opening and closing prices were collected. Historical prices for indexes were collected as far back as possible, while respective currencies were collected only for the period that had respective index price information.

As expected, Bloomberg data did not contain any discrepancies. However, data from Yahoo Finance, a non-premium data stream, contained some errors. Those errors showed up either as null or price of 0 on a given day. Days with invalid information were deleted, essentially treated as non-trading days, such as weekends and national holidays.

The next step in preparing data for statistical analysis was aligning prices of all indexes and currencies by days. This needed to be done using VLOOKUP procedure in Excel, as stock exchanges around the world observe different holidays during the year. Another challenge came with the Australian Securities Exchange as trading at this exchange begins at 23:50 of the

preceding day. Hence, data was shifted so that most of the trading hours align with a particular day, rather than the beginning of the trading.

Once all data was aligned by days, it was necessary to delete data for the days that do not have price information for all 7 stock indexes, or the number of stock indexes observed at the time. When constructing a statistical regression, only observations (days) containing information about all variables in the regression can be used. While Stata software can automatically drop invalid observations, it is important to delete those price observations before they are turned into percentages. Only that way, percentage changes are reflecting the same time period on all indexes. For example, let Euronext closed for trading on Tuesday, while NYSE remains open. If invalid observations would be dropped after converting into percentages, Wednesday data would present a one-day change for NYSE, but a two-day change for Euronext.

Once daily prices were aligned, it was necessary to construct returns. For each index, 3 different returns were constructed. First, returns during trading hours of a particular exchange. Second, the after-hours return, tracing returns from the closing price of previous day to the opening price of the current day. Third, the 24-hour return, tracing returns between the open price of the previous day and open price of the current day. When constructing returns of currencies, only the last method was used, tracing returns over 24 hours.

Unfortunately, both opening and closing prices were not available for all indexes included in this research. Most frequently, only daily changes in prices were tracked by the data sources. Table 3 shows the first day of data collection for each index and each trading session.

Table 3: Data Availability

	Open-Close *Trading hours*	**Close-Open** *After-hours trading*	**Open-Open (24h)** *Day-long trading*
S&P 500	1/3/1966	9/25/2007	1/3/1966
Japan Exchange Group	10/11/1984	2/8/1971	2/8/1971
Shanghai Stock Exchange	7/3/1997	7/3/1997	7/3/1997
Euronext	1/5/2000	1/5/2000	1/5/2000
Australian Securities Exchange*	4/4/2000	-	11/24/1992
Johannesburg Stock Exchange*	8/1/2002	-	7/3/1995
BM&FBOVESPA S.A.	-	4/28/1993	4/28/1993

Note: The table lists the first day of data availability for all stock exchanges. The first column depicts trading hours data (from 9:30 pm to 4:00 pm in the US). The second column shows after-hours trading (from 4:00 pm on a previous day to 9:30 am of today in the US). The last column shows a change in the index over the last 24 hours (from 9:30 am on a previous day to 9:30 of today in the US). An asterisk (*) depicts stock exchanges where after-hours data were present at some point in the past, but later were discontinued.

In addition to nominal returns, it was necessary to construct foreign exchange adjusted returns. Computation of adjusted returns was the sole reason why quotation of some currencies was inverted against the convention. The formula used to compute the foreign exchange adjusted return is presented below.

$$FX\ adjusted\ return = (1 + nominal\ return) * (1 + return\ on\ currency) - 1$$

3.3. Descriptive Statistics

Once all data was successfully collected and converted into a time series of returns, descriptive statistics were obtained from the raw data. This section provides an overview of outliers in descriptive statistics among stock exchanges and currencies used in this research. Table 4 represents the minimum and maximum values of all data for each statistical metric. As mentioned in the previous section, data is not available for all three trading periods (trading hours, after-hours, 24 hours) for some indexes. Hence, if the index is missing either trading hours or after-hours, the return on the other will be the same as 24-hour return. This causes some of the

values in the table to be identical. A complete table showing the descriptive statistics for each variable is presented in the appendix 3.1.

Table 4: Descriptive Statistics Analysis

	Max Mean		Min Mean		Max StDev		Min StDev		One Sessions Min		One Session Max	
	Value	Variable	*Value*	Variable	*Value*	Variable	*Value*	Variable	*Value*	Variable	*Value*	Variable
Nominal Returns												
Trading Hours	0.065%	sse	-0.017%	euronext	1.46%	sse	0.73%	asx	-20.47%	sp	16.06%	topix
After Hours	0.181%	ibovespa	-0.027%	sse	2.52%	ibovespa	0.29%	sp	-25.82%	ibovespa	41.20%	ibovespa
24 hours	0.181%	ibovespa	0.013%	euronext	2.52%	ibovespa	1.03%	sp	-25.82%	ibovespa	41.20%	ibovespa
Adjusted Returns												
Trading Hours	0.071%	sse	-0.098%	ibovespa	1.57%	jse	0.99%	sp	-20.47%	sp	16.86%	topix
After Hours	0.083%	ibovespa	-0.025%	sse	2.75%	ibovespa	0.29%	sp	-27.31%	ibovespa	29.43%	ibovespa
24 hours	0.083%	ibovespa	0.021%	euronext	2.75%	ibovespa	1.03%	sp	-27.31%	ibovespa	29.43%	ibovespa
Currencies												
24 hours	0.008%	jpyusd	-0.101%	brlusd	1.14%	brlusd	0.11%	cnyusd	-15.35%	brlusd	10.90%	brlusd

Note: The table shows extreme values among data collected for each statistical metrics observed, with both nominal and adjusted returns for trading hours, after hours, and 24 hours along the side. Currencies are showed in the last row. Individual statistical metrics are along the top with values reached and shortened names of index achieving the value. The table clearly shows that Brazilian ibovespa index accounts for most of the values due to the exchange rate crisis in 1999. On the other hand, larger markets, such as the US, showed smaller volatility.

Noticeably, Ibovespa index representing the Brazilian Stock Exchange accounts for most of the values in the table. This phenomenon can be easily explained by The Brazilian Exchange Rate Crisis of January 1999. All one session minimums and maximums presented in the table occurred during that time and they also significantly affected the mean and standard deviation values. While the Brazilian Real had a staggering -0.101% daily return since 1993, the daily average return since 2000 has been only -0.008%. Based on those observations, the rest of this research will account for the high volatility in Brazil before 2000.

