How Many Mutual Funds Do You Need to Create a Diversified Portfolio?

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จำนวนกองทุนที่เพียงพอในการใช้กระจายความเสี่ยงของพอร์ตโฟลิโอกองทุนรวม

น.ส.รุจิรา เลิศสวัสดิ์วงศ์

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The goals of this study are to examines diversification benefit when holding multiple equity funds in the portfolio for Thai market and identify the optimal number of equity funds that enough to eliminate diversifiable risk. Moreover, this study examines whether considering adding index funds in the portfolio better reduce portfolio volatility.

By creating random portfolio and measure the risks by using historical return, the empirical results suggest that holding multiple funds in the mutual fund portfolio allow investor achieve diversification benefits, but in the decreasing rate. These findings are consistent with previous study of O'Neal (1997), Potter (2001) and Lhabitant and Learned (2002) for U.S. market and Brands and Gallagher (2005) for Australian market. Additionally, the result from this study suggest that holding 13-14 funds is enough to eliminate diversifiable risk for Thai active equity fund portfolio, which is slightly more than U.S and Australian market. Also, considering including index funds in the equity fund portfolio can help slightly reduce portfolio volatility more than investing in only active funds.

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Field of Study:	Finance	Student's Signature .....
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Chapter 1
Introduction

Diversification is a well-known investment strategy of portfolio management which aims to reduce volatility of portfolio over time by investing in variety of different assets. Diversification can be employed by using mathematical models to find the optimal portfolio, which be known as Markowitz diversification. There is also another approach called Naive diversification which is the simple way to compose the diversified portfolio by equally assign the weight among the assets without an analysis of the risk, returns and covariance between assets or any sophisticated mathematical models.

Evan and Archer (1968) have examined the reduction of portfolio standard deviation by increasing number of stock holdings. They conduct the simulation by randomly selecting stocks into the portfolio and using equal weighting scheme. His simulation result suggests that most of the portfolio risk, measured by standard deviation, is eliminated by holding about 10 stocks in the portfolio.

After that, due to the simplicity of the methodology, the subsequent studies have followed Evan and Archer approach and some studies have extended their work to different market, holding period, risk measurement, etc. Most of studies agree on that the risk of portfolio will reduced when increases the number of stocks in the portfolio. However, the number of assets required to create diversified portfolio from those studies is different, ranging from 8 to above 100, depending on the market, the investment horizon, and the measure of risk.

To measure the risk from the investment, in practical, most of investor concern about the volatility of their terminal wealth more than the volatility during the holding period. Therefore, Radcliffe (1994) have proposed that standard deviation of terminal wealth should be used rather than time series standard deviation, especially for the long-term investment, as it reflects the risk to the money that investors will get at the end of their holding period.

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Most of past studies have focused on the developed markets. However, some studies find that the optimal number of stocks, to make portfolio diversified, depend on the specific stock market.

Later, a few of researchers have extended the previous studies by using mutual funds instead of stocks, as in general, investors can easily diversify their portfolio by investing through the mutual funds. However, although mostly mutual funds comprise of many assets in the portfolio, several past studies find that holding only one mutual fund is not able to reduce investment risk sufficiently and the number of funds that should be included in the portfolio in order to achieve diversification benefit are ranging from 5 to 10.

O'Neal (1997) and Brands and Gallagher (2005) have studied the impact of holding more than one mutual fund on the expected volatility of investors' return in the U.S. market and Australian market, respectively. They find that the volatility, which are measured by standard deviation of time series returns and terminal wealth of equity fund, is reduced when increase number of funds in the portfolio.

Most of past studies are primary examine the impact of increasing number of stocks on portfolio volatility. However, mutual funds become more popular among investors, both institutional and retail. In Thailand, mutual fund industry is continuously growing for many years. According to the Association of Investment Management Companies (AIMC), Thai mutual fund industry has 5.06 trillion baht of total assets under management (AUM) as at December 31, 2019.

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Therefore, this paper aims to investigate the diversification benefit when adding more mutual funds in the mutual fund portfolio with the 3 objectives as follow.

The first objective is to test whether adding more funds in the portfolio reduce the portfolio volatility. According to the past studies on the diversification for both equity and mutual fund, they find that increasing number of assets in the portfolio can reduce the portfolio risk. In order to measure the volatility of portfolio that consists of mutual fund, this study will use the time series standard deviation as well as the terminal wealth standard deviation. However, since the time series standard deviation and terminal wealth standard deviation take into account both positive and negative deviation from the mean, but normally investor does not view the positive deviation

as the risk of the portfolio. Therefore, this paper will examine the impact of adding more mutual funds in the portfolio reduce the portfolio negative volatility of terminal wealth by using mean variance and semi-variance as the measure of downside risk. According to the O'Neal (1997), he finds that increasing number of assets in the portfolio can reduce not only the volatility of returns but also the downside risk of terminal wealth as well.

Next objective is to find the optimal number of equity funds that enough to eliminate diversifiable risk. Since adding more assets cannot reduce total risks of the portfolio, there will be some level of risk that remains in the portfolio which called systematic risk. Moreover, holding multiple funds can incur the costs to the investor, such as front-end fees, especially for the active equity funds. According to the past studies in the developed market, 5-10 funds are required to make mutual fund portfolio well diversified. Therefore, this study will find the optimal number of equity funds that enough to eliminate diversifiable risk for the Thai market.

The last objective is to find whether considering adding index funds or passive funds to a portfolio better reduce portfolio volatility. Nowadays, many professionals offer the investment of "active blended with passive" instead of "active versus passive". This is because investing in only active fund may allow investor expose to the additional risk called active risk, as fund managers need to take active positions different from the market to generate additional return. In addition, index funds or passive strategies can offer markets exposure with lower cost compared to the active strategy. Therefore, this study will examine whether when the sample funds comprise of both active and passive fund can reduce volatility as well as downside risk faster than portfolio of pure active fund.

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Up until now, there are very few researches that study the number of mutual funds needed to create diversified portfolio. Moreover, all those previous researches have examined on the effects of holding multiple mutual funds on volatility in the developed market, such as U.S. market and Australian market. Therefore, this research has typically studied for the Thai equity fund to represent the result from one of emerging market. Normally, emerging stock market is more volatile than the developed market as it is likely to experience additional risks due to political instability, poor corporate governance, and immature regulatory and legal systems.

According to the volatility of Thai and U.S. market, the standard deviation of return for S&P 500 Index and SET index during 2010-2019 are 12.46% and 14.25%, respectively.

Moreover, this paper is the first paper that study the impact on mutual fund portfolio volatility when include the index funds into the sample set, while the previous studies use only active equity funds. Blending active and passive strategies in the portfolio supposed to decrease portfolio volatility and reduce the costs more than portfolio with purely active equity funds which expose to the additional risks, since fund managers seeks to beat the market return.

Additionally, nowadays not only institutional investors that use mutual fund as an investment vehicle and have specific investment horizon, but many retail investors are also invest in mutual fund for the specific period and quite in long term. For example, Long Term Equity Fund (LTF), Retirement Mutual Fund (RMF), and Super Saving Funds (SSF) are the special type of mutual funds that require investors to hold for specified period in order to get tax benefits. However, investing in only 1 or 2 funds may not help to reduce the risks of long-term investment sufficiently. Therefore, long-term investor, including institutional investor, can achieve diversification benefit by holding several funds in the mutual fund portfolio.

The results of this study suggest that holding multiple funds in the equity fund slightly reduce time-series standard deviation, but significantly decrease terminal wealth standard deviation. In addition, downside deviation of terminal wealth, which are measured by mean shortfall and semi-variance, are significantly reduced when increase the number of funds in the portfolio. However, the marginal diversification benefits also decreased when the number of funds increase. The result from this study also suggest that holding 13-14 funds is enough to eliminate diversifiable risk for Thai active equity fund portfolio. Moreover, considering including index funds in the equity fund portfolio can help reduce portfolio volatility greater than investing in only active funds. In addition, it also offers lower cost to the investor as normally index funds have lower fees than active funds.

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Chapter 2
Literature Review

According to the work of Markowitz (1952) on the portfolio selection, the risk of individual stock returns comprises of unsystematic risk and systematic risk. Unsystematic is the specific risk of the individual stock which can be eliminated when increase the number of stocks in the portfolio, while systematic risk is the market risk that cannot diversified away. Therefore, investor should invest in multiple assets to reduce the risk of their portfolio, only if the correlation between the assets is less than one, many studies have examined the relationship between portfolio size and the level of portfolio risk.

Evans and Archer (1968) study the impact of increasing number of securities held in the portfolio on the variation of returns. They run the simulation by assuming that investors buy stock randomly and equally invest in each stock. Using data of the stocks listed in S&P index for 10 years, from 1958 to 1967, they find that majority of the portfolio risk, measured by standard deviation of the semi-annual returns, is eliminated by holding about 10 stocks in the portfolio.

Upson, Jessup and Matsumoto (1975) find that when using time series standard deviation to measure the risk, the small numbers of stocks are needed to make diversified portfolio, but when using cross sectional measure of risk, the larger number of stocks are needed to achieve diversification.

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Radcliffe (1994) have suggested that investors are normally interest in their terminal wealth or the expected value of their investment at the end of holding period. Therefore, to measure portfolio risk for long term investment, standard deviation of terminal wealth should be used rather than time series standard deviation.

Lhabitant (2017) has summarized some studies regarding the number of assets required to make portfolio diversified. The studies before early of 1980s mostly find that 8 to 30 stocks are enough to create well-diversified portfolio, while after the mid-1980s, the numbers of stocks required increase to more than 100 before and backing to lower level in the late 2000s. These number are different because of the different in the market, the measure of risk, investment horizon.