On the other hand of the volatility spectrum is the S&P 500 index, representing US stock exchanges, as it had the smallest standard deviation of all indexes. An interesting phenomenon to notice is that most of the indexes posted a higher standard deviation in adjusted return, compared

to the nominal return. When looking at the mean daily returns, an interesting fact is that while Shanghai Stock Exchange index performs the best during trading hours, it performs the worst in the after-hours trading, out of all indexes included in this research. Lastly, the good performance of the Euro against the US dollar causes the adjusted daily return of Euronext to be higher than its nominal return.

Another important statistical metrics is skew, which describes the distribution of observations. Skew is measuring whether the distribution is symmetric, or not. In other words, negatively skewed distribution means frequent small gains and few extreme losses. As table 5 depicts on nominal 24-hour returns, a clear majority of indexes had a negative skew. This was expected as markets usually show large losses in bear markets, and steady small gains in bull markets. The only exception has been the Ibovespa index, which once again was affected by the currency crisis as the Ibovespa skew since January 2000 has been -0.55.

Table 5: Skew of Indexes

	sp	**topix**	**asx**	**ibovespa**	**jse**	**sse**	**euronext**
Skew	-0.8	-0.2	-0.3	1.1	-0.2	-0.1	-0.5

Note: The table shows skewness of all indexes included in this research. The table clearly shows the negative skew of most indexes, with the only exception being ibovespa index, once again affected by The Brazilian Exchange Rate crisis of January 1999.

3.4. Methodology

Correlation across global markets was simply explored using Microsoft Excel. However, difficulties came when generating correlation matrices, as there is a total of 105 correlations across nine five-year segments. A simple Visual Basic for Application macro was created to automatically generate the correlation matrices.

The *Prediction & Influenc*e section was conducted using Stata software for statistical regressions. Once a regression model was constructed, it was tested for heteroskedasticity, first-degree serial correlation, and misspecification. If a regression tested positively only for heteroskedasticity, robust standard errors were adopted. However, if regression contained a first-degree serial correlation, Newey-West Standard Errors were implemented. If misspecification was identified, the effort has been made to add squared and cubed terms into the regression model. The Description of each regression result used in this research informs the type of standard errors used.

Section 4: Importance of Foreign Exchange

As previously described, foreign exchange is a significant part of international investing. This section focuses on the performance of individual currencies, the correlation between currency and the stock market, and finally compares nominal and foreign exchange adjusted performance of indexes. This research is taking the perspective of a US investor and hence evaluates all currencies against the US dollar. It is important to keep in mind that while this section is mostly focusing on events within a foreign country, the foreign exchange rate is also affected by events in the US that are not connected to that country.

4.1. Analysis of Individual Currencies

Based on stock exchanges selected, this research studies a total of 6 currencies across the world. Due to The Brazilian Exchange Rate Crisis of January 1999, which significantly affected the Brazilian Real, an additional variable was added to trace the Brazilian Real since January 2000. A majority of the currencies included in the research are free-floating currencies. The only exception is Chinese Yuan, which is a hybrid between fixed and floating currency. A summary of all currencies is presented in Table 6.

Table 6: Summary of Individual Currencies

Currency	Type	Mean	St Dev	Min		Max	
				Value	Date	Value	Date
eurusd	Floating	0.007%	0.69%	-7.63%	10/6/2008	5.35%	12/17/2008
cnyusd	Managed floating	0.006%	0.11%	-1.82%	8/11/2015	2.05%	7/21/2005
jpyusd	Floating	0.008%	0.73%	-6.04%	4/9/2013	7.20%	10/7/1998
zarusd	Floating	-0.018%	1.11%	-14.36%	10/15/2008	6.85%	10/28/2008
brlusd	Fixed until 1999	-0.101%	1.14%	-15.35%	10/6/2008	10.90%	8/1/2002
brlusd*	Floating	-0.008%	1.17%	-15.35%	10/6/2008	10.90%	8/1/2002
audusd	Floating	0.006%	0.83%	-13.09%	10/6/2008	8.63%	10/13/2008

* indicates time series starting in January 2000

Note: The table summarizes all currency pairs used in the research. The type column indicates if foreign currency is pegged to other currency, managed floating, or free-floating. The next two columns show the average daily return and standard deviation of daily returns. Rest of the table shows the minimum and maximum one-day swings in a currency pair. It can be observed from the table that larger currencies are less volatile, with Chinese Yuan being by far the least volatile currency is the currency is under manager floating by the Chinese government.

Looking at the mean daily return of each currency, most of the currencies appreciated against the US dollar over time, the only exceptions being the South African Rand and the Brazilian Real. The later currency actually showed an astonishing 0.1% decline per day, when considering the volatile move from a fixed currency to a floating one in late ‘90s. When comparing the standard deviation of currencies, unsurprisingly, the Chinese Yuan is by far the least volatile currency, as the Chinese government limits its movement. One can also observe that currencies of more developed countries (Eurozone, Japan, Australia) showed lower volatility, compared to emerging countries. Interestingly, the Brazilian Real showed more volatility after the crisis, suggesting that the currency is still volatile, despite having a significantly better mean daily return.

Looking at the all-time one-day minimums and maximums, one observes that the US dollar was extremely volatile during the early stage of the Great Recession. Looking at The Wall Street Journal Dollar Index, the US dollar rallied during Fall 2008. Jolly (2008) attributed the appreciation of the US dollar to the capital flow, as US investors moved capital invested abroad

back to the US. This might serve as a warning to the US investors that in the event of a global financial turmoil, their investments in a foreign currency might lose value due to the appreciation of the US dollar.

4.2. Currency and Stock Market Correlation

In accordance with research done over the question of whether a strong equity market comes with a strong currency, findings on data used in this research show that there is no clear answer as half of the currencies showed a positive correlation, while the other half showed a negative correlation. Data used in this research also shows agreement with Aftab et al. (2015) who suggested correlation between the Chinese Yuan and Chinese stock markets is negative. The weakest correlation was between the Brazilian Real and the Brazilian stock exchange when including the currency crisis. The finding aligns with the general expectation as the currency moved due to reasons unrelated to movement in the stock market. A full overview of correlations between indexes and currencies during various time periods is presented in Table 7.

Table 7: Correlation Between Performance of Stock Markets and Currency

Index-Currency	All data	Excluding 2008	2008	1998-2007	2008-2018
euronext-eurusd	0.044	0.002	0.256	0.012	0.065
sse-cnyusd	-0.016	-0.003	-0.094	0.045	-0.042
topix-jpyusd	-0.077	-0.061	-0.237	-0.016	-0.213
jse-zarusd	-0.016	-0.003	-0.091	-0.019	-0.023
ibovespa-brlusd	0.002	-0.007	0.087	0.081	0.052
ibovespa-brlusd*	0.093	0.094	0.087	0.081	0.052
asx-audusd	0.016	0.016	0.008	0.025	0.022

* indicates time series starting in January 2000

Note: The table shows the correlation between a performance of index representing a stock exchange and currency used at the stock exchange during different time periods. The data shows that the direction of correlation tends to stay the same over time. However, the magnitude of correlation fluctuates over time, with a peak in 2008.

As showed in the previous section, 2008 was a year of unprecedent volatility in foreign exchange markets. Therefore, Table 7 presents correlations for all data excluding the year 2008

and correlations specifically for 2008. Data suggests that correlation between currencies and stock exchanges significantly increased during 2008, with the exception of Australia. More noticeably, the direction of correlation stayed the same for all currencies observed. Consequently, when excluding 2008, the correlation decreased. To observe the change in correlations between stock exchanges and their currency over time, correlations were observed for two 10-year periods (1998-2007 and 2008-2017). The only two countries showing a noticeable increase in correlations were the Eurozone and Japan. Correlation among other currencies generally stayed constant over time, with the exception of Brazil, which observed a decrease in correlation.

While the correlation between the performance of a country's stock exchange and currency is usually not very strong, the direction of correlation tends to stay the same over time. The magnitude of the correlation is also stable over time, except times of increased volatility when correlation significantly increases.

4.3. Comparative Performance

The most critical metrics when evaluating the importance of foreign exchange is the impact on actual returns. Table 9 shows a daily mean nominal return for each index, daily mean index return adjusted for foreign exchange, and the excess of adjusted daily return over nominal return. Those values are then annualized for better understanding.

Table 8: Effect of Currency Performance on Stock Returns

Index-Currency	Daily Nominal Mean	Daily Adjusted Mean	Daily Adjusted Excess	Annualized Adjusted Mean	Annualized Adjusted Excess	Excess as % of Annualized Nominal
euronext-eurusd	0.013%	0.021%	0.007%	4.62%	1.62%	56%
sse-cnyusd	0.040%	0.041%	0.002%	9.35%	0.36%	4%
topix-jpyusd	0.047%	0.062%	0.014%	14.29%	3.18%	33%
jse-zarusd	0.060%	0.042%	-0.018%	9.45%	-3.90%	-32%
ibovespa-brlusd	0.181%	0.083%	-0.097%	19.75%	-19.06%	-59%
ibovespa-brlusd*	0.060%	0.054%	-0.006%	12.41%	-1.25%	-10%
asx-audusd	0.030%	0.037%	0.006%	8.25%	1.40%	22%

* indicates time series starting in January 2000

Note: The table depicts the difference between the nominal performance of a stock exchange and the performance adjusted for the performance of currency used on an exchange. First three columns present daily data, while rest of the table is presented on annual basis for better understanding. Data shows that performance of Chinese markets is not affected by the currency risk, while the performance of euronext, topix, and jse is significantly affected by the currency risk.

The data shows that four out of six stock exchanges have a positive adjusted excess return over nominal return, meaning investors would be better off exposing themselves to the exchange rate risk. This is simply caused by the US dollar's depreciation in the long-term against currencies of those exchanges. The only two currencies outperforming the US dollar were the South African Rand and the Brazilian Real, causing investors to lose money when exposed to the exchange rate risk.

While the dependency on the performance of the US dollar was expected, looking at the magnitude of the foreign exchange effect sheds a new light on the problem of foreign exchange. The last column in the table above shows the percentage change in nominal return if an investor assumes the exchange rate risk. As expected, fluctuations in the Chinese Yuan have a smaller effect on returns. However, the Euro, the Japanese Yen, and the South African Rand have a large effect on returns. In fact, the return on *euronext* can increase by nearly 60% if an investor decides to be exposed to the exchange rate risk. Except for the Chinese Yuan, the foreign exchange has a

large effect as it deviates the nominal return between 10 and 60 percent, which can translate to a total return difference of one to three percent annually.

4.4. Conclusions

The importance of foreign exchange when investing abroad cannot be overlooked by investors. Over a long-term period, exposure to the exchange rate risk can affect the total return from investing abroad by one to three percent annually. However, the risk increases significantly in a period of financial turmoil, when foreign exchange becomes more volatile. Investors should be aware of the correlation between the performance of stock exchange and its currency as the direction of the correlation tends to be stable, with increases in magnitude in years of increased volatility. Apart from the Chinese Yuan, whose effects can be disregarded, investors need to take a long-term view on the US dollar, which is going to drive most of the currency exchange risk. Investors that are not confident in their knowledge of foreign exchange, should mitigate currency exchange risk by either purchasing currency hedged ETFs in the US, or use currency futures.

Section 5: Correlation Across Markets

As described in the literature review, there is a clear consensus that stock exchanges around the world are correlated. The main discussion at the moment revolves around the issue of increased correlation in times of greater volatility. Researching such a specific issue is beyond the scope of an undergraduate thesis, hence, this section will focus on observing the change in correlation among exchanges over a long-term period. To observe changes in correlation over time, the data was divided into 5-year segments between 1973 and 2017. A correlation matrix of all exchanges with available data at the time was then created for each segment. Nominal returns were used since the previous section found that currencies included in the research tend to move

similarly against the US dollar, which would translate to an increased correlation among returns if adjusted returns were used.

5.1. The United States and Japan

Since indexes representing the United States and Japan were the only two with data available between 1973 and 1987, it was possible to obtain a significantly larger time series for correlations between the two. As Table 9 suggests, the correlation between the two markets was fairly low in the '70s and then drastically increased during the '80s. This can most likely be attributed to increases in globalization during the decade.