Benjelloun (2010) extends the study from Evans and Archer by studied in other measure of risk, different weighting scheme and different time periods. Apart from time series standard deviation, he also measured portfolio risk by using terminal wealth standard deviation (TWSD), to resolve the ignorant of cross-sectional risk. Monthly return of U.S. stock return during 1980-2000 is used in the simulation. After running regression, he found that forty to fifty stock is needed to achieve the diversification in the U.S. stock market regardless of how the risk is measured.

Although most of previous studies on the impact of portfolio size on the reduction of investment risk has focused on the U.S stock market, there are some papers that study in other developed markets than the U.S. market. Solnik (1974) performs the study for U.S and major seven European stock markets and finds that the risk of a portfolio decreases in all countries, and the U.S. market gains more risk reduction from diversification than European stock markets since the U.S. market is larger. Alexeev and Tapon (2012) study on the optimal number of securities that investor should hold in order to reduce the diversifiable risk. They find that the optimal portfolio size is different depend on the measure of risk, and the specific stock market. They recommend that the number of stocks needed to create diversified portfolio are 40 to 70 stocks for the US, from 30 to 65 for the UK, from 30 to 50 for Japan; from 20 to 50 for Canada; and from 30 to 50 for Australia.

In addition, many researches also extend the study on the diversification achievement from holding various numbers of mutual funds in the portfolio.

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O'Neal (1997) examines the impact of holding more than one mutual fund on the expected volatility of investors' return as well as their terminal wealth. He uses the quarterly return of U.S. mutual funds and constructed the simulations by random selection and equally weighting. Besides time series standard deviation, he also adds one more measure of risk, which is terminal wealth standard deviation as he believes that it is more appropriate to measure portfolio risk for investors who plan their investment for pre-specified period. The simulations suggest that the increasing number of mutual funds holding slightly reduce the time series standard deviation of portfolio return, but it significantly reduces the terminal wealth standard deviation, which was greater decreased for the longer holding period. However, he finds that the marginal benefit of holding more mutual funds decreases when the numbers of funds

increase. The paper also considers the downside risks and suggests that mean shortfall and semi-variance are reduced by holding more mutual funds in the portfolio.

Another study of the U.S. mutual funds is proposed by Potter (2001). This study employs the random simulation for 7 fund categories, which are aggressive growth, asset allocation, balanced, equity income, growth, growth & income, and small company. He finds that more than 5 funds should be held in order to eliminate most of the portfolio risk, for most of the fund categories. However, there is still some proportion of risk that remains even after portfolios of twenty funds are created

Even for the hedges fund, Lhabitant and Learned (2002) find that when randomly and equally adding more funds to a portfolio, portfolio return tends to stable, but the standard deviation as well as downside risk decrease. They also suggest the portfolio of 5 to 10 hedge funds provides most of the diversification benefits.

Brands and Gallagher (2005) provide a study of portfolio performance as a function of the number of funds in the fund of funds portfolio. Using monthly return data from Australian equity funds during 1989-1999, they find that, on average, the volatility which is measured by standard deviation of time series return and terminal wealth is reduced as increasing number of funds in the portfolio, while the mean return remains constant as the number of funds increase. In addition, the paper suggests that most diversification benefits are achieved when including approximately 6 active equity funds in portfolio.

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Chapter 3
Data

3.1 Data

As the purpose of this study is to identify the effect on volatility when increase the number of funds with same investment objective in portfolio, therefore, this paper will focus on diversification by adding only equity fund in the portfolio. At the present, Association of Investment Management Companies (AIMC) has divided Thai equity fund into 3 categories based on their investment policy and their characteristics. Firstly, Equity general is for the funds that invests at least 80% of its total net assets in Thailand equities. Secondly, Equity Small – Mid Cap is for the fund that invests in Thailand equities which having the market capitalization less than 50,000 MB at least 80% of its total net assets. Thirdly, Equity Large Cap is for the fund that invests at least 80% of its total net assets in Thailand equities that are in the constituent of SET 50 Index. In addition, there is another type of equity fund called the index fund. The index fund is the fund that has a passive management strategy which aims to track the benchmark index, such as SET50 Index, SET100 Index.

The data used for this study, which consists of monthly total return of Thai equity fund during 2010-2019, are collected from Morningstar direct. The monthly total return from Morningstar are calculated by taking the change in monthly net asset value, reinvesting all income and capital-gains distributions during that month, and dividing by the starting NAV. and I do expect that the sample will not significantly suffer from the survivorship bias as there are very few obsolete funds in such period. In addition, only primary share class of each fund will be included in the dataset, as the fund with more than one share class has the same investment objectives as well as portfolio constituents, but different in distribution policy, fees or other requirements.

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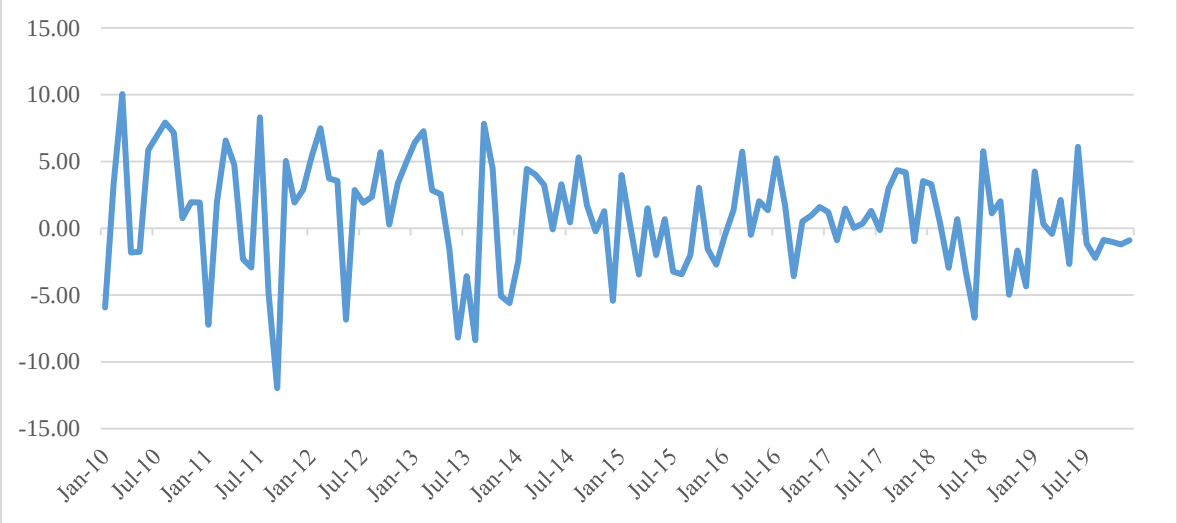
3.2 Data Descriptive

The overview of historical return of Thai active equity fund during 2010-2019 is shown in Figure 1. On average, Thai active fund has performed positively after 10 years. However, there are some events that cause equity fund returns significantly drop during the period, such as severe flooding in 2011, Anti-government protests in

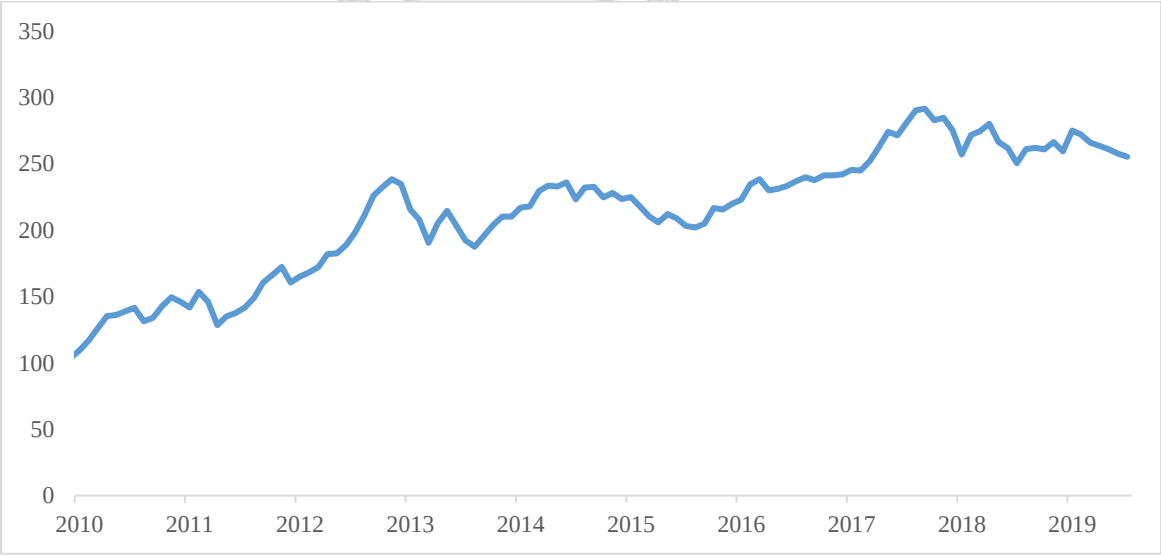
2013-2014, Bangkok bombing in 2015, and concerns of U.S.-China trade wars in 2018

Figure 1: Historical Monthly Return of Thai Active Equity Fund (2010-2019)
This figure shows the historical monthly total return of 147 Thai active equity funds during January 2010 – December 2019, which are plotted by using monthly return



Source: Morningstar Direct

Figure 2: Average Cumulative Wealth from Investing in Thai Active Equity Fund (2010-2019)
This figure shows the average cumulative wealth from investing in 147 Thai active equity funds during January 2010 – December 2019, which are plotted by using monthly return and assume that initial investment is equal to 100



Source: Morningstar Direct

The summary statistics of Thai active equity fund performances during 2010-2019 for are shown in the Table 1. The data includes minimum, maximum and mean of the fund performance. The sample funds in the consideration comprise of 147 active equity funds which have full track record during 2010-2019. The best-performing fund can achieve return around 1.2599% per month (15.1192% per year) for this 10 year, which is 10% more than the worst one. The standard deviation of monthly return for all of funds are ranging from 2.8008% to 5.0012% (or 9.7021% to 17.3247% per year). On average, monthly return and standard deviation of active equity fund monthly return during 2010-2019 are 0.8642% and 4.1933% per month (10.3708% and 14.5261% per year) respectively. The 10-year terminal wealth returns of the 147 active equity funds are ranging between 143.8248% to 406.6924% of the initial investment. On average, investing in active funds can earn return around 256.4398% of the initial investment with standard deviation of 43.0079%.

Table 1: Summary statistics of active equity fund during 2010-2019
Table 1 shows summary statistics of active equity funds performance, which is calculated by using monthly returns. The samples are the active equity funds which have full track record during January 2015 – December 2019

	Count	Minimum	Maximum	Mean
Average monthly return (%)	147	0.3815	1.2599	0.8642
Average standard deviation of monthly return (%)	147	2.8008	5.0012	4.1933
10-year terminal wealth return (%)	147	143.8248	406.6924	256.4398

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Since one of the objectives of this study is to examine whether adding index funds into a portfolio better reduce portfolio volatility, but during 2010-2019, there are only 8 index funds which have full track record. Therefore, to increase the sample of index fund, I will use the data of the equity funds during 2015-2019, which comprise of 178 active funds and 15 index funds in order to answer the above objective. Table 2 is the descriptive statistics of return, standard deviation of return and terminal wealth of equity funds during 2015-2019 for different management styles.

According to Table 2, since the performance of active funds depends on capability of each fund manager, the annualized return of active funds has wider range than the index funds. The best-performing active fund can achieve average return of

0.7457% per month (8.9486% annually) while the worst-performing fund loses around -0.3173 per month (or -3.8070% annually). In the meantime, all index funds can earn positive return during this 5-year period, ranging between 0.3093% to 0.4757% per month (3.7118% to 5.7085% per year). In addition, on average, index funds slightly outperform active funds in terms of both time series return as well as 5-year terminal wealth return. Meanwhile, the annualized standard deviation between these two management styles are not significantly different. This is consistent with the article from Morningstar Thailand (2018), which indicate that SET 50 Index Fund has higher average return than actively managed equity large cap fund, but also has slightly higher standard deviation. Moreover, there are some type of active funds that offer lower standard deviation, such as smart beta, or equity70-30 (equity portion 70% of NAV). Additionally, for the 5-year terminal wealth return, index funds offer the higher terminal wealth return around 5% on average, but standard deviation of terminal wealth return is lower.

Table 2: Summary statistics of active funds and index funds performance during 2015-2019
Table 2 shows summary statistics of equity funds performance for different management styles, which is calculated by using monthly returns. The samples are the active equity funds and index funds which have full track record during January 2015 – December 2019

	Count	Minimum	Maximum	Average
Active fund				
Average monthly return (%)	178	-0.3173	0.7457	0.2729
Average standard deviation of monthly return (%)	178	2.0235	4.2880	3.0286
5-year terminal wealth return (%)	178	79.3102	149.3593	115.0995
Index fund				
Average monthly return (%)	15	0.3093	0.4757	0.3644
Average standard deviation of monthly return (%)	15	2.9961	3.2512	3.1758
5-year terminal wealth return (%)	15	116.8775	129.0517	120.7395

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Chapter 4
Methodology

This study assumes that total risk of portfolio comprises of systematic risk and unsystematic risk. The unsystematic risk should be eliminated when adding more mutual funds in the portfolio until the level of risk that cannot be reduced which is called systematic risk.

4.1 To examine whether adding more mutual funds in the portfolio reduce the time series standard deviation and the terminal wealth standard deviation.

This study assumes that investment horizon is 10 years and the amount of 1 THB is invested at the beginning of the holding period. To create the random portfolio, we perform the following process.

1) Randomly select the mutual funds from the sample of 147 active equity fund.
2) Create equally-weighted portfolios that consist of 1, 2, 3, ... , 30 randomly selected active equity funds (N=30).
3) For each N-mutual fund portfolio, the random selected mutual fund portfolio is repeated for 5,000 times. (K=5,000)

Then, to see the relationship between the number of mutual funds in the portfolio and portfolio volatility, this study will calculate the portfolio volatility of the historical return, for a certain number of mutual funds in the portfolio by using 2 measurement of risk.

The first measure is the time series standard deviation (TSSD) which is a common measurement of risk, that measures the deviation of time series return from the average return. TSSD will be calculated as follow.

$$TSSD_N^i = \sqrt{\sum_{s=1}^{S} \frac{(R_s^i - \bar{R}_N^i)^2}{S-1}} \quad (1)$$

where $TSSD_N^i$ is the time series standard deviation of a N-mutual fund portfolio *i*

$R_s^i = \sum_{j=1}^{N} \frac{r_{j,s}^i}{N}$ is the return of portfolio i at time s

$r_{j,s}^i$ is the return on fund j in portfolio i, at time s, and

$\bar{R}_N^i = \sum_{S=1}^{S} \frac{R_s^i}{S}$ is the average time series return, over time, of portfolio i

The average time series standard deviation of K portfolios, each size of N is calculated as follow.

$$\overline{TSSD}_N = \sum_{i=1}^{k} \frac{TSSD_N^i}{K} \quad (2)$$

Therefore, to see the relationship between the number of mutual funds in the portfolio and time series standard deviation, I will compute the mean of 5,000 time series standard deviations for each number of funds in the portfolio, which is from 1-30 funds. Then, the time series standard deviation obtained from the calculation represents the time series volatility that investor is exposed from holding certain number of mutual funds in portfolio.

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The second measure of risk used in this study is the terminal wealth standard deviation (TWSD). In practical, there are many investors, both institutional and retail investor, who plan their investment with fixed time horizon, such as retirement or long-term saving plan. Therefore, these investors will more concern about the volatility of their terminal wealth than the volatility during the holding period. Terminal wealth is the expected portfolio value at the end of the specific investment horizon, which is calculated by compounding the returns over the holding periods. The level of terminal wealth depends on the stocks included in the portfolio as well as the length of the holding period.

Standard deviation of terminal wealth is the measurement of the variation of the terminal wealth, which reflects the risk that investors probably face at the end of their investment period. This measure depends on the holding period and the asset held.

Terminal wealth standard deviation (TWSD) over K portfolio, with N mutual funds in each portfolio, is calculated as follow,

$$TWSD_N = \sqrt{\sum_{i=1}^{K} \frac{(TW_N^i - \overline{TW}_N)^2}{K-1}} \tag{3}$$

For equal weight portfolios, the terminal wealth of portfolio of N mutual funds is calculated as follow,

$$TW_N^i = \frac{1}{N} \sum_{j=1}^{N} TW_j^i \tag{4}$$

where $TW_j^i = \prod_{s=1}^{S} (1 + r_{j,s}^i)$ is the return of portfolio i at time s

$r_{j,s}^i$ is the return on fund j in portfolio i, at time s

$\overline{TW}_N^i = \sum_{j=1}^{N} \frac{TW_N^i}{K}$ is the average terminal wealth over K portfolios, with N mutual funds in each portfolio

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Therefore, to see the relationship between the number of mutual funds in the portfolio and terminal wealth standard deviation, I will compute the standard deviation of 5,000 terminal wealth for each number of funds in the portfolio, which is from 1-30 funds. Then, the terminal wealth standard deviation obtained from the calculation represents the dispersion of terminal wealth of certain number of mutual funds that investor hold in such period.

4.2 To examine whether adding more mutual funds in the portfolio reduce downside risk measured by mean shortfall and semi-variance

As the terminal wealth standard deviation (TWSD) is measured the deviation from the mean in both positive and negative side, however, investors normally not view the positive deviation as the risk of their investment. Therefore, this paper will examine the effect of the increase in mutual fund holding on downside risk.

To see the relationship between the number of mutual funds in the portfolio and portfolio downside risk, we will construct the random portfolio by using the same process as in the section 4.1. However, instead of measuring the dispersion of terminal wealth or TWSD, this paper will also more focus on the negative side of the terminal wealth by using the following downside risk measurements.

1.2.1 Mean shortfall, which will measure the deviation from the mean of the observation that below the mean. Hence, mean shortfall of the terminal wealth will be calculated as follow.

$$Mean\ shortfall = \sum_{i=1}^{N} \frac{TW_K^i - \overline{TW}_K}{K} \tag{5}$$

where $TW_K^i = TW_K^i\ if\ TW_K^i < \overline{TW}_K$ or

$\overline{TW}_K, if\ TW_K^i \geq \overline{TW}_K$

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1.2.2 Semi-variance, which is will measure the squared deviation from the mean of the observation that below the mean. This measure will give more weight on the observations which are greater below than mean, so it will suitable to measure downside risk, as investor is normally more averse with the larger downside deviation. Thus, semi-variance of the terminal wealth will be calculated as follow.

$$Semi - variance = \sum_{i=1}^{N} \frac{(TW_K^i - \overline{TW}_K)^2}{K} \tag{6}$$

where $TW_K^i = TW_K^i \; if \; TW_K^i < \overline{TW}_K$ or

$$\overline{TW}_K, if \; TW_K^i \geq \overline{TW}_K$$

4.3 To find the optimal number of equity funds that enough to eliminate diversifiable risk

In order to find the optimal number of equity funds that enough to eliminate diversifiable risk, this paper will employ the following regression model to identify the estimate of asymptote, which is the same method as Benjelloun (2010) have used in his study.

$$Y = A\frac{1}{N^2} + B \tag{8}$$

where N is the number of mutual funds in portfolio

Y is the measures of risk

A is the slope

B is the intercept, which is the estimate of the asymptote

I fit this regression model with the number of mutual funds in portfolio (N) and the measures of risk (Y), which are calculated in the previous section, in order to find slope (A) and intercept (B). As this paper has 4 measures of risk, then the regression will be evaluated 4 times to find the slope and the intercept for each measure of risk

From the regression model, when the number of mutual funds in portfolio increases, Y will converge towards B. Then, B is an estimate of the asymptote which is considered as the systematic risk. Therefore, in order to find optimal number of equity funds that enough to eliminate diversifiable risk, this study will assume that when the measure of risk (Y) is smaller than the intercept (B) with the closest value, the corresponding number of funds is the optimal number of well diversified mutual fund portfolio.