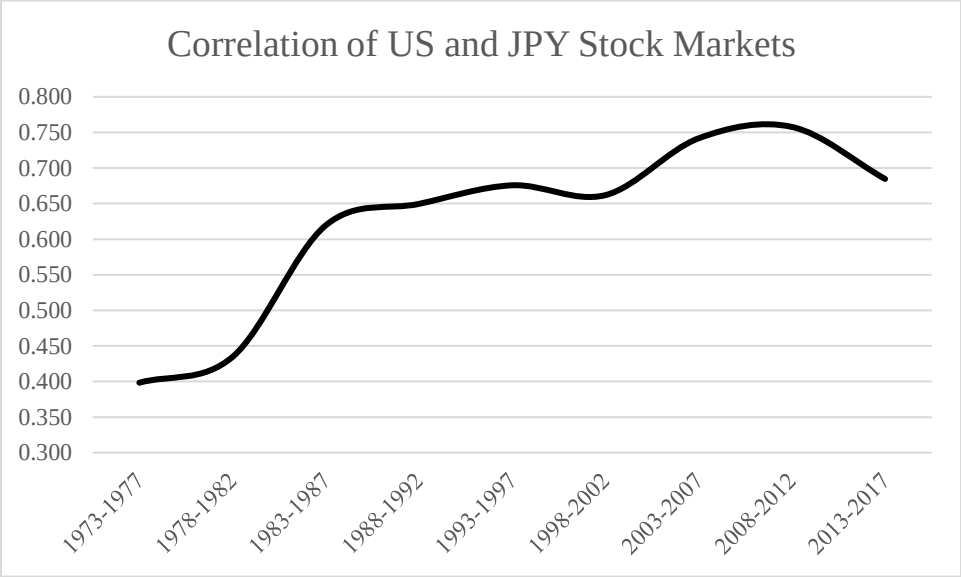
Table 9: Correlation between S&P 500 and Topix between 1973 and 2017

	1973-1977	1978-1982	1983-1987	1988-1992	1993-1997	1998-2002	2003-2007	2008-2012	2013-2017
sp vs. topix	0.398	0.435	0.619	.650	.676	.662	.742	.758	.685
Δ(%)		9%	43%	5%	4%	-2%	12%	2%	-10%

Note: The table shows the development of correlation between US and Japanese markets over 45-year period. One can observe, that the correlation significantly increased in the 80's, which can be attributed to the start of globalization.

After the significant increase during the '80s, the correlation between the two markets observed a steady increase over the next decade. During the first decade of the 21st century, the correlation between the two markets climbed to an astonishing 0.75. Considering these markets do not have simultaneous trading hours, the correlation is very significant. Therefore, investors should invest in the Japanese markets only if they are looking to invest in individual companies, as systematic risk between the two markets will be very similar. On the other hand, if investors are looking for international diversification, there are better places than Japanese markets for that purpose. Figure 2 depicts the development of the correlation between US and Japanese markets over time.

Figure 2: Correlation of S&P 500 and Topix over 45 years



Note: The graph depicts the evolvement of correlation between US and Japanese stock markets over 45-year period. A clear trend of increasing correlation over time, with a peak during 2008-2012 segment, can be observed. The trend suggests that US investors will soon need to look beyond the Japanese markets for diversification of equity portfolios in upcoming years.

5.2. Other Countries

Correlations of other stock exchanges with the United States mostly followed a similar pattern of increasing correlation over time, with a peak in the 2008-2012 segment. The Australian Stock Exchange and the Johannesburg Stock Exchange were the only two not following the pattern as closely since the correlation of those two exchanges decreased in the 2003-2007 segment. When considering the magnitude of correlation of indexes representing global exchanges against the S&P 500, *euronext* (Eurozone) and *ibovespa* (Brazil) were trailing right behind *topix* (Japan). The high correlation between *sp* and *euronext* was expected as *euronext* is representing a highly developed market of the Eurozone. The high correlation of *sp* with *ibovespa* was most likely caused by almost identical trading hours.

In general, the correlation of the US markets with other markets was larger than correlations among other markets themselves. This was especially surprising, as some of the markets have overlapping trading hours. For example, the correlation between *sp* and *topix* (Japan) was higher than the correlation between *topix* and simultaneously traded *asx* (Australia) and *sse* (China). In addition, the correlation between the US and those two markets was also higher than the correlation between Japan and the same two markets. Based on this observation, it is reasonable to believe the US is influencing other markets. This is discussed further in the *Prediction & Influence* section. Either way, it is significantly harder for US investors to seek international diversification compared to investors from different countries. However, when US investors seek international diversification, they should invest in exchanges with smaller market capitalizations.

5.3. Great Recession

While correlation among global markets is increasing over time, a special consideration should be placed on the Great Recession. In fact, as Table 10 suggests, in the segment containing the Great Recession, 20 out of 21 correlations increased from the preceding period. Even more notably, in a subsequent period (2013 – 2017) every single correlation in the correlation matrix decreased compared to the preceding period. This agrees with the research, such as Longin and Solnik (1995), or Goetzmann et al. (2005), suggesting increased correlation during times of greater volatility. As already discussed, investigating this issue further is beyond the scope of a thesis. The Great Recession should serve as a great warning for investors seeking international diversification. Especially, since the correlation of smaller exchanges did increase more significantly during the Great Recession compared to larger exchanges located in developed

markets, implying that emerging markets might not be as powerful diversification tool as those markets appear to be during less volatile time periods.

Table 10: Correlation Across Markets between 2008 and 2012

2008 - 2012	sp		topix		asx		ibovespa		jse		sse	
	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)
sp	1.000											
topix	0.758	2%	1.000									
asx	0.305	364%	0.184	591%	1.000							
ibovespa	0.721	16%	0.476	-1%	0.322	196%	1.000					
jse	0.420	50%	0.188	30%	0.400	88%	0.539	67%	1.000			
sse	0.336	275%	0.191	526%	0.099	4%	0.388	159%	0.265	136%	1.000	
euronext	0.768	0%	0.696	14%	0.198	-4647%	0.618	28%	0.379	29%	0.202	264%

Note: The matrix shows correlation across markets in the 2008-2012 segment. Value to the right from the correlation shows the percentage increase from the 2002-2007 segment. The table clearly shows that nearly all correlations across markets increased during the time segment that contained the Great Recession and subsequent recovery. The percentage change in correlation between euronext and asx shows a large negative change, which was caused by a very low negative correlation in preceding 5-year segment.

5.4. Conclusions

US investors seeking international diversification need to select markets very carefully. Investing in developed markets, such as Eurozone or Japan, does not really diversify a portfolio, as those markets are highly correlated. Hence, emerging countries with smaller stock exchanges are a better choice, as the correlation is lower. At the same time, investors should invest in markets in various time zones, as markets with overlapping trading hours tend to be more correlated. If the trend of continual increase in correlation across markets over time persists in the future, it will be increasingly harder to diversify portfolios with international equities and investors will need to consider different asset classes, such as bonds. Lastly, investors should keep in mind that correlation across markets tends to increase in times of greater volatility.