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4.4 To examine whether considering to adding index funds or passive funds to a portfolio better reduce portfolio volatility.

In 4.1- 4.3, to study the relationship between number of funds in mutual fund portfolio, I have considered only the active equity funds. Therefore, the randomly selected portfolio will consist of active equity fund only.

However, nowadays many professionals recommend that blending active and passive strategies can help investors reduce portfolio volatility, since holding only active funds on may allow investors expose to addition risk as fund managers need to take active positions different from the market to generate additional return. Hence, this study will examine whether considering to adding index funds to a portfolio better reduce portfolio volatility.

Previously, in 4.1-4.3, I assume that the holding period is 10 years (2010-2019). However, there are only 8 index funds which have full track record during 2010-2019. Therefore, to increase the sample of index fund, I will change the investment horizon to be 5 years and will use the data of the equity funds which have full track record during 2015-2019 instead. Therefore, the new sample funds for methodology 4.4 will comprise of 178 active funds and 15 index funds.

Then, to see whether considering to adding index funds to a portfolio better reduce portfolio volatility compared to holding only active funds in the portfolio, I will create random portfolios which equally consist of active funds and passive fund. For example, when number of equity funds in the portfolio is equal to four, I will randomly select two active funds and two index funds from the sample. Meanwhile, I will also create the random portfolio which comprise of only active funds with the same length of holding period to make comparison.

After that, the methodology in 4.1 – 4.3 will be repeated with the new sample in order to examine whether considering to adding index funds to portfolio better reduce portfolio volatility.

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Chapter 5
Empirical Results

During 2015-2019, on average, annualized return and standard deviation of active equity funds are 10.3708% and 14.5261% respectively. The best-performing fund can achieve return of 15.1192% annually, while the worst-performing fund can get return around 4.5779% annually. The10-year terminal wealth returns of all active equity funds are ranging between 143.8248% to 406.6924% of the initial investment. On average, investing in active funds for 10 years (2010-2019) can earn return around 256.4398% of the initial investment with standard deviation of 43.0079%.

According to the past studies, holding more than one mutual fund in the portfolio can reduce some level of risk. In developed market, such as U.S. and Australian, holding for 5-10 funds can make mutual fund portfolio well diversified. Therefore, this paper aims to investigate the diversification benefit when holding multiple funds in the equity portfolio for Thai market.

5.1 Impact of holding multiple funds in the portfolio on the portfolio volatility

After creating the random portfolio, which consist of randomly selected active equity funds from 1 to 30 funds (N=30). For each N-mutual fund portfolio, the random selected mutual fund portfolio is repeated for 5,000 times (K=5,000). For a certain number of mutual funds in the portfolio, I calculate portfolio return, terminal wealth. In addition, I also calculate the Average Time Series Standard Deviation ("TSSD") and Terminal Wealth Standard Deviation ("TWSD") to measure the portfolio volatility.

According to the results from the calculation in Table 3, annualized return and terminal wealth return of the portfolio are not significantly different when holding more funds, In terms of portfolio volatility, the TSSD of portfolio returns slightly decreases when increase numbers of funds, but in the decreasing rate. To measure the percentage of reduction in TSSD, I will standardize each TSSD by dividing by the TSSD of holding only one fund in the portfolio. Adding more funds from 1 to 30 into the portfolio can reduce the TSSD by 5% approximately and holding more than 10

funds does rarely help to reduce TSSD (as also presented in the Figure 2). This finding is consistent with previous studies. Since each mutual fund normally invests in many stocks, when holding more mutual funds, the number of unique stocks that be added to the portfolio increases with decreasing rate.

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Table 3: Portfolio Volatility of Active Equity Funds for 10 years Holding Period (2010-2019)

Table 3 provides the results from the calculation using active equity funds monthly return during 2010-2019. For each N-mutual fund portfolio, the random selected mutual fund portfolio is repeated for 5,000 times. (K=5,000). The Average Time Series Standard Deviation (TSSD) and Terminal Wealth Standard Deviation (TWSD) is calculated using formula 2 and 3 respectively.

Formula 2: The average time series standard deviation of K portfolios, $(\overline{TSSD}_N) = \sum_{i=1}^{k} \frac{TSSD_N^i}{K}$ where $TSSD_N^i = \sqrt{\sum_{s=1}^{S} \frac{(R_s^i - \bar{R}_N^i)^2}{S-1}}$ is the time series standard deviation of a N-mutual fund portfolio i, R_S^i is the return of portfolio i at time s , $\bar{R}_N^i$ is the average time series return, over time, of portfolio i.

Formula 3: Terminal wealth standard deviation over K portfolio each size of N, $(TWSD_N) = \sqrt{\sum_{i=1}^{K} \frac{(TW_N^i - \overline{TW}_N)^2}{K-1}}$, where

$TW_N^i = \frac{1}{N}\sum_{j=1}^{N} TW_j^i$ is the terminal wealth of portfolio of N mutual funds, $TW_j^i = \prod_{s=1}^{S}(1 + r_{j,s}^i)$ is the return of portfolio i at time s, $\overline{TW}_N^i = \sum_{j=1}^{N} \frac{TW_N^i}{K}$ is the average terminal wealth over K portfolios, with N mutual funds in each portfolio.

Number of funds	Average return (annualized)	Average Time Series Standard Deviation (TSSD)	Average TSSD as a Percentage of Single Fund Portfolio TSSD	Average 10-year Terminal Wealth return	Terminal Wealth Standard Deviation (TWSD)	TWSD as a Percentage of Single Fund Portfolio TWSD
1	10.4061%	14.5129%	100.00%	257.4030%	43.2710%	100.00%
2	10.3761%	14.1830%	97.73%	256.0865%	31.2757%	72.28%
3	10.3631%	14.0666%	96.92%	255.5198%	25.3478%	58.58%
4	10.3664%	14.0051%	96.50%	255.5369%	22.1382%	51.16%
5	10.3686%	13.9768%	96.31%	255.4918%	19.6312%	45.37%
6	10.3737%	13.9589%	96.18%	255.5725%	18.0146%	41.63%
7	10.3889%	13.9462%	96.09%	255.9090%	16.5675%	38.29%
8	10.3650%	13.9332%	96.01%	255.2694%	15.2099%	35.15%
9	10.3834%	13.9306%	95.99%	255.7208%	14.7542%	34.10%
10	10.3614%	13.9237%	95.94%	255.1258%	13.6108%	31.45%
11	10.3653%	13.9094%	95.84%	255.2523%	13.1151%	30.31%
12	10.3841%	13.9023%	95.79%	255.7106%	12.2444%	28.30%
13	10.3757%	13.9024%	95.79%	255.4859%	11.9682%	27.66%
14	10.3690%	13.8986%*	95.77%	255.3009%	11.3179%*	26.16%
15	10.3687%	13.8927%	95.73%	255.3081%	11.1638%	25.80%
16	10.3575%	13.8830%	95.66%	255.0350%	10.5459%	24.37%
17	10.3685%	13.8817%	95.65%	255.2995%	10.0585%	23.25%
18	10.3692%	13.8817%	95.65%	255.3195%	10.0793%	23.29%
19	10.3738%	13.8812%	95.65%	255.4246%	9.7371%	22.50%
20	10.3685%	13.8812%	95.65%	255.2743%	9.2969%	21.49%
21	10.3759%	13.8771%	95.62%	255.4692%	9.1007%	21.03%
22	10.3715%	13.8741%	95.60%	255.3621%	8.9457%	20.67%
23	10.3746%	13.8723%	95.59%	255.4393%	8.6731%	20.04%
24	10.3729%	13.8732%	95.59%	255.3836%	8.3957%	19.40%
25	10.3742%	13.8782%	95.63%	255.3945%	8.2955%	19.17%
26	10.3743%	13.8707%	95.57%	255.4138%	7.8916%	18.24%
27	10.3706%	13.8715%	95.58%	255.3180%	7.8919%	18.24%
28	10.3696%	13.8671%	95.55%	255.3014%	7.7314%	17.87%
29	10.3703%	13.8676%	95.55%	255.3099%	7.4895%	17.31%
30	10.3709%	13.8657%	95.54%	255.3273%	7.3126%	16.90%
Intercept		*13.9001%*			*11.7573%*	
Slope		*0.6603%*			*36.1973%*	

The last 2 rows are the outcome of the regression model from equation 8, $Y = A\frac{1}{N^2} + B$, where A Y is the measures of risk, A is the slope, B is the intercept, which is the estimate of the asymptote. When the measure of risk (Y) is smaller than the intercept (B) with the closest value, the corresponding number of funds is the optimal number of well diversified mutual fund portfolio and these levels are marked by an asterisk (*)

On the other hand, from the Table 3 and Figure 3, the TWSD significantly decreases when holding more funds in the portfolio. However, the marginal diversification benefits also decreased when the number of funds increased. To measure the percentage of reduction in TWSD, I will standardize each TWSD by dividing by the TWSD of holding only one fund in the portfolio. According to the result in the Table 3, the portfolio with 4 funds can reduce TWSD to around 51% of single fund portfolio. Holding 15 funds, TWSD will be reduced to 25% of single fund portfolio. If adding more funds from 1 to 30 into the portfolio, it can reduce the TWSD by approximately 83%. This finding is consistent with previous studies which suggest that investors will get diversification benefits, especially for TWSD, if they invest more than one mutual fund.

To summarize, these findings are consistent with previous study of O'neal (1997), Potter (2001) and Lhabitant and Learned (2002) for U.S. market and Brands and Gallagher (2005) for Australian market. Although return and terminal wealth are not significantly different when investing more than one mutual fund, but it can slightly reduce TSSD and significantly decrease TWSD. TWSD measures the possibility that portfolio terminal wealth can deviate from market portfolio terminal wealth, and it is more suitable for measures the volatility of investment especially for investors who have pre-specified time period as it reflects the risk to the money that investors will get at the end of holding period.

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In addition, to find the optimal number of funds that enough to eliminate diversifiable risk, this paper will employ the regression model (equation 8). When the number of mutual funds in portfolio increases, value of risk will converge towards the intercept or an estimate of the asymptote. Therefore, this study will assume that when the measure of risk (Y) is smaller than the intercept (B) with the closest value, the corresponding number of funds can be assumed as the optimal number of well diversified mutual fund portfolio.

According to Table 3, the last two rows of the table show the outcome of the regression on equation 8. In Table 3, if consider to TSSD and TWSD portfolio with 14 funds onwards will give the risk level less than the intercept, which is the estimate of the asymptote. Therefore, the results of this study suggest that holding 14 funds is enough to eliminate diversifiable risk for Thai active equity fund portfolio, which is

slightly more than the previous studies in the developed market, such as U.S or Australian market, require 5-10 funds to make portfolio well-diversified. This is consistent with Lhabitant, F.S. (2017), who suggest that for the market with high idiosyncratic risk, higher number of assets will be needed to achieve diversification. According to Fan, Steve & Opsal, Scott & Yu, Linda. (2015), the average idiosyncratic risk in developed countries is smaller than emerging countries.

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Figure 3: Average Time-Series Standard Deviation (TSSD) for Each Number of Active Equity Funds in the Portfolio

Figure 3 illustrates that average time-series standard deviation (TSSD) decreases as a function of the number of active equity funds in the portfolio, but at a decreasing rate.

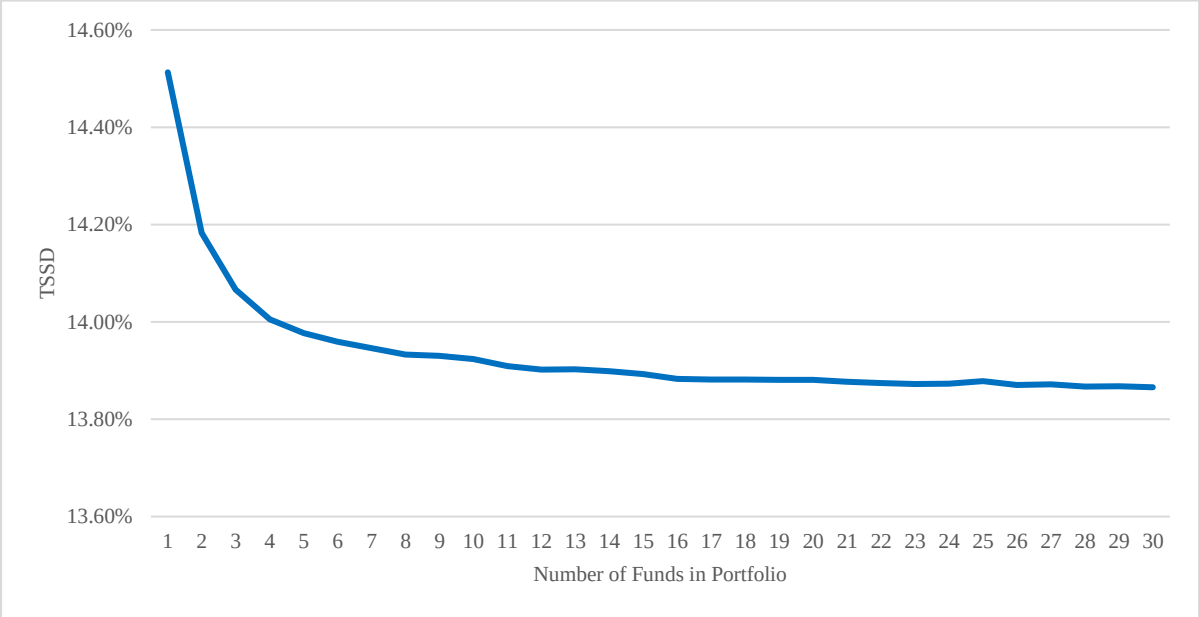
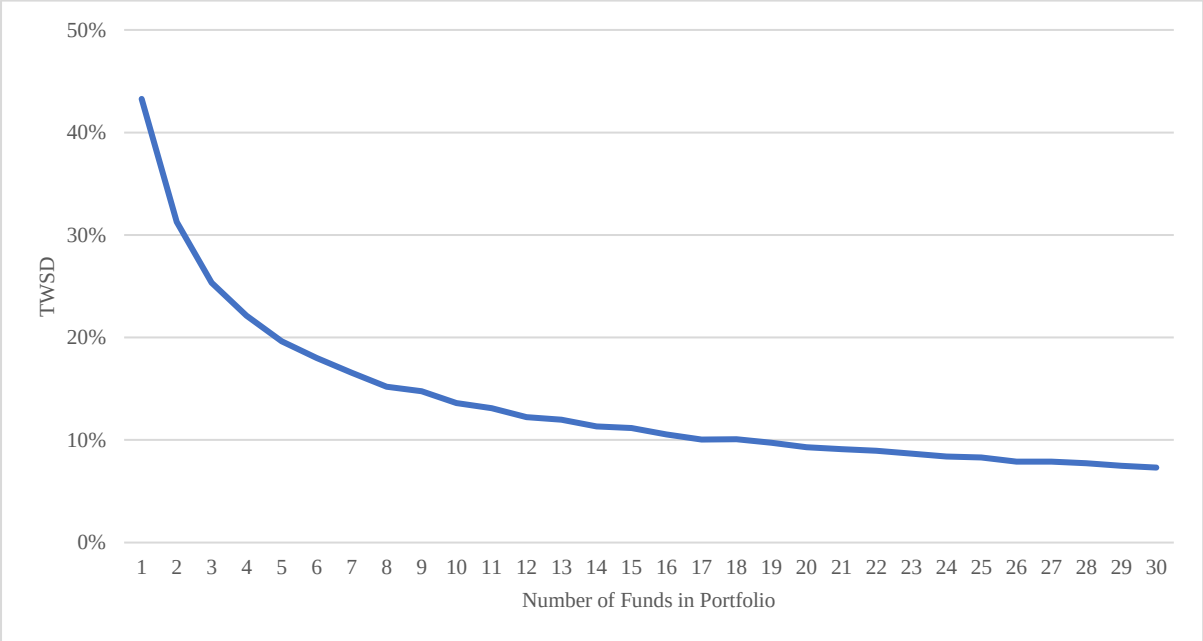


Figure 4: Average Terminal Wealth Standard Deviation (TWSD) for Each Number of Active Equity Funds in the Portfolio

Figure 4 illustrates that average terminal wealth standard deviation (TWSD) decreases as a function of the number of active equity funds in the portfolio, but at a decreasing rate.



5.2 Impact of holding more funds in the portfolio on the portfolio downside volatility

As the terminal wealth standard deviation (TWSD) is measured the deviation from the mean in both positive and negative variations, however, investors normally not view the positive deviation as the risk of their investment. Therefore, this paper will examine the effect of the increase in mutual fund holding on downside risk. To see the relationship between the number of mutual funds in the portfolio and portfolio downside risk, I calculate mean shortfall and semi-variance of terminal wealth to measure the portfolio downside risk.

The results of downside volatility measurements are presented in the Table 4, Figure 4, and Figure 5. Both measurements significantly decrease when holding more funds in the portfolio, but at the decreasing rate. To measure the percentage of reduction in downside risk measurements, I will standardize each downside risk measurements by dividing by the downside risk measurements of single fund portfolio. For mean shortfall of terminal wealth, if adding more funds from 1 to 30 into the portfolio, mean shortfall can reduce from -17% to -3% approximately. Portfolio with 4 funds can reduce mean shortfall around 50% compared to holding only one fund.

Another downside risk measurement for this study is the semi-variance of terminal wealth. This measurement will give more weight on the observations which are greater below than mean, therefore it is suitable to measure downside risk as well, as investors are normally more averse with the larger downside deviation. According to Table 4, holding more funds from 1 to 30 into the portfolio, semi-variance is reduced from 10% to 2.7% approximately. Holding only 2 funds can reduces half of the semi-variance of single portfolio, and when add 10 funds to portfolio semi-variance are reduced to 10% of single fund portfolio. These findings are consistent with previous study of O'neal (1987) for the U.S equity funds that holding multiple funds can reduce downside risk, which are measured by mean shortfall and semi-variance of terminal wealth.

In addition, to find the optimal number of funds that enough to eliminate diversifiable risk, this paper will employ the regression model (equation 8 in the same way that used in 5.1

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According to Table 4, the last two rows of the table show the outcome of the regression on equation 8. If consider to mean shortfall, portfolio with 14 funds onwards will give the risk level less than the intercept, which is the estimate of the asymptote. While using the semi-variance as a measure of risk, portfolio with 13 funds is enough to give the risk level less than the intercept Therefore, the results of this study suggest that holding 13-14 funds is enough to eliminate diversifiable downside risk for Thai active equity fund portfolio.

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Table 4: Portfolio Downside Volatility of Active Equity Funds for 10 years Holding Period (2010-2019)

Table 4 provides the results from the calculation using active equity funds monthly return during 2010-2019. For each N-mutual fund portfolio, the random selected mutual fund portfolio is repeated for 5,000 times. (K=5,000). The Mean shortfall and Semi-variance of terminal wealth is calculated by using formula 5 and 6 respectively.