Section 6: Prediction & Influence

While correlations across global markets are important for investors diversifying their long-term portfolio, many day traders are interested in the intraday dynamics of global markets. Therefore, this section considers intraday returns to see if the performance of earlier international markets around the world can predict the performance of a specific market later in the day. The subsequent question is, whether there are any markets that can be more easily predicted than others. Lastly, this section will circle back to the question of some markets being enough to influence the rest of the world. As described in the methodology section, conclusions are based on regression analysis.

6.1. Prediction of the US Markets

Many professionals and researchers are building sophisticated models to predict the performance of the of the US markets. However, for the purpose of this thesis, a simple regression model has been constructed. From the 6 different variables presented in the data selection section, only three markets were selected, as their closing occurs before the US markets open for trading on the same day. Those indexes were *asx* (Australia), *topix* (Japan), and *sse* (China). The jse (South Africa) index was also considered as the overlap with US markets lasts only for 30 minutes. However, when *jse* was added to the regression model, it showed disproportionately high practical and statistical significance.

Model 1: Regression Predicting the Performance of S&P500

$$\widehat{sp500} = \beta_0 + \beta_1\, asx(trading\ hours) + \beta_2\, topix(trading\ hours) + \beta_3\, sse(trading\ hours) + \beta_4\, t + u$$

Table 11: Results of Regression Predicting the Performance of S&P500

	Coefficients	Newey-West Standard Error	t-statistic
Australia	.0743 *	.0218	3.41
Japan	.6664 *	.0235	28.39
China	.0515 *	.0114	4.51
Time trend	0	0	-0.80
Constant	.0010	.0011	0.90
Adj. R^2	.6069		
n	3845		

* indicates 1% level of significance

Note: The table shows results of the regression presented in model 1. The model takes the performance of three indexes earlier on the same day to predict the performance of S&P 500. While all three indexes are statistically highly significant, the performance of Japanese markets represented by topix is also practically significant. In addition, three indexes explain about 60% of S&P's performance, which is much higher than anticipated.

With adjusted R^2 of nearly 61%, the regression model seemed to be an exceptionally good predictor of US market performance. The Japanese Stock Exchange showed by far the greatest practical significance, as a one percent increase in the performance of *topix* index, increased the performance of S&P500 by .67 percent, holding everything else constant. Both *asx* and *sse* did not have high practical significance compared to this result. However, both coefficients were positive, which was expected. Since the regression results showed serial correlation and heteroskedasticity, Newey-West Standard Errors were adopted. All three variables were statistically significant at the 1% level.

6.2. Prediction of Smaller Markets

With having a strong regression model for predicting the performance of US markets, the question regarding the prediction of smaller markets arose. Are smaller markets more vulnerable to the influence of larger markets, or can they not be well predicted since they are less correlated to other global markets? The first regression model presented below is predicting the

performance of *jse*, using the performance of *asx*, *topix*, *sse* earlier that day and *sp* from the previous day.

Model 2: Regression Predicting the Performance of JSE Index

$$\widehat{jse\_oc} = \beta_0 + \beta_1\ sp\_lag(trading\ hours) + \beta_2\ asx(trading\ hours) + \beta_3\ topix(trading\ hours) + \beta_4\ sse(trading\ hours) + \beta_5\ t + u$$

Table 12: Results of Regression Predicting the Performance of JSE Index

	Coefficients	**Newey-West Standard Error**	**t-statistic**
United States (t-1)	.2758 *	.0290	9.51
Australia	.1382 *	.0340	4.06
Japan	.1446 *	.0271	5.33
China	.0878 *	.0161	5.44
Time trend	0	0	-1.17
Constant	.0024	.0019	1.31
Adj. R^2	.1219		
n	3348		

* indicates 1% level of significance

Note: The table shows the result of regression model 2. The model is predicting the performance of Johannesburg Stock Exchange index, using performance of US markets on a previous day and performance of Australian, Japanese, and Chinese markets earlier on the same day as independent variables. All independent variables are highly statistically significant, as well as practically significant. However, with R^2 of 12%, the independent variables explain a much smaller number of JSE's performance compare to regression model 1.

Compared to the regression model predicting the performance of US markets, this model seemed to be more realistic with the R^2 of only 12%. While all independent variables were practically significant, none of them had an excessive effect over other variables. Despite adopting Newey-West Standard Errors once again, all variables showed statistical significance at the 1% level. In addition to the model predicting the performance of *jse*, a model predicting *asx* was also constructed, using performance of *jse*, *euronext*, and *sp* from the previous day.

Model 3: Regression Predicting the Performance of ASX index

$$\widehat{asx\_oc} = \beta_0 + \beta_1\ jse\_lag(trading\ hours) + \beta_2\ euronext\_lag(trading\ hours) + \beta_3\ sp\_lag(trading\ hours) + \beta_4\ t + u$$

Table 13: Results of Regression Predicting the Performance of ASX index

	Coefficients	Newey-West Standard Error	t-statistic
South Africa (t-1)	.1191 **	.0234	5.08
Eurozone (t-1)	.0652 *	.0279	2.34
United States (t-1)	.1829 **	.0306	5.97
Time trend	0	0	0.19
Constant	-.0002	.0012	-0.14
Adj. R^2	.1359		
n	3347		

* indicates 5% level of significance ** indicates 1% level of significance

Note: The table shows result of regression model 2. The regression model is predicting the performance of Australian Stock Exchange, using performance of South African, Eurozone's, and US markets on a previous day. As ASX opens at 0:00, choosing returns from a previous day is a logical choice. All the independent variables are practically significant, as well statistically significant at least at 5% level. Similarly to model 2, model 3 has relatively low R^2 of only 14%.

The regression model predicting the performance of *asx* showed a similar result as Model 2 predicting the performance of *jse*. The R^2 of this model was almost 14%, which seemed like a reasonable value. In addition, all independent variables had practical significance. However, the performance of *euronext* from a previous day is the first independent variable in regressions introduced so far that was not statistically significant.

Regression models predicting the performance of *jse* and *asx* showed that predicting the performance of smaller markets is more difficult, as those markets are less correlated to major markets around the world. The R^2 of the models was smaller compared to the prediction of US markets. The two models can explain over 10% of the index's predicted performance, which can be a significant factor for investors.