Formula 5: Mean shortfall of terminal wealth = $\sum_{i=1}^{N} \frac{TW_K^i - \overline{TW}_K}{K}$ where $TW_K^i = TW_K^i \; if \; TW_K^i < \overline{TW}_K$ or $\overline{TW}_K, if \; TW_K^i \geq \overline{TW}_K$

Formula 6: Semi-variance of terminal wealth = $\sum_{i=1}^{N} \frac{(TW_K^i - \overline{TW}_K)^2}{K}$ where $TW_K^i = TW_K^i \; if \; TW_K^i < \overline{TW}_K$ or $\overline{TW}_K, if \; TW_K^i \geq \overline{TW}_K$

Number of funds	Mean Shortfall of terminal wealth	Mean Shortfall as a Percentage of Single Fund Portfolio	Semi-variance of terminal wealth	Semi-variance as a Percentage of Single Fund Portfolio TWSD
1	-16.8006%	100.00%	10.2633%	100.00%
2	-12.5963%	74.98%	5.2059%	50.72%
3	-10.1560%	60.45%	3.2828%	31.99%
4	-8.8031%	52.40%	2.5386%	24.73%
5	-7.8934%	46.98%	1.9360%	18.86%
6	-7.2042%	42.88%	1.6508%	16.08%
7	-6.5892%	39.22%	1.3985%	13.63%
8	-6.0824%	36.20%	1.1756%	11.45%
9	-5.9178%	35.22%	1.1141%	10.86%
10	-5.4444%	32.41%	0.9387%	9.15%
11	-5.2418%	31.20%	0.8651%	8.43%
12	-4.8888%	29.10%	0.7503%	7.31%
13	-4.7967%	28.55%	0.7207%*	7.02%
14	-4.5344%*	26.99%	0.6391%	6.23%
15	-4.4628%	26.56%	0.6270%	6.11%
16	-4.2191%	25.11%	0.5651%	5.51%
17	-4.0229%	23.95%	0.5131%	5.00%
18	-4.0243%	23.95%	0.5169%	5.04%
19	-3.8782%	23.08%	0.4770%	4.65%
20	-3.7002%	22.02%	0.4397%	4.28%
21	-3.6253%	21.58%	0.4165%	4.06%
22	-3.5720%	21.26%	0.3977%	3.88%
23	-3.4588%	20.59%	0.3699%	3.60%
24	-3.3527%	19.96%	0.3507%	3.42%
25	-3.3334%	19.84%	0.3418%	3.33%
26	-3.1426%	18.71%	0.3190%	3.11%
27	-3.1471%	18.73%	0.3111%	3.03%
28	-3.0742%	18.30%	0.3032%	2.95%
29	-3.0031%	17.88%	0.2824%	2.75%
30	-2.9372%	17.48%	0.2656%	2.59%
Intercept	*-4.7101%*		*0.7474%*	
Slope	*-14.0184%*		*10.2676%*	

The last 2 rows are the outcome of the regression model from equation 8, $Y = A\frac{1}{N^2} + B$, where A Y is the measures of risk, A is the slope, B is the intercept, which is the estimate of the asymptote. When the measure of risk (Y) is smaller than the intercept (B) with the closest value, the corresponding number of funds is the optimal number of well diversified mutual fund portfolio and these levels are marked by an asterisk (*).

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Figure 5: Mean Shortfall for Each Number of Active Equity Funds in the Portfolio, 10 years Holding Period (2010-2019)

Figure 5 illustrates that mean shortfall decreases as a function of the number of active equity funds in the portfolio, but at a decreasing rate.

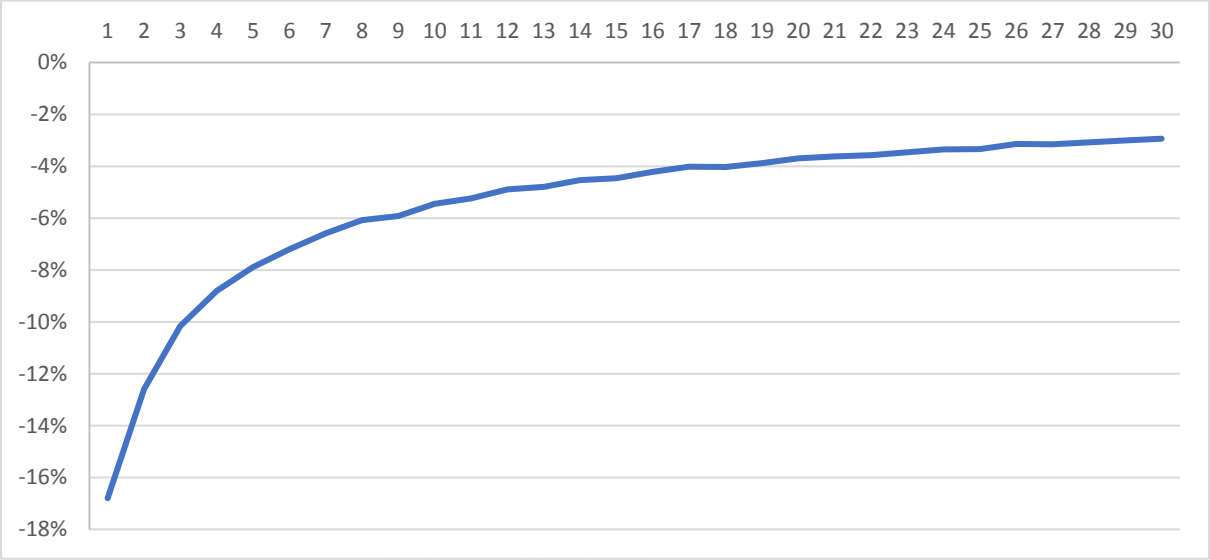
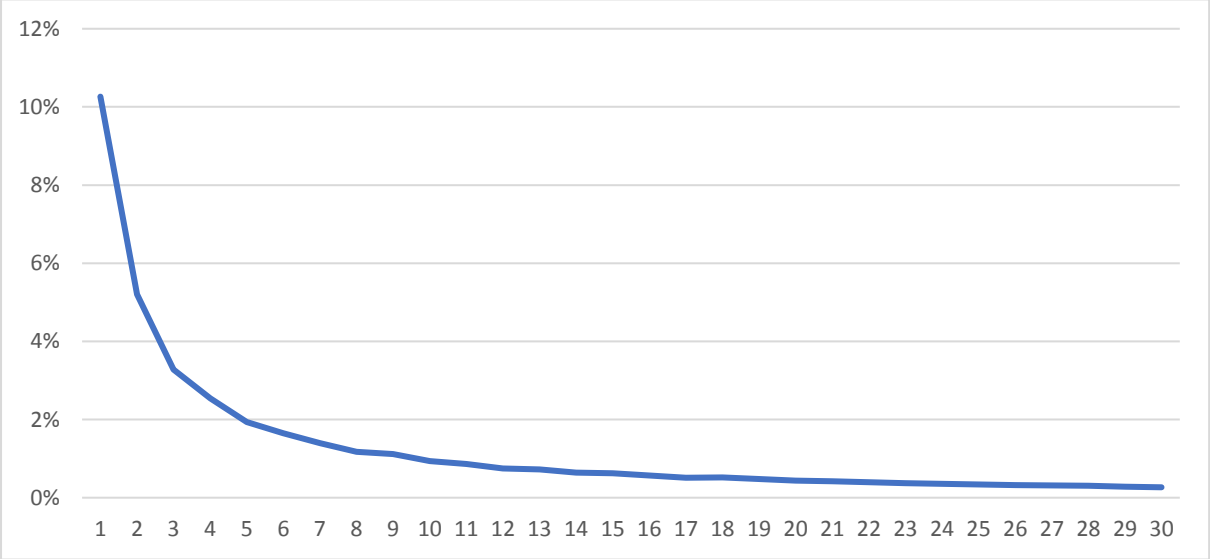


Figure 6: Semi-Variance for Each Number of Active Equity Funds in the Portfolio, 10 years Holding Period (2010-2019)

Figure 6 illustrates that semi-variance decreases as a function of the number of active equity funds in the portfolio, but at a decreasing rate.



5.3 Impact of including index funds in the portfolio on portfolio volatility

Apart from active equity portfolio, this study also examines whether considering to adding index funds to a portfolio better reduce portfolio volatility. To have enough index funds to create random portfolio, which equally consists of active fund and index funds, I have to change the investment horizon to be 5 years (2015-2019). Then, the results from calculation with new samples and new investment horizon are presented in the Table 5.

According to Table 5, portfolios that include index funds can achieve slightly higher returns than portfolios that consist of only active funds for both average annualized return and 5-year terminal wealth return. This is consistent with the data descriptive shown in Table 2. As during 2015-2019, index funds slightly outperform active funds in terms of both time series return as well as 5-year terminal wealth return on average. Then, when include the index funds in the portfolio, it helps to increase portfolio return, compared to the portfolio with only active funds

However, annualized return and terminal wealth return of the portfolio remain constant when increase the number of funds in the portfolio. For portfolio volatility, the results are consistent with previous empirical results in 5.1-5.2 for both portfolio with and without index funds. Investing more than one mutual fund can slightly reduce TSSD, but significantly decrease TWSD, mean shortfall and semi variance. Nevertheless, the marginal diversification benefits also decreased when the number of funds increased.

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According to the results in the Table 3, adding more funds from 1 to 30 into the portfolio can reduce TWSD from 11% to 1.5% for portfolio that include index fund, and 1.9% for active fund's portfolio. In addition, increasing number of funds in the portfolio from 1 to 30 can also reduce semi-variance, which measures downside risk, from 0.7 to 0.01% for portfolio that include index fund, and 0.02% for active fund's portfolio. The huge decrease of semi-variance when increasing number of portfolios is because semi-variance in this study measure the downside deviation compare to the mean of terminal wealth for each number of funds. So, when increase the number of funds, the deviation as well as downside deviation are decrease, especially for semi-variance which has the greater decrease, as it is the measure that give more weight for the value that greater below than the mean. This pattern of the

results is consistent with O'Neal (1987), who had studied the impact of inversing number of funds on the downside risk. Therefore, these results suggest that investors will get diversification benefits when investing multiple funds.

To find the optimal number of funds that enough to eliminate diversifiable risk, I use the method as same as 5.3. The last two rows of Table 5 show the outcome of the regression. According to Table 5, regardless including index funds in the portfolio, using TSSD as a risk measurement, investor will require 12 funds to eliminate diversifiable risk. But using TWSD or mean shortfall as a measure of risk, investor will require 14 funds to make portfolio well-diversified. However, asymptote of using semi-variance as a risk measure is reached faster with portfolio that include index funds. Therefore, for investor who more averse with the larger downside deviation, holding 6 index funds and 6 active funds is enough to make portfolio well-diversified, while holding only active funds requires 14 funds.

In addition, the portfolio with index funds can reduce TWSD and downside deviation more than portfolio which consist of only active funds. To measure the percentage of reduction in measure of risk, I will standardize each risk measurement by dividing by the risk measurement of holding only one fund in the portfolio. As shown in Table 6, 14-fund portfolio that include index funds can reduce TWSD to 23% of single-fund portfolio TWSD, while holding only 14 active funds can reduce TWSD to 26% of single-fund portfolio. So, the reduction in TWSD, mean shortfall and semi-variance is slightly greater for portfolio that include index funds. Results of the reduction in each risk measurement when adding number of funds are also graphed in Figure 6, 7, 8.

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To sum up, holding multiple funds in the portfolio can reduce the risk of portfolio, but in a decreasing rate. However, including index fund in the portfolio can help reduce TWSD and downside deviation slightly more than portfolio which consist of only active funds. These results are consistent with the recommendation from many professionals nowadays. Blending active and passive strategies can help investors reduce portfolio volatility, since holding only active funds may allow investors expose to additional risk as fund managers need to take active position different from the market to generate additional return. Also, the performance of active funds depends

on capability of each fund manager, so the return of active funds usually has wider range than the index funds.

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Table 5: Portfolio Volatility of Equity Funds by Management Style, 5-year Holding Period (2015-2019)

Table 5 provides the results from the calculation using equity funds monthly return during 2015-2019. For each N-mutual fund portfolio, the random selected mutual fund portfolio is repeated for 5,000 times. (K=5,000). The column Active&Index represents the results of portfolio which equally consist of active funds and index funds. The column Active represents the results of portfolio which consist of active fund only. The Average Time Series Standard Deviation (TSSD), Terminal Wealth Standard Deviation (TWSD), Mean shortfall and Semi-variance of terminal wealth are calculated using formula 2, 3, 5 and 6 respectively.

Formula 2: The average time series standard deviation of K portfolios, $(\overline{TSSD}_N) = \sum_{i=1}^{k} \frac{TSSD_N^i}{K}$ where $TSSD_N^i = \sqrt{\sum_{s=1}^{S} \frac{(R_s^i - \bar{R}_N^i)^2}{S-1}}$ is the time series standard deviation of a N-mutual fund portfolio i, R_s^i is the return of portfolio i at time s , $\bar{R}_N^i$ is the average time series return, over time, of portfolio i.

Formula 3: Terminal wealth standard deviation over K portfolio each size of N, $(TWSD_N) = \sqrt{\sum_{i=1}^{K} \frac{(TW_N^i - \overline{TW}_N)^2}{K-1}}$, where $TW_N^i = \frac{1}{N}\sum_{j=1}^{N} TW_j^i$ is the terminal wealth of portfolio of N mutual funds, $TW_j^i = \prod_{s=1}^{S}(1 + r_{j,s}^i)$ is the return of portfolio i at time s, $\overline{TW}_N^i = \sum_{j=1}^{N} \frac{TW_N^i}{K}$ is the average terminal wealth over K portfolios, with N mutual funds in each portfolio.

Formula 5: Mean shortfall of terminal wealth $= \sum_{i=1}^{N} \frac{TW_K^i - \overline{TW}_K}{K}$ where $TW_K^i = TW_K^i \; if \; TW_K^i < \overline{TW}_K$ or $\overline{TW}_K, if \; TW_K^i \geq \overline{TW}_K$

Formula 6: Semi-variance of terminal wealth $= \sum_{i=1}^{N} \frac{(TW_K^i - \overline{TW}_K)^2}{K}$ where $TW_K^i = TW_K^i \; if \; TW_K^i < \overline{TW}_K$ or $\overline{TW}_K, if \; TW_K^i \geq \overline{TW}_K$

Number of funds	Average return (annualized)		Average Time Series Standard Deviation (TSSD)		5-year Terminal wealth return		Average Terminal Wealth Standard Deviation (TWSD)		Mean shortfall of terminal wealth		Semi-variance of terminal wealth	
	Active& Index	Active	Active& Index	Active	Active& Index	Active	Active& Index	Active	Active& Index	Active	Active& Index	Active
1	3.2320%	3.2320%	10.4656%	10.4656%	114.8699%	114.8699%	11.3924%	11.3924%	-4.3780%	-4.3780%	0.7208%	0.7208%
2	3.5378%	3.2718%	10.4665%	10.1290%	116.3616%	115.0474%	7.6590%	8.2102%	-2.8493%	-3.2024%	0.3779%	0.3641%
4	3.5348%	3.2810%	10.3376%	9.9283%	116.2917%	115.0791%	5.3657%	5.7662%	-2.0977%	-2.2831%	0.1707%	0.1765%
6	3.5669%	3.2699%	10.2910%	9.8599%	116.4628%	115.0077%	4.3120%	4.6457%	-1.7307%	-1.8386%	0.1037%	0.1115%
8	3.5409%	3.2623%	10.2661%	9.8331%	116.3079%	114.9596%	3.7281%	4.0751%	-1.5146%	-1.6203%	0.0755%	0.0875%
10	3.5447%	3.2603%	10.2550%	9.8017%	116.3227%	114.9515%	3.2616%	3.6092%	-1.3114%	-1.4397%	0.0563%	0.0671%
12	3.5464%	3.2487%	10.2458%*	9.7906%*	116.3280%	114.8835%	2.8626%	3.3100%	-1.1592%	-1.3231%	0.0428%*	0.0562%
14	3.5402%	3.2772%	10.2414%	9.7822%	116.2895%	115.0417%	2.6197%*	2.9436%*	-1.0565%*	-1.1735%*	0.0353%	0.0441%*
16	3.5367%	3.2702%	10.2396%	9.7779%	116.2655%	115.0031%	2.3907%	2.8053%	-0.9580%	-1.1218%	0.0291%	0.0402%
18	3.5469%	3.2752%	10.2291%	9.7739%	116.3276%	115.0273%	2.2151%	2.6701%	-0.8842%	-1.0564%	0.0246%	0.0369%
20	3.5343%	3.2747%	10.2328%	9.7617%	116.2492%	115.0297%	2.0560%	2.5053%	-0.8182%	-1.0002%	0.0210%	0.0315%
22	3.5440%	3.2766%	10.2271%	9.7565%	116.3063%	115.0412%	1.8952%	2.3782%	-0.7545%	-0.9453%	0.0179%	0.0288%
24	3.5385%	3.2734%	10.2210%	9.7597%	116.2765%	115.0187%	1.7955%	2.2447%	-0.7177%	-0.8972%	0.0161%	0.0257%
26	3.5428%	3.2662%	10.2254%	9.7549%	116.2977%	114.9785%	1.7021%	2.1486%	-0.6760%	-0.8570%	0.0145%	0.0236%
28	3.5365%	3.2734%	10.2232%	9.7489%	116.2606%	115.0217%	1.5774%	2.0748%	-0.6284%	-0.8272%	0.0128%	0.0220%
30	3.5439%	3.2735%	10.2236%	9.7524%	116.3021%	115.0179%	1.4608%	1.9435%	-0.5860%	-0.7770%	0.0108%	0.0192%
Intercept			*10.2519%*	*9.7920%*			*2.6877%*	*3.1233%*	*-1.0687%*	*-1.2433%*	*0.0454%*	*0.0545%*
Slope			*0.2562%*	*0.7197%*			*9.5269%*	*9.1389%*	*-3.5991%*	*-3.4745%*	*0.7194%*	*0.7054%*

The last 2 rows are the outcome of the regression model from equation 8, $Y = A\frac{1}{N^2} + B$, where A Y is the measures of risk, A is the slope, B is the intercept, which is the estimate of the asymptote. When the measure of risk (Y) is smaller than the intercept (B) with the closest value, the corresponding number of funds is the optimal number of well diversified mutual fund portfolio and these levels are marked by an asterisk (*).