6.3. Influence of Markets on each Other

Lastly, this research explored the influence of western markets on Asian markets around the world and vice versa. While the previous two subsections used returns from trading hours for the creation of predicting regression models, this subsection considered the influence of returns during the trading hours of one market on the returns of another market's after-hours trading. The underlying assumption is that it is highly unlikely the after-hours trading performance in one market could affect the trading hours performance in another market. Hence, the research always measures the influence of the trading hours performance in one market on the after-hours performance in another market. Unfortunately, returns from both trading and after hours are present only for four indexes (*topix*, *sse*, *euronext*, *sp*).

Table 14: Interdependence of Markets

Dependent Variables (After Hours Trading)	*Independent Variables (Trading Hours)*			
	sp_lag	**euronext_lag**	**topix**	**sse**
sp	-	-	-.0081 (.0134) [R]	.0252 ** (.0103) [R]
euronext	-	-	-.0065 (.0168) [N]	.0869 *** (.0153) [N]
topix	.0986 *** (.0129) [R]	-.0208 (.0189) [N]	-	-
sse	.1830 *** (.0178) [N]	.1804 *** (.0192) [N]	-	-

R denotes usage of robust errors, N denotes usage of Newey West Standard Errors * indicates 10% level of significance, ** 5%, *** 1%

Note: The table presents a result of 8 different regressions with one dependent and one independent variable. Values along the side present variables being predicted in a regression, while variables along the top present independent variables. A value on the first row of a cell then represents the coefficient of independent variables, along with the indication of significance. A value on the second row then indicates standard errors, along with an indication of type of errors used. Since the section focuses only on the relation between the two variables, the time trend and the constant are not shown. For a full result of each regression, please refer to appendix 6.1. Results presented in the table suggest that smaller markets are more influenced by larger markets. Additionally US markets have a significant effect Japanese markets.

Several conclusions can be drawn from the results presented in the Table 14. Most importantly, the results of *sse* (China) suggest that smaller markets are more influenced in after-hours trading by larger markets, such as US and Eurozone. Surprisingly, the performance of Chinese markets has a notable effect on after-hours trading in US and Eurozone, even though the impact is rather statistically significant than practically significant. On the other hand, the influence of Japanese markets seems to be non-existent compared to the effect of Chinese markets. As expected, the effect of US markets on other markets around the world is very significant. The effect of the US markets on the Chinese markets is also practically significant. The fact that *euronext* does not seem to have as high of an effect on Japanese markets could be explained by the overlapping US and Eurozone markets for a decent portion of trading hours. However, one would expect that *euronext* would show a weaker influence on Chinese markets as well, but that is not the case.

6.4. Conclusion

As expected, predicting the performance of stock markets was extremely difficult. If a reliable prediction model could be found, it would be quickly exploited by investors. Nonetheless, the research presented a simple model predicting the performance of the S&P 500. Surprisingly, the regression model showed a high R^2. The prediction of smaller markets showed to be more difficult, as not all independent variables were statistically and practically significant. In addition, the regression models showed a much lower R^2. However, this aligned with the previous section of this research, which found that smaller markets are less correlated to other markets around the world. Lastly, researching the potential influence of markets on each other turned out to be even more difficult, as results were not uniform and often went against

expectations. However, it can be concluded that during after-hours trading, smaller markets are more vulnerable to movements in large markets, especially the US markets.

Section 7: Conclusion

International diversification of portfolios became a norm for US investors in the 21st century. This thesis summarizes several key aspects of international investing each investor should keep in mind while investing abroad.

Foreign exchange risk plays a critical role when investing abroad and the behavior of currency tied to the investment country should be well known by investors. Generally, smaller currencies tend to move similarly against the US dollar, requiring investors to have a solid understanding of the US dollar performance. The Chinese Yuan is an exception, as the currency is not nearly as volatile. Correlation between the performance of a stock exchange and its currency is not particularly large, but it increases during times of greater volatility. While the magnitude is not as large, the direction of correlation for each market tends to persist over time, giving an idea to investors of how to protect themselves. Most importantly, investors should know which stock exchanges are most affected by their respective currencies. According to this research, the performance of *euronext* (Eurozone), *topix* (Japan), and *jse* (South Africa) is significantly affected by their respective currencies and investors should consider hedging against the currency risk when investing in those markets.

Another important factor investors should consider is the increase in correlations across global equity markets over time. Especially notable, is the effect on the two historically largest markets, the US and Japan, whose correlation nearly doubled over the last 40 years. Altogether with the peak in correlation across global markets during the Great Recession, investors seeking diversification should know what the correlation of selected market is against the US markets.

For example, given the large correlation between the US and Japan, investing in Japan might not provide the diversification benefit one would hope for. In addition, predicting the performance of smaller markets is significantly harder compared to large markets such as the US. Therefore, investors truly seeking international diversification might need to invest in smaller markets around the world.

While this thesis provided a broad overview of international markets for investors, future research with more sophisticated mathematical models is needed. Based on the results of this research, future research should focus on the specific effect of greater volatility, both positive and negative, in the markets and how those periods of time affect international investing.