Table 6: Portfolio Volatility as a Percent of Single-Fund Portfolio Volatility by Management Style, 5-year Holding Period (2015-2019)

Table 6 represents percentage of reduction for each measure of risk, calculated by dividing each risk measurement by the risk measurement of holding single fund in the portfolio

Number of funds	Average Time Series Standard Deviation (TSSD)		Average Terminal Wealth Standard Deviation (TWSD)		Mean shortfall of terminal wealth		Semi-variance of terminal wealth	
	Active& Index	Active	Active& Index	Active	Active& Index	Active	Active& Index	Active
1	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
2	100.01%	96.78%	67.23%	72.07%	65.08%	73.15%	52.42%	50.51%
4	98.78%	94.87%	47.10%	50.61%	47.91%	52.15%	23.68%	24.49%
6	98.33%	94.21%	37.85%	40.78%	39.53%	42.00%	14.39%	15.47%
8	98.09%	93.96%	32.72%	35.77%	34.60%	37.01%	10.48%	12.14%
10	97.99%	93.66%	28.63%	31.68%	29.95%	32.88%	7.80%	9.30%
12	97.90%	93.55%	25.13%	29.05%	26.48%	30.22%	5.93%	7.80%
14	97.86%	93.47%	22.99%	25.84%	24.13%	26.81%	4.90%	6.12%
16	97.84%	93.43%	20.99%	24.62%	21.88%	25.62%	4.04%	5.58%
18	97.74%	93.39%	19.44%	23.44%	20.20%	24.13%	3.41%	5.12%
20	97.78%	93.27%	18.05%	21.99%	18.69%	22.85%	2.92%	4.37%
22	97.72%	93.22%	16.64%	20.88%	17.23%	21.59%	2.49%	3.99%
24	97.66%	93.26%	15.76%	19.70%	16.39%	20.49%	2.23%	3.57%
26	97.71%	93.21%	14.94%	18.86%	15.44%	19.57%	2.01%	3.28%
28	97.68%	93.15%	13.85%	18.21%	14.35%	18.89%	1.77%	3.05%
30	97.69%	93.19%	12.82%	17.06%	13.38%	17.75%	1.50%	2.66%

Figure 7: Average Terminal Wealth Standard Deviation (TWSD) by Management Style, 5-year Holding Period (2015-2019)

Figure 7 illustrates that average terminal wealth standard deviation (TWSD) of (1) portfolio which equally consist of active funds and index funds (2) portfolio which consist of active fund only. TWSD decreases as a function of number of funds in the portfolio regardless different management style. However, the asymptote active fund portfolio is higher, which imply that holding only active funds may expose to the higher TWSD.

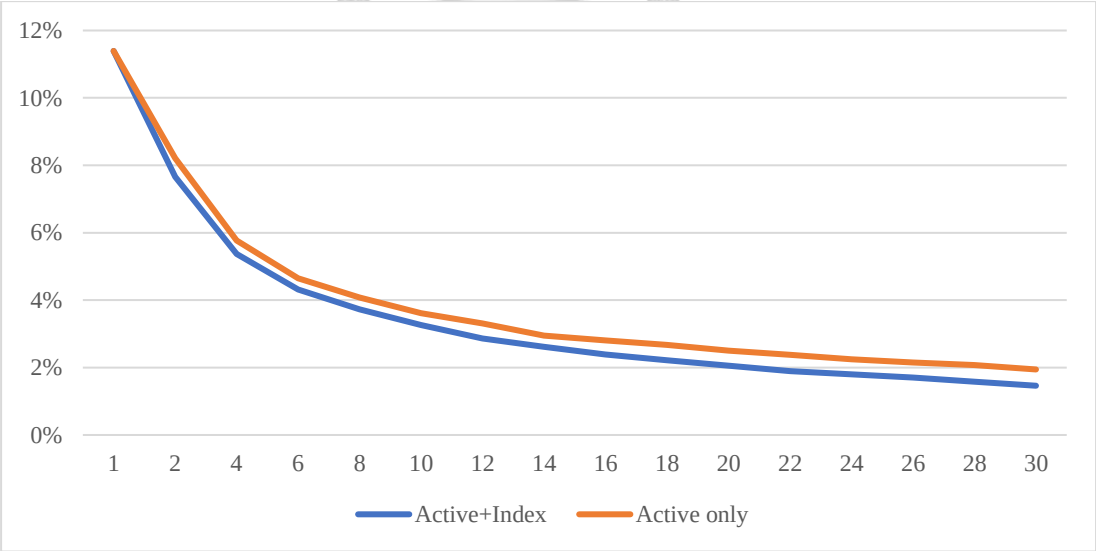
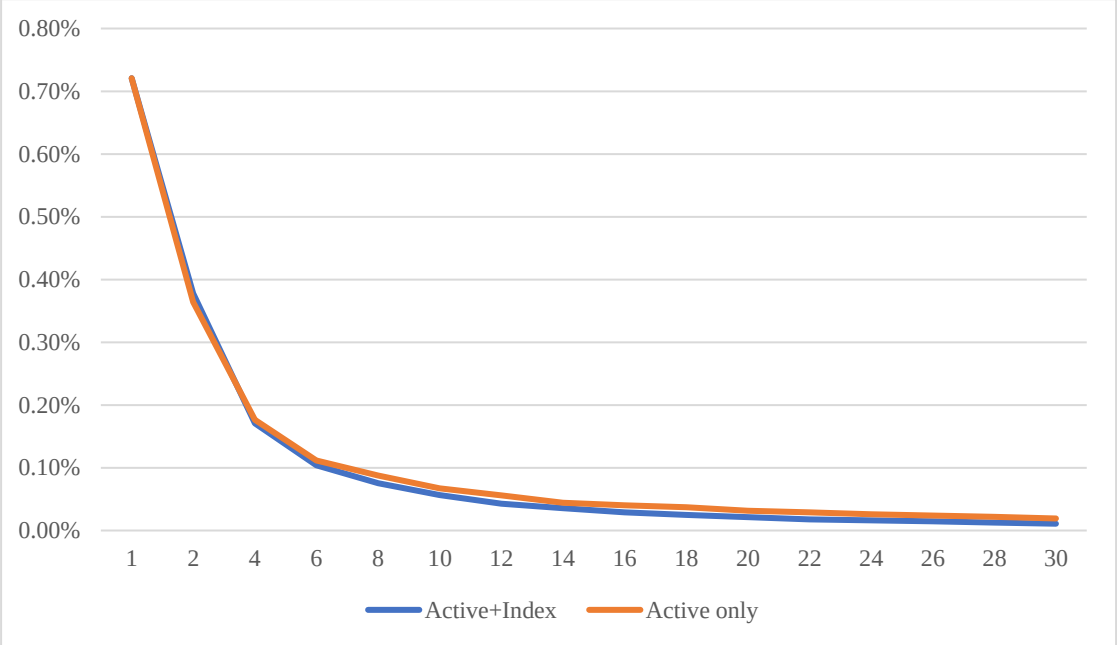


Figure 8: Semi-Variance by Management Style, 5-year Holding Period (2015-2019)
Figure 8 illustrates that semi-variance of (1) portfolio which equally consist of active funds and index funds (2) portfolio which consist of active fund only. Semi-variance decreases as a function of number of funds in the portfolio regardless different management style. However, the asymptote active fund portfolio is slightly higher, which imply that holding only active funds may expose to the higher downside risk, which can be measured by using semi-variance.



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Chapter 6
Conclusion

The goal of this studies is to examine whether adding more funds in the portfolio reduce the portfolio volatility, including downside deviation. This paper also finds the optimal number of equity funds that enough to eliminate diversifiable risk. Moreover, this study examines whether considering adding index funds or passive funds to a portfolio better reduce portfolio volatility.

The tests in this study are conducted by creating random portfolio and using the historical monthly return of Thai equity funds during January 2010 - December 2019. However, to study the diversification benefit of portfolio that consist of active and index funds, I use the return during January 2015 - December 2019 instead, in order to increase the number of index funds in the samples. The portfolio volatility of this study is measured by using time-series standard deviation (TSSD), Terminal-wealth standard deviation (TWSD). For downside risk, this study uses mean shortfall and semi-variance as risk measurements. The results of each objective can be summarized as follow.

Firstly, to test whether adding more funds in the portfolio reduce the portfolio volatility. The results are consistent with previous studies in developed market which suggests that investors will get diversification benefits if they invest more than one mutual fund. annualized return and terminal wealth return of the portfolio are not significantly different when holding more funds, but it can slightly reduce TSSD and significantly decrease TWSD. However, the marginal diversification benefits also decreased when the number of funds increase. Moreover, to test whether adding more mutual funds in the portfolio reduce the portfolio negative volatility. The results are consistent with previous studies in developed market. Mean shortfall and semi-variance of terminal wealth are significantly decreased when holding more funds in the portfolio, but at the decreasing rate. For mean shortfall of terminal wealth, portfolio with 4 funds can reduce mean shortfall around 50% compared to holding only one fund. While using semi-variance, holding only 2 funds can reduce half of the semi-variance of single portfolio.

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Next, to find the number of funds that enough to eliminate diversifiable risk for equity funds in Thai market. the results of this study suggest that holding 13-14 funds is enough to eliminate diversifiable risk for Thai active equity fund portfolio. While previous studies in the developed market, such as U.S or Australian market, require 5-10 funds to make portfolio well-diversified. This is consistent with Lhabitant, F.S. (2017), who suggest that for the market with high idiosyncratic risk, higher number of assets will be needed to achieve diversification. According to Fan, Steve & Opsal, Scott & Yu, Linda. (2015), the average idiosyncratic risk in developed countries is smaller than emerging countries.

Lastly, to study whether considering adding index funds to a portfolio better reduce portfolio volatility than portfolio that consist of active funds only. The result of this study suggests that including index fund in the portfolio can slightly help reduce TWSD and downside deviation more than portfolio which consist of only active funds. These results are consistent with the recommendation from many professionals nowadays. Blending active and passive strategies can help investors reduce portfolio volatility, since holding only active funds may allow investors expose to additional risk as fund managers need to take active position different from the market to generate additional return. Moreover, the performance of active funds depends on capability of each fund manager, so the return of active funds usually has wider range than the index funds.

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To sum up, investor who want to invest through equity funds, especially for long-term investment, should invest in multiple funds to achieve diversification benefit. Moreover, considering including index funds in the equity fund portfolio can slightly help reduce portfolio volatility more than investing in only active funds. In addition, it also offers lower cost to the investor as normally index funds have lower fees than active funds.

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