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Appendix

Appendix 3.1: Descriptive Statistics of Data Collected

Table 15: Descriptive Statistics of All Variables Collected

Variables	Obs	Mean	St Dev	Min	Max
sp_openclose	12,307	0.00030	0.00991	-0.2047	0.1079
sp_closeopen	12,306	0.00003	0.00286	-0.0954	0.0573
sp_24h	12,306	0.00033	0.01032	-0.2039	0.1067
topix_openclose	11,050	0.00004	0.00951	-0.0896	0.1606
topix_openclose_fxadj	7,031	0.00010	0.01335	-0.0810	0.1686
topix_closeopen	11,049	0.00043	0.00814	-0.1304	0.1408
topix_closeopen_fxadj	7,031	0.00058	0.01049	-0.0946	0.1216
topix_24h	11,049	0.00047	0.01277	-0.1145	0.1505
topix_24h_fxadj	7,031	0.00062	0.01614	-0.1221	0.1309
asx_openclose	5,541	0.00013	0.00733	-0.0735	0.0476
asx_openclose_fxadj	5,541	0.00020	0.01168	-0.1350	0.1380
asx_closeopen	-	-	-	-	-
asx_closeopen_fxadj	-	-	-	-	-
asx_24h	5,540	0.00030	0.00956	-0.0967	0.0756
asx_24h_fxadj	5,540	0.00037	0.01272	-0.1725	0.0844
ibovespa_openclose	-	-	-	-	-
ibovespa_openclose_fxadj	-	-	-	-	-
ibovespa_closeopen	5,435	0.00181	0.02521	-0.2582	0.4120
ibovespa_closeopen_fxadj	5,433	0.00083	0.02752	-0.2731	0.2943
ibovespa_24h	5,435	0.00181	0.02521	-0.2582	0.4120
ibovespa_24h_fxadj	5,433	0.00083	0.02752	-0.2731	0.2943
jse_openclose	4,915	0.00035	0.00979	-0.0730	0.0707
jse_openclose_fxadj	4,915	0.00019	0.01572	-0.2034	0.1177
jse_closeopen	-	-	-	-	-
jse_closeopen_fxadj	-	-	-	-	-
jse_24h	4,914	0.00060	0.01305	-0.1186	0.1087
jse_24h_fxadj	4,914	0.00042	0.01702	-0.1697	0.1098
sse_openclose	4,443	0.00065	0.01463	-0.0909	0.0818
sse_openclose_fxadj	4,438	0.00071	0.01472	-0.0902	0.0835
sse_closeopen	4,442	-0.00027	0.00884	-0.0863	0.0909
sse_closeopen_fxadj	4,437	-0.00025	0.00881	-0.0857	0.0909
sse_24h	4,442	0.00040	0.01812	-0.1095	0.1359
sse_24h_fxadj	4,437	0.00041	0.01808	-0.1107	0.1341
euronext_openclose	3,893	-0.00017	0.01045	-0.0584	0.0697
euronext_openclose_fxadj	3,892	-0.00010	0.01252	-0.1169	0.0975
euronext_closeopen	3,892	0.00030	0.00952	-0.1048	0.0624
euronext_closeopen_fxadj	3,892	0.00037	0.01213	-0.1378	0.0828
euronext_24h	3,892	0.00013	0.01428	-0.1175	0.1037

Variables	Obs	Mean	St Dev	Min	Max
euronext_24h_fxadj	3,892	0.00021	0.01612	-0.1430	0.1068
eurusd	3,892	0.00007	0.00691	-0.0763	0.0535
cnyusd	4,438	0.00006	0.00113	-0.0182	0.0205
jpyusd	7,031	0.00008	0.00725	-0.0604	0.0720
zarusd	4,934	-0.00018	0.01112	-0.1436	0.0685
brlusd	5,450	-0.00101	0.01138	-0.1535	0.1090
audusd	5,555	0.00006	0.00827	-0.1309	0.0863

Note: The table shows the number of observations, daily mean, standard deviation of daily returns, minimum and maximum one-day change for all variables collected. Missing data suggest that particular type of data was not provided by Yahoo Finance, as summarized in Table 3.

Appendix 5.1: Correlation Across Markets Over Time

Table 16: Correlation Across Markets between 1988 and 1992

1988 - 1992	sp		topix	
	corr	Δ(%)	corr	Δ(%)
sp	1.000			
topix	0.650	4.9%	1.000	
asx	0.516	-	0.273	-

Note: The table shows correlation across three markets (US, Japan, and Australia) in period between 1988 and 1992. A change in correlation from previous period is also included.

Table 17: Correlation Across Markets between 1993 and 1997

1993 - 1997	sp		topix		asx		ibovespa		jse	
	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)
sp	1.000									
topix	0.676	4%	1.000							
asx	0.314	-39%	0.284	3.9%	1.000					
ibovespa	0.287	-	0.258	-	0.234	-	1.000			
jse	0.428	-	0.531	-	0.457	-	0.477	-	1.000	
sse	-0.214	-	-0.220	-	-0.241	-	-0.283	-	-0.222	-

Note: The table shows correlation across five markets (US, Japan, Australia, Brazil, and South Africa) in period between 1993 and 1997. A change in correlation from previous period is also included.

Table 18: Correlation Across Markets between 1998 and 2002

1998 - 2002	sp		topix		asx		ibovespa		jse		sse	
	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)
sp	1.000											
topix	0.662	-2%	1.000									
asx	0.192	-39%	0.092	-68%	1.000							
ibovespa	0.419	46%	0.337	31%	0.174	-26%	1.000					
jse	0.412	-4%	0.459	-13%	0.161	-65%	0.309	-35%	1.000			
sse	-0.024	-89%	-0.028	-87%	0.052	-122%	-0.033	-88%	0.021	-110%	1.000	
euronext	0.600	-	0.536	-	0.083	-	0.355	-	0.433	-	0.051	-

Note: The table shows correlation across six markets (US, Japan, Australia, Brazil, South Africa, and China) in period between 1998 and 2002. A change in correlation from previous period is also included.

Table 19: Correlation Across Markets between 2003 and 2007

2003 - 2007	sp		topix		asx		ibovespa		jse		sse	
	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)
sp	1.000											
topix	0.742	12%	1.000									
asx	0.066	-66%	0.027	-71%	1.000							
ibovespa	0.622	48%	0.480	42%	0.109	-37%	1.000					
jse	0.279	-32%	0.144	-69%	0.213	33%	0.323	4%	1.000			
sse	0.090	-475%	0.031	-207%	0.095	83%	0.150	-554%	0.112	423%	1.000	
euronext	0.766	28%	0.610	14%	-0.004	-105%	0.484	36%	0.293	-32%	0.055	9%

Note: The table shows correlation across six markets (US, Japan, Australia, Brazil, South Africa, and China) in period between 2003 and 2007. A change in correlation from previous period is also included.

Table 10: Correlation Across Markets between 2008 and 2012

2008 - 2012	sp		topix		asx		ibovespa		jse		sse	
	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)
sp	1.000											
topix	0.758	2%	1.000									
asx	0.305	364%	0.184	591%	1.000							
ibovespa	0.721	16%	0.476	-1%	0.322	196%	1.000					
jse	0.420	50%	0.188	30%	0.400	88%	0.539	67%	1.000			
sse	0.336	275%	0.191	526%	0.099	4%	0.388	159%	0.265	136%	1.000	
euronext	0.768	0%	0.696	14%	0.198	-4647%	0.618	28%	0.379	29%	0.202	264%

Note: The matrix shows correlation across markets in the 2008-2012 segment. Value to the right from the correlation shows the percentage increase from the 2002-2007 segment. The table clearly shows that nearly all correlations across markets increased during the time segment that contained the Great Recession and subsequent recovery. The percentage change in correlation between euronext and asx shows a large negative change, which was caused by a very low negative correlation in preceding 5-year segment.

Table 20: Correlation Across Markets between 2013 and 2017

2013 - 2017	sp		topix		asx		ibovespa		jse		sse	
	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)	corr	Δ(%)
sp	1.000											
topix	0.685	-10%	1.000									
asx	0.143	-53%	0.029	-84%	1.000							
ibovespa	0.392	-46%	0.183	-61%	0.168	-48%	1.000					
jse	0.342	-18%	0.110	-41%	0.231	-42%	0.337	-37%	1.000			
sse	0.234	-30%	0.060	-69%	0.042	-57%	0.180	-54%	0.238		1.000	
euronext	0.625	-19%	0.544	-22%	0.089	-55%	0.287	-53%	0.348	-8%	0.125	-38%

Note: The table shows correlation across six markets (US, Japan, Australia, Brazil, South Africa, and China) in period between 2013 and 2017. A change in correlation from previous period is also included.

Appendix 6.1: Results of Individual Regressions Presented in Table 14

Model 4: Regression Exploring the Influence of Japanese Trading on US After Hours

$$\widehat{sp\_co} = \beta_0 + \beta_1 \ topix\_oc \ + \beta_2 \, t + u$$

Table 21: Results of Regression Exploring the Influence of Japanese Trading on US After Hours

	Coefficients	**Robust Standard Error**	**t-statistic**
Japan	-.0081	.0134	-0.60
Constant	-.0036	0	1.87
Adj. R^2	.0015		
n	2,232		

Time trend variable became 0 after rounding * indicates 10% level of significance, ** 5%, *** 1%

Note: The table shows results of regression that explores the influence of independent variable trading hours on dependent variable's after-hours trading.

Model 5: Regression Exploring the Influence of Chinese Trading on US After Hours

$$\widehat{sp\_co} = \beta_0 + \beta_1 \ sse\_oc \ + \beta_2 \, t + u$$

Table 22: Results of Regression Exploring the Influence of Chinese Trading on US After Hours

	Coefficients	**Robust Standard Error**	**t-statistic**
China	.0252 **	.0103	2.44
Constant	-.0034	.0020	-1.79
Adj. R^2	.0074		
n	2,232		

Time trend variable became 0 after rounding * indicates 10% level of significance, ** 5%, *** 1%

Note: The table shows results of regression that explores the influence of independent variable trading hours on dependent variable's after-hours trading.

Model 6: Regression Exploring the Influence of Japanese Trading on Eurozone's After Hours

$$\widehat{euronext\_co} = \beta_0 + \beta_1\ topix\_oc\ + \beta_2\ t + u$$

Table 23: Results of Regression Exploring the Influence of Japanese Trading on Eurozone's After Hours

	Coefficients	**Newey-West Standard Error**	**t-statistic**
Japan	-.0065	.0168	-0.39
Constant	-.0011	.0014	-0.77
Adj. R^2	.0000		
n	3,892		

Time trend variable became 0 after rounding * indicates 10% level of significance, ** 5%, *** 1%

Note: The table shows results of regression that explores the influence of independent variable trading hours on dependent variable's after-hours trading.

Model 7: Regression Exploring the Influence of Chinese Trading on Eurozone's After Hours

$$\widehat{euronext\_co} = \beta_0 + \beta_1\ sse\_oc\ + \beta_2\ t + u$$

Table 24: Results of Regression Exploring the Influence of Chinese Trading on Eurozone's After Hours

	Coefficients	**Newey-West Standard Error**	**t-statistic**
China	.0869 ***	.0153	5.66
Constant	-.0006	.0014	-0.46
Adj. R^2	.0172		
n	3,892		

Time trend variable became 0 after rounding * indicates 10% level of significance, ** 5%, *** 1%

Note: The table shows results of regression that explores the influence of independent variable trading hours on dependent variable's after-hours trading.

Model 8: Regression Exploring the Influence of US Trading on Japanese After Hours

$$\widehat{topix\_co} = \beta_0 + \beta_1\ sp\_oc\_lag\ + \beta_2\, t + u$$

Table 25: Results of Regression Exploring the Influence of US Trading on Japanese After Hours

	Coefficients	**Robust Standard Error**	**t-statistic**
United States (t-1)	.0987 ***	.0129	7.63
Constant	.0001 *	.0002	1.91
Adj. R^2	.0154		
n	11,049		

Time trend variable became 0 after rounding * indicates 10% level of significance, ** 5%, *** 1%

Note: The table shows results of regression that explores the influence of independent variable trading hours on dependent variable's after-hours trading.

Model 9: Regression Exploring the Influence of Eurozone Trading on Japanese After Hours

$$\widehat{topix\_co} = \beta_0 + \beta_1\ euronext\_oc\_lag\ + \beta_2\, t + u$$

Table 26: Results of Regression Exploring the Influence of Eurozone Trading on Japanese After Hours

	Coefficients	**Newey-West Standard Error**	**t-statistic**
Eurozone (t-1)	-.0208	.0189	-1.11
Constant	.0005	.0017	0.28
Adj. R^2	.0000		
n	3,892		

Time trend variable became 0 after rounding * indicates 10% level of significance, ** 5%, *** 1%

Note: The table shows results of regression that explores the influence of independent variable trading hours on dependent variable's after-hours trading.

Model 10: Regression Exploring the Influence of US Trading on Japanese After Hours

$$\widehat{sse\_co} = \beta_0 + \beta_1\ sp\_oc\_lag\ + \beta_2\, t + u$$

Table 27: Results of Regression Exploring the Influence of US Trading on Chinese After Hours

	Coefficients	**Newey-West Standard Error**	**t-statistic**
United States (t-1)	.1831 ***	.0178	10.28
Constant	.0054 ***	.0009	5.77
Adj. R^2	.0658		
n	4,442		

Time trend variable became 0 after rounding * indicates 10% level of significance, ** 5%, *** 1%

Note: The table shows results of regression that explores the influence of independent variable trading hours on dependent variable's after-hours trading.

Model 11: Regression Exploring the Influence of Eurozone Trading on Chinese After Hours

$$\widehat{sse\_co} = \beta_0 + \beta_1\ euronext\_oc\_lag\ + \beta_2\, t + u$$

Table 28: Results of Regression Exploring the Influence of Eurozone Trading on Japanese After Hours

	Coefficients	**Newey-West Standard Error**	**t-statistic**
Eurozone (t-1)	.1804 ***	.0192	9.39
Constant	.0052 ***	.0012	4.39
Adj. R^2	.0475		
n	3,892		

Time trend variable became 0 after rounding * indicates 10% level of significance, ** 5%, *** 1%

Note: The table shows results of regression that explores the influence of independent variable trading hours on dependent variable's after-hours trading.